

DEVELOPING A GLOBAL STRATEGY TO MEET CLIMATE CHANGE

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1. Introduction

A global strategy implies the possibility for concerted global action, but let us admit at the outset that this is very unlikely. The global construction industry consists of hundreds of thousands of players, ranging in size from a draughtsman or a carpenter and his cousin to a small number of very large and sophisticated multi-national design-construction firms. All these enterprises are operating within a mind-boggling range of climatic, social, economic, cultural, technical and regulatory environments. To this complexity we must add the fact that communities and buildings are part of the pattern of daily life, and most people therefore feel able to express their views confidently on these matters, a fact that complicates decision-making.

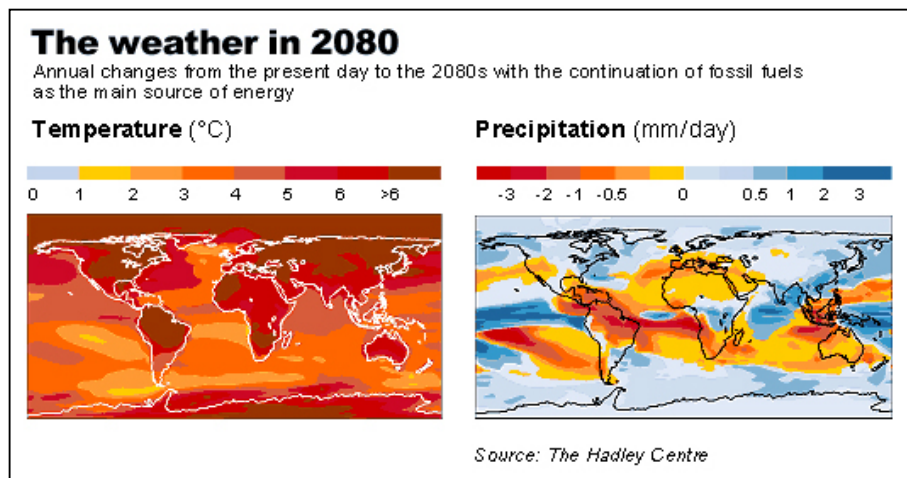
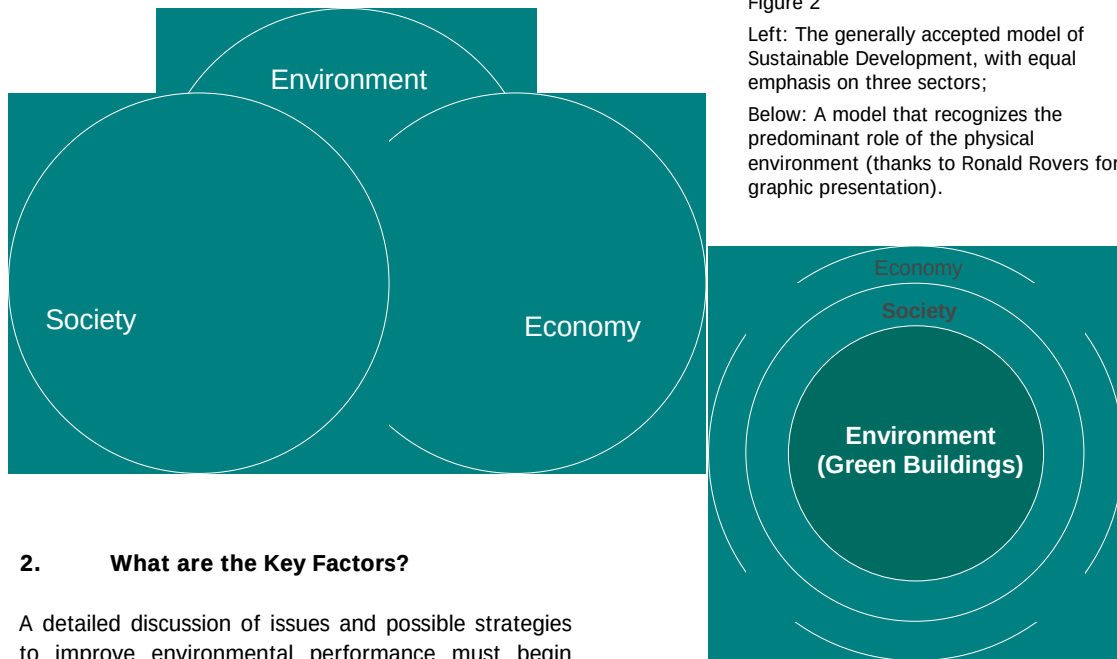


Figure 1: The need for action is clear

Nevertheless, we can hope to achieve some concerted action within countries and even regions, and to develop systems that will allow a meaningful exchange of information to take place between regions. Under favourable conditions, this may result in a more rapid spread of ideas concerning the design and construction of buildings and structures that will have a reduced output of the greenhouse gases (GHGs) that are responsible for climate change and other life-threatening environmental impacts.

Why do we focus on environmental issues in a conference that speaks to sustainable building, e.g. including social and economic factors as well as environmental ones? Simply because it is the environmental impacts, including GHGs, air pollutants, soil and water degradation and bad indoor climates, that will kill us or at least make us unwell in the short to medium term; and it is the unthinking and rapid plundering of non-renewable resources that may stop us from even attempting improvements in the long term. Social and economic issues are certainly vital, and we will get nowhere without addressing them as part of an integrated strategy for action, but a major improvement in the environmental performance of the built environment must be the end result of our actions.



2. What are the Key Factors?

A detailed discussion of issues and possible strategies to improve environmental performance must begin with a definition of goals and inventory of relevant factors that may affect the achievement of these goals. The key global goals include:

- A reduction of embodied GHG in new construction and renovations;¹
- A reduction of operating GHG in new and existing buildings and related transportation systems;

It should be noted that we include related transportation systems for both embodied and operating emissions because the locations of buildings can have major impacts on decisions whether to use private or public transport, with consequent impacts from both the construction of the required infrastructure and the operation of vehicles.

Every country and region (and even sub-regions within countries) may have a variety of ecological characteristics that will lead to other issues becoming of critical importance. These may include a scarcity of water or of certain materials or fuels, the impact of air pollutants on human health, soil or water pollution, wastes, the use of ecologically valuable or sensitive sites or the use of valuable farmland. In all countries with cold climates, the quality of the indoor environment is also of major importance because of the large proportion of time spent indoors. As we move from green building to sustainable building, issues such as affordability and local employment become relevant.

Undoubtedly, however, energy and emissions remain at the core of the sustainable building issue, and there are a number of over-riding issues and trends in S.E. Asia that even an outsider can perceive as being relevant.

- The region is sub-tropical, and an obvious consequence is high temperatures and relative humidity levels. A host of building-related factors are linked to this, including a tradition of designing buildings to be open and permeable to the exterior, and to rely on natural ventilation; and building traditions that take into account resistance to decay and insect attack. Of course, these building traditions evolved in the context of simple rural lifestyles, so they are mainly applicable to pre-industrial types of activity;

¹ Embodied energy and emissions can be defined as being a result of the extraction of resources to produce building materials, the manufacturing process and transportation to the building site.

- The region as a whole is in the throes of a massive shift from agricultural and rural life to a more urbanized way of life, although some countries have almost completed this shift. Building-sector consequences include one segment of the building industry that pursues indigenous and low-technology construction at the same time as another part is involved in sophisticated and high-technology building practices largely derived from the West;
- Another factor this a major factor in most S.E. Asian countries is the low average income, and the great gulf between rich and poor. New construction is often built with non-traditional (expensive) materials on urban (expensive) land, and these factors make it difficult to provide the benefits of new housing to poor people. This can lead to social destabilization in the mid to long term, which benefits neither rich nor poor.

One of the main factors in growth of energy consumption and environmental impacts is that rapid population growth in most countries is fuelling a demand for new construction, and higher incomes are leading to rising standards for space and quality of construction and fit-up in new and old buildings. This has several implications:

- More housing units and non-residential buildings are being constructed, which means that, even if new buildings are built and operated very efficiently, the total embodied and operating energy and emissions may still rise markedly because of the greater aggregate floor area;
- The appeal of western models of living is leading to a greater adoption of low-density forms of development in suburban areas. This is a very wasteful form of development, due to the new infrastructure (roads, sewers, water etc.) needed, and the greater reliance on the use of private vehicles for transportation. Linked to rising standards is the possibility that existing buildings may lose their appeal to consumers;
- Higher standards of fit-up lead to a larger number of household appliances in residential buildings and to a greater demand for air conditioning in all building types. Let us remember that mechanical cooling and ventilation usually is powered by electricity, which is usually produced in very inefficient thermal power plants.

Having made the generalizations above, we must note that these context factors are only partly applicable to some S.E. Asian countries, such as Myanmar, Laos, Cambodia, East Timor, Vietnam and Indonesia. Table 1 below indicates some underlying reasons for this assessment; very low incomes and a high proportion of the population living at below poverty levels.

Country	Population, millions	Pop. Growth	Median age, years	Percent urban	GDP per capita	Pop. below poverty
Cambodia	13.4	1.8%	19.5	17.4%	\$1,900	36%
Indonesia	238.5	1.49%	26.1	42.0%	\$3,200	27%
Laos	6.1	2.44%	18.6	19.7%	\$1,700	40%
Malaysia	23.5	1.83%	23.8	58.1%	\$9,000	8%
Myanmar	42.7	0.47%	25.7	28.2%	\$1,800	25%
Philippines	86.2	1.88%	22.1	59.3%	\$4,600	40%
Taiwan	22.7	0.64%	33.7	NA	\$23,400	1%
Thailand	64.93	0.91%	30.5	20.0%	\$7,400	10.4%
Vietnam	82.7	1.3%	24.9	24.5%	\$2,500	37%

Figure 3: Selected Characteristics of S.E. Asian Countries²

² All data is from World Bank, except for Taiwan data which is drawn from the CIA website (World Bank does not include data on Taiwan in any form).

3. What Strategies Can Lead to Improvements in Performance?

The ideal scenario in developed countries is quite simple: convince those in power that climate change is a real threat that will, in the mid-term, overwhelm any short-term economic or social benefits of inaction. Having gained a consensus for action, a carbon tax would then be implemented to impose a significant cost to using fossil fuels and to pay for GHG-reduction measures. In developing or other countries with a significant proportion of the population living below the poverty line, however, this type of solution could impose major hardship.

Workable approaches for S.E. Asian countries will of course vary, but some general ideas appear to be worth exploring. These are, in fact, quite simple and have already have been the subject of many studies, but are worth repeating here. They include:

A: Planning, Transportation and Energy Supply

- Develop urban planning strategies that ensure the effective use of urban land (high densities, incentives for mixed uses, and discouragement of low-density new development);
- Plan nodal developments for new construction that are linked to public transport routes and that avoid use of land that is valuable in ecological or agricultural terms;
- Build efficient public transport systems and upgrade existing ones; provide generous user subsidies as long as systems are basically viable in economic terms;
- Reduce the demand for private transport through the measures described above, but also through specific measures to discourage car use (tolls, high parking fees), and to improve the efficiency of car usage (express lanes for high-occupancy vehicles, promotion of car-sharing schemes etc.).
- Switch from oil- or coal-fired generation plants to more renewable sources (a green power scenario);

B: The Building Sector

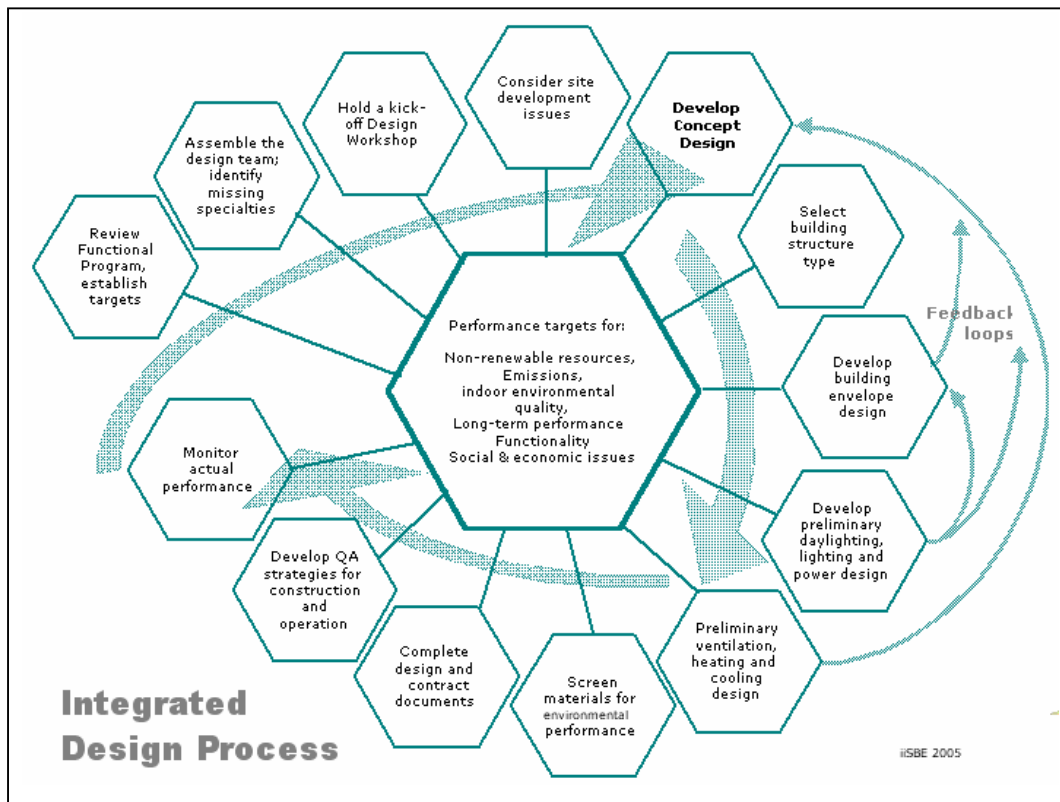
- Limiting the demand for new construction is difficult, since demographic factors are uncontrollable. However, increasing expectations for space and equipment in the residential sector might be dampened through education programs and perhaps also possibly through tax measures that would apply to built area per capita above a certain threshold.
- Demand for new commercial and institutional facilities is similarly controllable only to a certain extent, but since such buildings often involve the adoption of foreign technologies, there is an obligation by regulatory authorities to ensure that performance is of a high order, and professional education programs can also help to ensure that wasteful excesses are avoided in this sector.
- A crucially important strategy is to make the best use of the existing building stock, since this represents something like 95% of the total building stock at any time. Functional existing buildings must be protected from demolition unless absolutely necessary³. Inventories of the characteristics and condition of existing buildings should be carried out to identify good candidates for renovation. Techniques must be developed to renovate older buildings so they serve current market needs, through incentives, demonstrations, training and education for renovation. In this regard, it must be noted that performance upgrade packages for existing buildings must account for a great deal of variation in the types of existing buildings.
- Energy-efficiency regulations for equipment and for buildings (preferably measured by GHG emissions), are vital instruments in pushing the bottom end of the market towards an acceptable level of performance. They also serve a very important function as a baseline for various incentive programs. To ensure effectiveness, results must be monitored on an on-going basis and there

³ A recent case in Hong Kong reinforces this point. A developer proposed to demolish seven two-year old buildings that contained 2740 apartments, simply because market demand had switched to different types of units. The demolition would have created 200,000 tonnes of waste and was fortunately stopped (source: personal communication from K.S. Wong, Hong Kong)

must be a meaningful level of enforcement. The latter is not always easy to achieve in economies experiencing rapid growth.

It should be noted that the European Union has established an Energy Performance Directive, and all EU members are to have energy performance regulations in place by January, 2006. This is part of the EU's commitment to meet Kyoto requirements, but it should also be noted that the EU plans to go considerably beyond Kyoto,

- The design process itself can be improved to facilitate the achievement of high performance. A technique called Integrated Design Process (IDP) has been developed within a Canadian demonstration program called C-2000, and similar approaches have been developed within an International Energy working group, and also within a small number of private design firms. The IDP approach has demonstrated that a small number of process changes can help designers to produce buildings that have substantially better performance in many respects compared to conventional ones, at very little or no cost increase.



- Performance guidelines and labelling systems to promote sustainable performance, such as BREEAM (UK), HK-BEAM (Hong Kong), LEED (USA), Casbee (Japan) or GBTool (International), can lift performance standards in the market without the use of subsidies, in regions where the market actors are relatively sophisticated. Such programs should be compatible with energy regulations, but include a much broader range of issues, including water consumption, materials usage, GHG emissions, ecological impacts, indoor environmental quality. It is important to ensure that such systems are compatible with local climatic, technologies, industry and cultural conditions.
- Demonstrations are always an effective way of introducing the industry to new design approaches and technologies. Demonstrations of new house designs is relatively inexpensive and uncomplicated in a management sense; but demonstrations of high-performance commercial or institutional buildings must recognize that the demonstration component of a large project is bound to be a very small proportion of the total cost, so the ability to demand that certain conditions be met may be limited. Demonstration projects should be attuned to local needs, but there is much to learn from projects already carried out as part of EU programmes or International

Energy Agency (IEA) programs such as Task 23 or Annex 35⁴. Projects analysed as part of these research programs are mainly European, North American or Japanese, but the issues covered, the problems encountered and lessons learned should be part of the background information reviewed by anyone thinking of carrying out demonstrations. In the EU, many demonstration programmes over a period of at least 15 years have established a necessary factual basis for the current Kyoto initiatives, which now have a firm empirical basis to rest their projections on⁵.

Even in the somewhat less well-organized Canada, demonstration programs such as C2000 and the Commercial Buildings Incentive Program (CBIP) have proven their worth in bringing high-performance ideas to the industry at large. The building industry is highly conservative and it always helps to have “hands-on” examples available.



Left: A C-2000 Demonstration project in Winnipeg, Canada, in which 95% of the materials of two existing materials were incorporated in the new building. This project, which featured 50% better energy performance than conventional buildings created a high level of interest in the whole region, at comparatively modest cost.

- One measure that could help in improving the performance of the existing and new building stock would be to apply the International emissions trading (IET) is one of the four ‘flexible mechanisms’ contained in the Kyoto Protocol to assist industrialized countries in Kyoto Annex 1 to meet their emissions reduction commitments under Article 3.

The Clean Development Mechanism (CDM) program has been operational since 2000, and matches vendors of emission reduction certificates in developing countries with would-be purchasers in developed countries. CDM projects have ranged from large industrial projects to bio-gas generation in Central American villages. The program falls under the responsibility of the UNFCCC, which has established an Executive Board (EB) to manage the process⁶.

So far, very few projects have been generated in the building sector, but if a widespread expansion of emissions trading is desired, the building sector will have to be included. An obstacle to this is the varied nature of buildings, and the relatively small per-project reduction in GHGs (relative to baseline), but this could be overcome by developing a standardized but adaptable protocol and calculation tool, and by grouping projects into larger bundles. Such a

⁴ Some of these case study buildings can be seen on the IEA website, or the Buildings file of the *Sustainable Building Information System* (SBIS) database, at www.sbis.info.

⁵ See, for example, two excellent recent publications produced for EURIMA (European Insulation Manufacturers Association), *Mitigation of CO₂ Emissions from the Building Stock and Cost-Effective Climate Protection in the EU Building Stock*, both produced by ECOFYS, a German consultancy. For further information see www.eurima.org.

⁶ See *The Marrakesh Accords & the Marrakesh Declaration*, unedited draft, 10/11/2001, *Small Scale CDM Projects: An Overview*, World Bank Carbon Finance Unit; May 14, 2003, and *Simplified Modalities and Procedures for Small-Scale Clean Development Mechanism Project Activities*, Annex II of UNFCCC/CP/2002/7/Add.3

mechanism could find wide application in developing countries that participate in CDM, and could provide the stimulus to rapidly the energy performance of the building stock in the region.

iiSBE has initiated a project in Chile to develop a methodology to apply CDM to the building sector. The financing for that project is not yet guaranteed, and it is for new construction only. However, the largest potential is to apply CDM to the existing buildings sector, and iiSBE will be attempting to launch a project of this nature in the near future.

4. What does High Performance Cost?

Do high-performance buildings actually cost more? The answer is that it depends. If high-performance features are grafted onto a conventional design, the marginal cost can be very high, but if the appropriate steps are taken very early in the process, the cost can be low, or even zero. To this argument, we must add the fact that the reference or comparison cost is often poorly defined.

It can certainly be stated with certainty that, while a high-performance building might have slight extra capital costs (under 5%), operating savings will certainly cause the life-cycle costs of the high-performance building to be lower. However, this raises the question of who pays and who benefits. If additional construction costs are borne by the developer, while savings in operating costs are gradually accumulated by another party, then there is no incentive to build green or sustainably.

The client is always crucial to success, and we can say that, to ensure a high level of motivation, the client should benefit from long-term savings, and also be willing to accept a longer payback period than normal. Thus, governments and large corporations with an image to maintain are usually prime candidates. If we want sustainable building to become deeply entrenched in the industry, steps must be taken to ensure that smaller players can enjoy the same benefits without being exposed to excessive financial risk.

However, it can be said with certainty that any investor or client who designs a building in 2005 that has poor energy performance is exposing his organization to a high level of risk because of the probable escalation of energy prices over the next 50 years.

5. Organizing for Action

The point has been made several times in this paper that sustainable construction is an interdisciplinary activity. Even if we limit the discussion to green building, it is clear that environmental issues cut across most professions. Experience with design facilitation has shown that all key stakeholders must be involved if good results are expected, and this principle applies to more than the construction industry.

Different continents have organized in different ways to meet the challenges. In Europe, a long tradition of government leadership has been maintained, and the European Commission competes with national governments, in a positive way, to provide leadership in this sector. The relatively smooth cooperation of European and national industry associations, and the excellent work of some outstanding engineers and architects, have all combined to place Europe in a global leadership position with respect to action on climate change.

Although North America is relatively far behind in terms of action achieved, there are some interesting developments in the area of non-governmental action that offer promise for the near future. Specifically, the establishment of the U.S. Green Building Council (USGBC) four years ago and the Canadian Green Building Council (CaGBC) two years ago, has totally changed the picture in the building sector. Both organizations offer certification, training and professional development related to a performance assessment system called LEED (Leadership in Energy and Environmental Design), and both have seen dramatic growth in membership. Ironically, the LEED system itself acknowledged by many observers as being oversimplified and inflexible, but the strength of the organizations and the deep involvement of members in their activities overcome these limitations. These two organizations

offer memberships to design professionals, product manufacturers, regulators, government officials and other key actors, and this integration is a significant factor in their success.

iiSBE has assisted in the formation of similar groups in Europe and Asia, for the purpose of developing and testing its performance assessment, GBTool⁷, and iiSBE is ready to assist other groups to form. Given the different social and cultural values in these regions, the national groups tend to be initiated by governments, but several have evolved to include a wide variety of associations and stakeholder groups. Thus, we start from different points, but end up in similar situations in order to ensure success -- with non-governmental or quasi-governmental groups that provide a forum for integrated action to implement sustainable building.

In conclusion, it is clear that the need for action is urgent, and that success requires efforts to be undertaken on a broad front. Every key stakeholder group needs to be involved and they all need to work together in the most efficient and cooperative way possible, if we are to survive the next fifty years.

⁷ iiSBE has helped or is helping to establish local groups in Brazil, Chile, Italy, Israel, Korea, Mexico and Spain. Some of these are local Chapters of iiSBE and others are separate organizations with friendly ties to iiSBE.

ACTION FOR SUSTAINABILITY: OPPORTUNITIES FOR PARTNERSHIP FROM THE AFRICAN PLAN OF ACTION

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Abstract

This paper discusses the outcomes of the SB'04 Africa conference, specifically the Action Plan being developed for promoting sustainable building and construction (SBC) in Africa, within the context of the broader Agenda 21 for Sustainable Construction in Developing Countries developed by the CIB, UNEP-IETC and CSIR South Africa in preparation of the 2002 World Summit for Sustainable Development. Using Open Space Technology™ the priorities for an Action Plan for Africa was identified as a structured, coordinated process for mainstreaming SBC that would involve the establishment of a coordinating body that can champion SBC and oversee the development of a knowledge foundation comprising of knowledge generation through collaborative research, a shared information portal, an education and training programme for built environment professionals, an outreach and awareness raising programme aimed at both stakeholders and the general public, the establishment of building support centres, the development of locally relevant assessment, rating and labeling systems and a Best Practice recognition scheme. In addition, sustainable self-help housing was identified as a critical area for intervention and a first strategic entry point through which SBC can be promoted. There are numerous opportunities for collaboration and partnerships between the African region and the countries of Asia and the South Pacific, both within the knowledge foundation activities and through addressing the issue of sustainable self-help housing.

Keywords : Sustainable building, sustainable construction, action plan, knowledge foundation.

1. Introduction

When the International Council for Research and Innovation in Building and Construction (CIB) published its *Agenda 21 for Sustainable Construction* in 1999 (Bourdeau, ed., 1999), it pointed to a number of differences between developed market economies, transition economies and developing countries. These differences related to interpretations of terminology, technological needs, market emphasis, identified priorities, and the scale and types of challenges and barriers to be faced. The report also acknowledged that there is some truth to criticism that the international discourse on sustainable building and construction showed “an almost complete absence of the developing world and its problems” (Du Plessis, 1999).

In an attempt to rectify this omission, the CIB, in partnership with UNEP-IETC¹ and the CSIR² in South Africa, developed an *Agenda 21 for Sustainable Construction in Developing Countries* (A21SCDC) (Du Plessis, ed., 2002). After a process involving 21 people from 13 countries the final document was launched at the World Summit on Sustainable Development (Johannesburg, 2002) and the international Sustainable Building 2002 conference in Oslo.

While the A21SCDC outlined a generic framework for a R&D Agenda and Strategy for Action for introducing sustainable building and construction in the developing countries, it concluded that this framework needs to be fleshed out at a regional level through the development of regional Agendas or Plans for Action that respond to the specific needs and priorities in each region.

Delegates to the Oslo conference also suggested the need for more input from developing countries into the international discourse. To encourage the equal participation of low-income countries in the

¹ United Nations Environment Programme – International Environmental Technology Centre

² Council For Scientific and Industrial Research – specifically the Division of Building and Construction Technology

international discussions, it was decided that a series of five regional conferences will be held in Africa, Latin America and the Caribbean, South East Asia, China, and Central / Eastern Europe in 2004. This would allow the development of detailed action plans to advance sustainable building agendas in these regions. These Action Plans will be presented at the next international Sustainable Building Conference in 2005 in Tokyo and widely distributed to stakeholders in the regions.

The objective of this paper is to present the priorities for action outlined in the African Plan for Action identified during the SB'04 Africa conference, describe how these fit into the A21SCDC, and discuss the opportunities for cooperation between Africa and South East Asia and the Pacific.

2. The A21SCDC Framework³

The *Agenda 21 for Sustainable Construction in Developing Countries* rested on two elements:

- a research & development agenda built around a matrix of the enablers needed for sustainable building and construction, and
- a framework for stakeholder action.

Development is supported by technology based on science. The goals of sustainable development cannot be met without the use of science and technology that supports the principles of sustainability – these are the **technological enablers**. However, for technology enablers to be successful, supporting processes for stimulating technology development, technology transfer and management are required, as well as access to those technologies. This requires the presence of functioning **institutional enablers** such as supporting institutional structures (e.g. universities, professional councils and government departments), policy and strategies, educational programmes, financial mechanisms and regulations and legislation. Furthermore, specific **value system enablers** are necessary to bring about the successful uptake of technologies and behaviours that are conducive to sustainable development. The enablers are interdependent and multi-dimensional, following a systemic approach, as opposed to the usual sectoral approach. They are both driving certain actions and requiring specific actions for their development and implementation. Developing the necessary enablers requires an approach that operates simultaneously at various scales, as well as different time horizons.

- In terms of **scale**, enablers need to cover a range of needs from the urban level right down to the level of components and materials.
- In terms of **timeframes**, there are certain immediate enablers that will have to be developed to provide a sound basis from which to work, while medium term and long-term solutions are simultaneously developed.
 - The **immediate** enablers relate to the creation of an enabling environment and the collection and sharing of information for benchmarking and assessment.
 - The **medium** term enablers relate to the mitigation of impact and actual implementation of sustainable construction practices.
 - The **long-term** enablers relate to the creation of a totally new and more sustainable built environment paradigm.

From the above a matrix was plotted (see Table 1) onto which a specific problem such as urbanization, resource efficiency or the development of new materials can be mapped.

³ The framework is explained in more detail in the full A21SCDC document available at www.sustainablesettlement.co.za/policy or from www.cibworld.nl

However, sustainable building and construction requires that all the different stakeholders cooperate in the implementation of a clear strategy that involves specific supportive actions by all role players. This strategy formed the second part of the A21SCDC and was built around the following elements:

- Capacity building
- Access to funding
- Partnership and cooperation
- Internal housekeeping
- Encouraging and supporting implementation
- Monitoring and evaluation.

The challenge of A21SCDC was to take this framework to the different regions and identify the priority areas of action within the framework, as well as the priority problems that will form the lenses through which the framework should be applied.

Table 1 – Framework of enablers for the A21 SCDC Research & Development Agenda

Time	Technological	Institutional	Values
Immediate	• Benchmarking & Assessment • Knowledge systems & data-capturing	• Clarified roles and responsibilities • Education • Advocacy & awareness • Cooperation and partnership	• Mapping the route to change • Understanding the drivers • Re-evaluating heritage
Medium	• Technologies to mitigate impact	• Linking research to implementation • Develop regulatory mechanisms	• Develop a new way of measuring value and reward • Develop codes of conduct
Long-term	• Technologies of the future • Changing the construction process	• Strengthening implementing mechanisms • Using institutions as drivers • Regional centres of excellence	• Corporate social responsibility • Reporting

3. The African Plan for Action

3.1 Methodology.

During the SB'04 Africa conference a day and a half discussion session, based on Open Space Technology™, was held to identify the key priorities for action in Africa. Each participant was invited to identify any issue or opportunity around the theme "Africa: Action for Sustainability" which they felt was important. These topics were discussed in small, self-selected groups and the discussions were documented. Participants then had the opportunity to vote for four topics to take to further discussions. These four topics were then discussed in detail the next day, again by groups who self-selected a particular topic. The groups were then given an opportunity to rotate between the topics, adding to the notes, and the initial group could then consolidate the thinking. This process served to identify the priority areas for action and go deeper into the specific actions required. The notes from these further discussion sessions are being used as the basis from which to formulate a draft action plan.

3.2 Chief recommendations.

The primary challenge was identified as making sure that research and development should focus on methods to improve quality of life in such a way that environmental and social impacts are minimized, while developmental goals are being realized. The discussion sessions prioritized the development of institutional enablers as a basis from which to manage and coordinate the development of other enablers. The establishment of two interlinked institutional enablers was identified as a first priority for action. These were:

- A structured, coordinated process to mainstream sustainable building and construction, supported by a coordinating body in each sub-region;
- A linked knowledge foundation that includes research, education & training, awareness raising and advocacy.

Self-help housing was identified as a critical area for intervention and a possible strategic entry point or lens through which the A21SCDC framework can be populated and sustainable building and construction can be promoted.

3.3 Establishing a knowledge foundation.

A knowledge foundation consists of five basic elements that feed into each other. The starting point is the gathering and creation of knowledge. However, for knowledge to be of value requires that it be shared amongst peers and transferred to others through education and wider dissemination. This enables implementers to access relevant knowledge and apply it in project design. Projects should be monitored and evaluated and the results fed back into the process of gathering and creating new knowledge. (Du Plessis and Havemann, 2004). Participants at the discussion session identified a number of components required of a knowledge foundation for SBC in Africa, Fig.1 maps the identified components (discussed below) against the elements of a knowledge foundation.

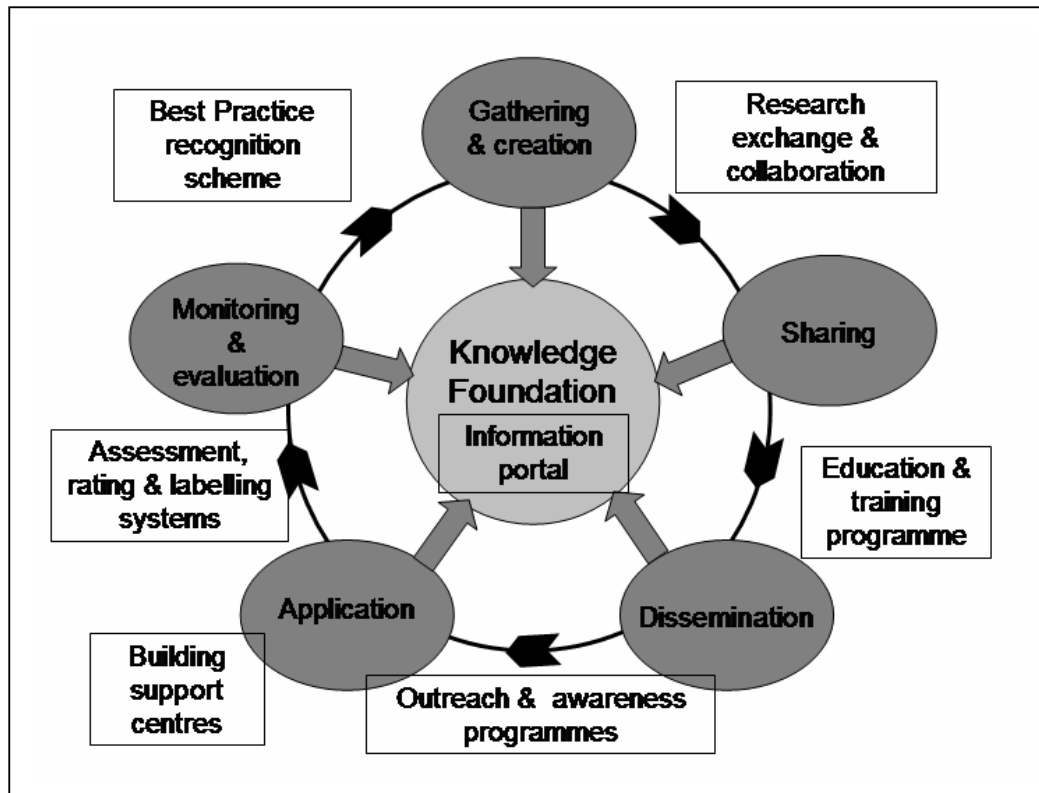


Fig.1 Elements of the proposed knowledge foundation

4. Areas for Possible Collaboration

Asia and the countries of the South Pacific share similar conditions (for example climate and biophysical environment, problems with rapid, informal urbanisation, different levels of development, and building traditions) with African countries. Within the components of the knowledge foundation there are a number of opportunities for collaboration between Africa and Asia and the South Pacific (ASP). The possible areas of opportunity are briefly discussed below. It should be kept in mind that these are generic opportunities that can be applied to the entire A21SCDC framework and to any issues pertinent

to sustainable building and construction. While self-help housing has been identified as the critical area of intervention in Africa, this does not mean that collaboration on other aspects of sustainable building and construction should not be encouraged.

a) A research collaboration and exchange programme.

Due to a number of factors, Africa's research capacity has fallen behind that of other regions and many of its brightest scientists are working outside the continent due to a lack of funding and facilities. In order to strengthen the African S&T base and generate knowledge that is not only relevant to Africa but also local intellectual property, it is suggested that a programme be established that encourages and enables research collaboration between researchers working within Africa and between African research institutes and researchers from countries dealing with similar problems in both the developed and developing regions of the world. For scientists from outside Africa, it would provide an opportunity to test the theories and technologies developed in their own countries in a very different cultural and economic context, thereby leading to more robust and universally applicable solutions.

b) An information portal.

There is a critical need for a regularly maintained, easily accessible source of information that can be used by practitioners, educators and other interested parties such as clients, local government and funding agencies. The proposed information portal would provide, *inter alia*,

- access to tools, guidelines and Best Practice examples relevant to Africa;
- a regional database of accredited 'green building' practitioners;
- information about funding opportunities and programmes;
- news about training courses, events and new publications;
- a network of related information sources within other developing countries and countries with similar climatic conditions.

Collaboration opportunities in this area rest on the sharing of access to knowledge and data and the establishment of an intra-regional network of scientists and practitioners.

c) Education and training programme.

A three-pronged education and training programme is required. The first leg would be to introduce sustainable building and construction as an integral part of built environment courses taught at tertiary institutions through the development of new curricula monitored by professional bodies such as the International Union of Architects. The second would be the development of continued professional courses that would provide a credible accreditation system for "green" building professionals. The third is a basic education programme for other stakeholders such as local government and suppliers. Du Plessis and Havemann (2004) provide a more detailed framework for such an education and training programme.

Collaboration on education and training can be supported through a two-way exchange programme of students, lecturers and professionals and a series of cross-regional seminars.

d) Outreach and awareness raising programmes.

To promote sustainable building and construction with the general public that eventually constitutes the client base, a number of public awareness campaigns or outreach programmes were suggested. These ranged from programmes in schools and the media (e.g. magazine articles or television programmes) to low-level activism like the preparation of "pester questionnaires" with which to interrogate material suppliers and even developers, placing pressure on them to improve their offerings.

Many of the ASP countries have experience in these kinds of outreach and awareness raising programmes. This experience can be transferred to Africa through the training of local outreach agents and sharing learning and experiences.

e) Building support centres.

Building support centres would provide the public with technical assistance in retrofitting existing buildings and building new buildings to improve their sustainability. This was seen as a particularly valuable tool in Africa where the majority of houses are owner-built. Such building support centres would also act as training centres and can be linked to existing NGO activities, or run as part of a community service programme for built environment graduates and the tertiary training institutions.

The establishment and operation of building support centres with a sustainability basis presents an opportunity to strategically direct Overseas Development Aid funding into a number of critical delivery areas such as energy, water and sanitation, but to do so in an integrated and locally appropriate way. These centres can further be supported through volunteer programmes that bring in experienced practitioners, as well as young professionals to assist local professionals serving disadvantaged communities.

f) Assessment, rating and labelling systems.

To facilitate the application of knowledge developed, as well as the monitoring and evaluation of SBC assessment, rating and labelling systems specific to Africa is required. Although the CSIR has developed an assessment system (see Gibberd, 2002) suitable for use in Africa, it relies on the further development of indicators specific to the challenges experienced on the continent. There is also currently no system for rating and labelling building components and materials except that developed in the industrialised countries. In most cases the development of these tools does not require new frameworks, but rather detailed research to determine specific values related to manufacturing processes and the performance of materials and components in the various climatic conditions of the continent.

Here the opportunities for collaboration lies in matching local knowledge with the sophisticated research infrastructure available in some ASP countries to provide a better information platform for both parties.

g) Best Practice recognition scheme.

The final element to be developed is a Best Practice recognition scheme to capture and share knowledge between practitioners, evaluate the impact of the Knowledge Foundation and generate new knowledge. Establishing local best practice schemes that use a common evaluation method and sharing those best practices on a linked electronic platform provides an opportunity for sharing learning and identifying new areas for collaborative research and technology transfer.

5. Conclusions

In Africa, SBC is being addressed from a very low knowledge base and therefore the establishment of a common, collaborative knowledge foundation supported by a championing body that can effectively promote SBC across the continent, was identified as a priority action. The establishment of such a knowledge foundation would be strengthened by an initial focus on one area that could be the lens through which a first category of technological, institutional and value enablers can be developed. Sustainable self-help housing was identified as the focus area that could be such a strategic entry point. Although mainly an informal economy activity, the discussion participants were of the opinion that self-help housing constitutes the main construction activity in Africa. Housing provision, rapid urbanisation and the achievement of some of the Millennium Goals (e.g. eradicating slums, providing clean water and adequate sanitation), are inextricably linked. Enabling sustainable self-help housing therefore becomes a way of ensuring that the development that is stimulated by initiatives such as the Millennium Development Goals, the Johannesburg Plan of Implementation, and the New Partnership for Africa's Development, will promote SBC in Africa. However, while self-help housing was seen as the priority issue to be addressed, the delegates also felt that a programme focussed on commercial/formal

building and construction that use the First Economy initiatives in SBC as a driver for Second Economy aspirations and opening up markets for more sustainable technologies, is a critical part of what should be a two-pronged strategy to get both economies in Africa to support sustainable building and construction.

This paper dealt mainly with the elements identified as part of the knowledge foundation, as that is where most opportunities lie for partnerships and collaboration between Africa and the countries of the ASP region. As the countries of the so-called developing world starts embracing SBC, it is important that they follow a model that is not just about doing a bad thing less bad (to quote William McDonough, 2002), merely improving on bad habits taken over from the industrialised countries, but that they start developing enablers for SBC that is locally appropriate, drawing on local strengths and responding to local problems, drawing on some of their own pre-industrial society wisdom. While a lot can be learned from how the countries of the industrialised world are responding to their own SBC challenges, the countries of the developing world would stand a better chance of finding appropriate solutions if they collaborate on sharing learning and generating new knowledge from their common experience, whether this be climatic context or economic situation. It should also be understood that some countries within both regions are far ahead of others on the development path. On their shoulders falls the responsibility of providing leadership, being the explorers that open up the unknown route to a sustainable future, while guiding and supporting the stragglers. For ultimately we all share one fate.

Acknowledgements

I would like to thank the Development Bank of Southern Africa (DBSA) for generous financial support for the Action Plan Workshop during the SB'04 Africa conference and to Mr Glenn Havemann of the DBSA for his insightful contributions to the discussions presented in this paper.

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DEVELOPMENT OF SUSTAINABLE BUILDING IN CHINA: A REPORT FROM THE SB04 CHINA CONFERENCE, SHANGHAI, SEPTEMBER 2004

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Abstract

SB04 China Conference was organized by the Shanghai Research Institute of Building Sciences at the Wan Ping Hotel, Shanghai China, from 20 to 22 September, 2004. It was co-hosted by the iiSBE, CIB and supported by the SB05 Tokyo, United Nation Environment Programme (UNEP), the Chinese Ministry of Construction, the Shanghai Committee of Construction and Management, the Shanghai Committee of Science and Technology, the Shanghai 2010 EXPO Bureau, and others. There were two thematic plenary sessions and four concurrent sessions during the conference. Besides the plenary and concurrent sessions, the conference also incorporated a mini-exhibition of sustainable projects, an opening ceremony of the newly formed Shanghai Green Building Council, and site visit of an experimental eco-building in Shanghai.

The paper presents the issues brought about by the conference. The scope and challenges of sustainable building development in China were also highlighted.

1. Introduction

1.1 Basic Facts

SB04 China Conference (Fig.1) was organized by the Shanghai Research Institute of Building Sciences at the Wan Ping Hotel, Shanghai China, from 20 to 22 September, 2004. It was co-hosted by the iiSBE, CIB and supported by the SB05 Tokyo, UNEP, the Chinese Ministry of Construction, the Shanghai Committee of Construction and Management, the Shanghai Committee of Science and Technology, the Shanghai 2010 EXPO Bureau, and others. There were two thematic plenary sessions and four concurrent sessions during the conference. Besides the plenary and concurrent sessions, the conference also incorporated a mini-exhibition of sustainable projects, an opening ceremony of the newly formed Shanghai Green Building Council, and site visit of an experimental eco-building in Shanghai.



Fig.1 SB04 China Conference

1.2 Number of Participants

There were 238 participants from overseas and from all over China to attend the SB04 China Conference. A breakdown of the participants consisted of sixteen invited guests speakers, including six from overseas

and ten from China; thirty students; and finally one hundred and eighty two registered and paying participants.

1.3 Number of Countries

There were participants from eleven countries. They are UK, the Netherlands, Germany, France, Romania, Japan, Australia, New Zealand, USA, Canada and China. As for the Chinese participants, these were from fifteen cities and regions.

1.4 Number of Papers

The International Scientific Committee reviewed more than one hundred papers. Ninety papers were accepted. Fifty-six papers were selected for presentation during the conference.

2 Major Issues

The Organizer has scheduled a total of four themes that represented the most pressing issues for sustainable development of the building and construction sector.

Chinese developers, researchers and practitioners from different geographical locations, economies and markets were invited to present specific views based on projects or research. There were fruitful exchange of ideas and experience that are derived from a vast and fast developing country with differentiating socio-economic and market contributing factors. In this context, there were views and expertise sharing among delegates from fifteen cities and regions in the north, south and west of China, including Beijing, Ganshu, Guangzhou, Heilongjiang, Henan, Hong Kong, Hunan, Jiangsu, Jiling, Shandong, Shanghai, Shenzhen, Taiwan, Tianjin, and Zhejiang.

2.1 Topics and Issues Prepared for Discussion at SB04 China Conference

(i) Design, practice and policy of the sustainable building;

Topic 1: Development trends and strategy of global sustainable building

Topic 2: Design and layout of sustainable building

Topic 3: Examples of global sustainable building and analyze

(ii) Technology and Equipment of energy economical building, application and Development of regenerated energy in sustainable building;

Topic 1: Technology of effective Usage of resource in sustainable building

Topic 2: Development and application of environmental and economical equipments

Topic 3: New Technology and products of energy economical building

(iii) Evaluation system of green building and control improvement of building Environment;

Topic 1: Control, technology and products of building environment

Topic 2: Evaluation of sustainable building and analyses of the full periods

(iv) Green Eco-building materials and other sustainable building technology

Topic 1: Evaluation and Application of green building materials

Topic 2: Intelligent control System of Eco-building

Topic 3: Ecological configuration and scene in green building

3. Discussions

3.1 Plenary and Concurrent Sessions

The four themes represented a focused concern from Chinese scholars and practitioners on the scope and challenges of sustainable building development in China. Firstly, the scope concerns the lacking of sufficient knowledge to master the art and science of sustainable building. Secondly, challenges are perceived as primarily technological or physical in nature. Thirdly, there is a keen interest shown in

innovative technologies, equipment and materials that are available in international market. Interestingly, there were fewer worries about those softer issues of sustainable buildings such as policy, legislations, or agenda for the facts that are explained in next paragraphs.

As some paper suspects, the driver for changes exhibits a natural course of change in the national real estate and economic market systems, that is, from a real estate market that is non-existent in the days of a pre-1980s state-owned, work-related dormitories, to a post-1980 market-driven and individually owned private home. In a market-driven situation, developers have to think about strategies or tricks that could help promote property sales.... sustainability is embraced by innovative developers in advanced cities with incredible competitive real estate markets such as Beijing, Guangzhou and Shanghai, and eventually spread to other cities. The other significant impetus for driver for change is undoubtedly the release of the National White Paper on sustainable development, when China signed the Agenda 21 in early 90s. The release of the White Paper on domestic book market soon sparked off a proliferation of books and literature on the subject by domestic scientists and researchers, and spread the green message across the nation.

The conference also demonstrated a presence of research capabilities in national markets, where universities, research institutes, and design institutes collaborated in the research and developments of sustainable principles and technologies applicable to the local climatic and socio-economic requirements. In terms of implementation, there are evidence showing local governments funded or supported private initiatives to build demonstrative green projects in both residential and office sectors. Examples are the green research laboratory in Beijing, the Eco-Office and research laboratory in Shanghai, and numerous green residential neighborhood projects in other cities. While Chinese designers are primarily responsible for these projects, some projects showcase the collaboration of international, regional and local expertise in the design and construction of sustainable building. The collaborative efforts represent a process of transfer of knowledge and experience within the local, regional and international region for mutual benefit. The so-called green demonstrative projects also provide useful platform where sustainable design theories and application are tested or experimented. They also provide a feedback to pilot green legislations that are introduced by regional or local building control agencies from time to time.

The roles of government continues to take the lead in terms of setting policy and priorities at different levels appropriate to the Chinese administrative system. A noticeable action is the central government's active participation and support for the UN initiatives on climate change and the Kyoto Protocols. According to Xin Hua News Agency, 17 February, 2005, the National Strategic Policy Statement in response to climate change will be finalized within the year, and a number of State-funded national research on related topic to sustainable developments are in active perusal.

3.2 Mini-Exhibition

At the conference, the organizers have organized an exhibition (Fig.2) that shows recently completed sustainable buildings from cities with different contexts and issues such as Hong Kong and U.K. The exhibition is a welcomed by the conference participants.



Fig.2 Mini-exhibition

3.3 Building Visit

On the third day of the conference, there was an organized study tour of the Eco-Office (Fig.3) and Building Research Laboratory designed and constructed by the SRIBS. The objective of the eco-project is to showcase the state of the art knowledge and technologies available in Shanghai to implement a sustainable building. The municipal government of Shanghai initiated and funded the project as a regional model to promote and educate the public, professional and property developers about sustainable building procurement. The building research laboratory is an extension of building performance measurement and monitoring capabilities of the SRIBS. When fully operational, the building will serve as an experimental platform for such data collection and monitoring to enable further calibration and research by scientists at the SRIBS.



Fig.3 SRIBS Eco-Office

4. Major Outcomes of SB04China Conference

- (i) Publishing the proceedings of SB04China Conference with 600 pages (hard copy and CD).
- (ii) Introduction some advanced technology solutions such as solar energy application, water recycle technology, energy efficient Building, evaluation system for green building, and so on.
- (iii) Bring forth some case of best practice in overseas and China.
- (iv) Recommend raising guideline or regulation for local green building. Shanghai will go first in China.

4.1 Selection Process of SB 05Tokyo Fund Support Programme

The Scientific and Organizing Committee of the SB04China Conference has selected seven authors from the Shanghai oral presentations and three members from the Shanghai Organizing Committee as the nominated delegates from China for the SB05Tokyo Fund Support Program. Respective details are as follows.

Table 1 Details of authors

Name	Paper	Organization
Jiang, Yi	Beijing Green Olympic and its evaluation System	Professor, Tsinghua University
Zhang, Guoqing	Research on Modeling Method of Environmental Performance of Building Systems	Professor, Hu Nan University
Wei, Yu	Test investigation of automatic running and monitoring water quality in the device of water reuse	University of Shanghai for Science and Technology
He, Dasi	Air conditioning Load Prediction Methods Competition	Tongji University
Bu, Zhen	Introduction to energy efficiency technologies and simulation of energy consumption for ecological building	Shanghai Research Institute of Building Science
Li, Yuwu	Integration of the solar-assisted heat pump,water energy storage and liquid desiccant system	Shanghai Jiaotong University
Zhang, Hongru	Sustainable architecture	Shanghai Jianke Architecture Institute
3 members of the Organizing Committee of SB04 China	Introduction of Shanghai Eco-Building	
	Regional report on SB04China	

5. A call for international collaboration – two requests for SB05Tokyo

- (i) A consensus is reached by the conference discussion regarding the significant contribution by pilot or demonstration projects. There is a general understanding among the Chinese participants that this should continue to be a public or public-private initiative to promote the practice of sustainable building at a regional level. The conference organizer proposes to make a request to SB05 Tokyo to initiate an international exchange program in sustainable building to assist developing nations by means of advanced knowledge and know-how in sustainable building such as design practice, technologies, as well as promotion and policy.
- (ii) The reports by Chinese colleagues at the conference revealed an emerging recognition and demand for both project and research database in the field of post-occupancy building performance, operation and monitoring. This recognition echoes a global interest for real and long term benefits of sustainability principles in buildings. A suggestion similar to the first request seems appropriate in this connection.

Acknowledgement

Main contents of this paper are also included in a country report in the Journal of Building Research and Information.

SUSTAINABLE BUILDING AND CONSTRUCTION IN SOUTH-EAST ASIA

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Abstract

South-East Asia (SEA) is currently witnessing increasing population growth and rapid urbanization. The implications of these demographics are the increased in the demand for buildings and infrastructures, with consequential effects such as massive construction and proliferation of new building projects likely to cause environmental degradation.

Generally, the awareness on sustainability issues in the building and construction sector in the developing countries of SEA is generally low, although gradually gaining supports from stakeholders. Common practices includes the reliance on construction methods, design and materials that are often outdated and inappropriate to local climates and conditions and to some extent, imposing expensive business models. The activity of building is seldom seen as meeting the needs of the society and environmental protection but rather for stimulating the economy. Managing the built environment in SEA is therefore a major challenge for the future. The paradigm shift towards creating a more sustainable built environment in the region certainly requires the participation of all stakeholders, public-private partnerships, governance mechanisms and also strategies to encourage its implementations.

The paper presents the current status of sustainable building and construction in SEA, with examples of regional initiatives as well as challenges and barriers to SBC practices in the public and private sectors.

Keywords: Sustainable Building, Construction, Challenges, Barriers, Partnerships, Environmental protection.

1. Introduction

Construction is one of the largest industries in both developing and developed countries in terms of investment, employment and contribution to GDP. Its impact on the environment is considerable across a broad spectrum of its activities. Their impact on the environment can be significant in the following areas:

- consumption of renewable and non-renewable resources such as minerals, water and timber for building materials and components. This may also lead to the loss of bio-diversity;
- pollution of air, water and land from manufacturing and transportation;
- committing land for a new facility may lead to deforestation, loss of agricultural land, expansion of urban areas with associated transport and social problems, more demand for water, electricity and other services, and loss of bio-diversity;
- decisions about project goals influence design, construction and operation of the facility in areas of resource usage, quality of indoor environment, traffic issues, recycling, waste management, maintenance and life of the facility as well as social environment.

Buildings account for more than 40% of total energy consumption, and the construction sector as a whole is responsible for approximately 40% of all human-produced wastes. Hence, the provision of

adequate housing and infrastructure for transport, communication, water supply and sanitation, energy supply, and commercial and industrial activities poses a major challenge (OECD).

As the population continues to grow, the need to house people and industry, facilitate transport, build infrastructure facilities, and store drinking water will need to be satisfied. Existing urban areas will continue to expand as will rural settlements and recreational areas. The impact of new developments (i) causes land degradation and erosion, surface and ground water pollution, and (ii) contributes to land clearing required for new developments and acquisition of more agricultural and grazing land. Land clearing for urban development also affects the ecosystem.

The construction industry has already taken up the challenge of embracing the principles of sustainable construction and is on the way towards meeting its environmental responsibility. However, with an anticipated population and consumption growth, more building stock will be constructed to meet the growing demand (Spence and Mulligan, 1995).

Sustainable development is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". The construction industry is both a major contributor to socio-economic development and a major user of energy and natural resources; therefore its involvement is essential to achieve sustainable development in our society.

The concept of sustainability in building and construction has evolved over many years. The initial focus was on how to deal with the issue of limited resources, especially energy, and on how to reduce impacts on the natural environment. Emphasis was placed on technical issues such as materials, building components, construction technologies and energy related design concepts. More recently, an appreciation of the significance of non-technical issues has grown. It is now recognised that besides economic and social sustainability, the cultural heritage aspects of the built environment are also important.

Still, sustainable construction adopts different approaches and is accorded different priorities in different countries. Hence, there are divergent views and interpretations between countries with developed economies and those with developing economies. With mature economies, developed countries are in the position to devote greater attention to creating more sustainable buildings by upgrading the existing building stock through the application of new developments or the invention and use of innovative technologies for energy and material savings, while developing countries are more likely to focus on social equality and economic sustainability (UNEP-IETC).

This paper presents an overview of the current state of sustainable building and construction in developing countries in SEA, with examples of regional initiatives and highlights of challenges and barriers to SBC practices in the public and private sectors.

2. Geographical Position

South-East Asia comprised of Malaysia, Singapore, Indonesia, Thailand, Vietnam, Laos, Cambodia, Brunei, Burma and Philippines, Fig.1 More than 85% of South-East Asia covers the area between 10 N – 10 S. South-East Asia can be regarded as a region of tropical islands because most of the lands is surrounded by ocean with an average distance of less than 200 km from the sea. Nearly half of the total area is in the form of peninsulas and extended subcontinents are part of mainland Asia, and remaining area consist of thousands of islands. Due to the geographical locations there is very little climatic variations amongst the countries.



Fig.1 Map of South-East Asia

3. Social and Economic Background

Most countries in South-East Asia region have undergone unparalleled social, political and economic transformations. Colonialism dominated much of the region but now replaced by other political systems. Economies, which were largely agrarian, became industrialized, export-oriented and better integrated with global markets. Agriculture was intensified to increase production for home consumption and export.

Rapid industrialization and economic growth have changed virtually every dimension of life in South-East Asia. Yet, by measures of health, education, nutrition, as well as income - the quality of life within the region remains poor for most people. At least one in three Asians has no access to safe drinking water and at least one in two has no access to sanitation (ADB 1997). Literacy rates are low, particularly for women (ADB 1997). Poverty is a major problem: some 75 per cent of the world's poor live in Asia (UNESCAP/ADB 1995).

In most countries, economic development and industrialization have taken a heavy toll on the environment. At the turn of the century, environmental degradation in the region was largely due to poor farming methods and colonial expansionist land practices in South-East Asia. In South-East Asia, rapid economic growth began in the early 1980s before the economic currency crisis in 1997.

Malaysia, Thailand and Singapore are the leading countries in South-East Asia with robust economic growth in spite of the recent economic 'currency' crisis. These countries report almost a full recovery from the crisis while Indonesia and the Philippines have experienced setbacks due to the recent political instability. Myanmar, Cambodia, Laos and Vietnam are lagging behind due to ideological crises. Although there are differences in terms of economic development among the South-East Asian countries, in general socio-economic patterns in this region throughout history share similar patterns of development – a major shift of economic dependency on agriculture to industrial-based production.

The Europeans during the colonial period introduced monetary-based agriculture economy with intensive plantation of rubber and oil-palm for the overseas market. However, by early 1980s there was a drastic reduction in the demand for rubber and palm-oil. Consequently, the governments in these countries shifted the economic pattern from agriculture to industrial production. The shift creates new types of professions, which has attracted migration by the rural population to the city.

Compared to the rural population, poverty levels of urban population in South-East Asia was small. Benefits of the countries' economic growth were mostly enjoyed by the urban population. The urban population explosion caused housing shortage with the cities becoming overcrowded. Migrants who could not afford to buy houses end up in squatters. The squatter environment is poor and exposed to pollution, diseases, fires and hailstorms since there is minimal provision from the public authorities. The growth of the slum and squatter areas is uncontrollable.

The issues commonly raised today are problems of uncontrolled development of urban growth, which is not managed based on environmental concern. One of the tangible results of this human error is an increase in flood-prone areas and river pollution, indirectly suffered by the population living in related areas.

4. Construction in South-East Asia

Asia is currently witnessing increasing population growth and rapid urbanisation which is predicted to grow at an average rate of 2.4% per annum between 2001-2015 (GEO3). In the less developed nations this figure rises as high as 40%. Some implications of these demographics are increased demand for buildings and infrastructure, massive construction and new building projects and therefore increased related environmental degradation. *Agenda 21 for Sustainable Construction in Developing Countries highlighted that*, "there is a sense of urgency about introducing sustainable construction practices into the developing world...as it is still largely under construction and every minute means the construction of a building, road or dam that will in all likelihood not be sustainable".

4.1 Existing Construction Issues

In some developing countries of South-East Asia, the construction industry is not fulfilling its potential role in development. Often, there seem to be some difficulties in the execution of construction projects due to inadequate capacity for the planning and design of projects; difficulty in obtaining tenders for small projects in which international contractors are not interested or for projects which are too large for local contractors to handle; inefficiency in planning, design and construction, and difficulties in obtaining materials. Delays in project delivery are common and represent a physical constraint on development.

Where construction projects are implemented, the cost is often higher than anticipated, and this represents a financial constraint on the successful implementation of development plans. This is due to various factors such as poor estimates, variations by the client, inappropriate technology and design, inappropriate tendering and contractual procedures, inefficient on-site supervision and construction management.

A problem endemic to developing country in South-East Asia, is the reliance on 'western' construction methods, designs and materials that are often outdated, not energy-efficient, inappropriate to local climates and conditions and impose business and trade models that are expensive and inappropriate. Subsequently, cement has replaced indigenous materials and is responsible for 8% of carbon dioxide emissions world-wide. The replication of western approach was the result of foreign investment with its corresponding imposed design, construction and development pattern models (Du Plessis, 2002).

For most South-East Asian countries, the import content of construction activity is high; approximately 30 per cent of the value of gross output may be accounted for imports, 60 per cent of all materials, as well as a significant percentage of professional, managerial, supervisory and even craft skills. In addition to finished products, developing countries are importing factor inputs such as machinery, energy and raw materials. The increasing dependence on imports has imposed a severe strain on the balance of payments and fuelled inflation.

In most developing countries, there is a severe shortage of skilled labour for the construction industry. A large percentage of the skills required are not available locally. The local contracting industry is not sufficiently developed. Local contractors to operate only on small residential projects while the larger industrial and commercial projects are awarded to foreign-based construction firms. This is the case even in countries where there exists a strong entrepreneurial tradition.

Although most developing countries have abundant natural resources that could meet the demand for basic building materials using largely indigenous inputs, the local production of building materials often does not meet demands. For example, there are severe bottlenecks in the supply of building materials due to demand fluctuations and lack of capital for the build-up of supplies, or inputs. In cement producing countries, cement is often regarded as a local product even when 60 per cent of the production cost is due to imported energy (Levin,1997).

In some countries where there is a monopoly in supply and shortages have been created deliberately in order to force up the price.. The steep rise in prices of land and building materials has effectively removed decent housing from the reach of low-and medium income groups in most developing countries.

The situation is aggravated by the widespread adoption of designs and technologies, that have been developed in a very different context in advanced industrialized countries. These designs and technologies are often unsustainable and inappropriate in light of supply of local resources and indigenous social and economic conditions. The technologies increase the dependence upon imported plants, materials and equipment, as well as foreign professionals and contractors, whilst inhibiting the development of local resources. This applies to construction of infrastructure as well as buildings, in both the public and the private sectors.

The acceptance and use of technological innovations by the industry has been slow due to various factors. Innovative materials and technologies developed by government research institutes are seldom used by governments in their own construction activities. Frequently, even government tenders for low-cost housing projects specify expensive conventional building materials and technologies instead of proven low-cost technologies developed by government research institutions. Due to lack of public sector demonstration projects, contractors stick to the "proven" technologies that are often unsustainable from the social, economic and environmental point of view, and wide application of new innovative building materials and technologies is impeded.

5. Sustainable Building and Construction Developments in South-East Asia

Sustainability, as a concept, has only recently been introduced to the building and construction sector and SBC is not yet an integral part of decision-making and business practice. Sustainable building and construction aims at introducing practices and technologies and designing more sustainable products that are more efficient in terms of resource and energy use, reduce the impact on the environment, provide better value of living and work conditions, whilst improving economic productivity and competitiveness. Priority areas are the reduction of resource use, particularly building materials, energy, and water, and innovation in design – because it is at this stage that the decisions can determine the efficiency and performance of a building and the degree of its impact across its lifecycle. Sustainable planning and procurement practices and policies are also high priority issues as well as customer/client/consumer awareness and innovative construction processes.

SBC requires a holistic, multi-disciplinary approach to buildings, involving all actors from planners, engineers, architects, contractors, clients/users across the life-cycle of the structure from commissioning, design, construction, use and deconstruction/demolition. The components of sustainable building and construction are promotion of the use of local, cost-effective, environmentally-preferable building materials, climate sensitive design, flexible/multiple use design, low-energy and energy-efficiency, higher quality at lower cost construction, water efficient and conscious features, lean and clean construction processes and life-cycle thinking

The introduction of sustainable building and construction in South-East Asia will promote integration of environmental considerations into decision making and environmental management practices at the conception, design, use and deconstruction stages of a building life-cycle. It therefore aims at resource efficiencies and mitigated impacts across the sector, throughout many stakeholder groups. Such practices improve environmental performance including planning considerations, access to local infrastructure, materials selections, improved sites, land and water use, environmental design, improved construction processes and waste management during construction and demolition. This

would also result in high performance buildings that are efficient during use with lengthened service lives, and generally with higher value with lower risk.

Economic dimensions of sustainability includes the creation of new markets and opportunities for sales growth ; cost reduction through efficiency improvements and reduced energy and raw material inputs and creation of additional added value.

In most of South-East Asia countries the awareness on sustainability issues in the building and construction sector is generally low and just beginning to address the challenges of sustainable construction. There is a growing awareness of energy efficiency issues in countries such as Malaysia, Singapore and Thailand, but still in its infancy. Some major national projects in sustainable construction and energy efficiency in buildings have been implemented by national governments and private sectors.

Among others existing sustainable construction projects in the region include the development of Putrajaya (the Federal Administrative City of Malaysia, Fig.2), Securities Commission Building (Malaysia), Telekom Tower (Malaysia), MECM Low Energy Office Building (Malaysia), Urban Redevelopment Authority Building (Singapore), Singapore Immigration and Registration Building, Hanoi Daewoo Hotel Building Vietnam and Plaza Bank International Indonesia.

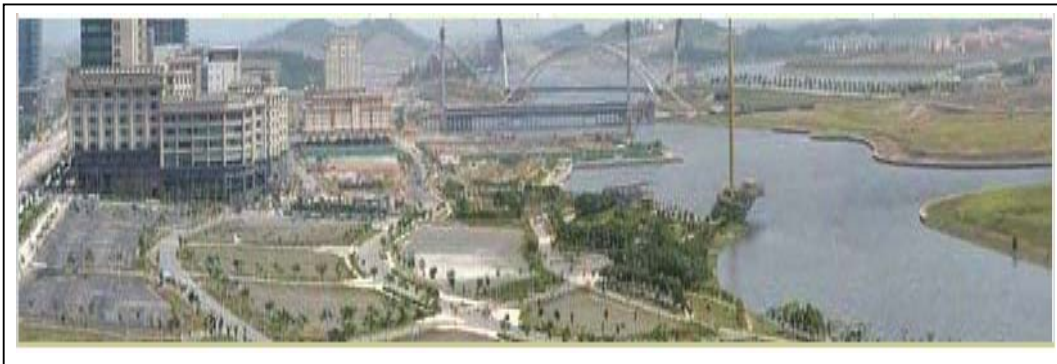


Fig.2 Putrajaya, Malaysia

The new KLIA is also designed to be an environmentally friendly airport with its central theme of an "airport in the forest" and a "forest in the airport", Fig. 3. The airport is perhaps unique in the world for its environmental aspirations. The central theme is carried out through a rain forest arboretum in the center of the international terminal and forested grounds surrounding the facility.

The forested edges of the airport will serve as a buffer to keep the surrounding development in control, while concentric landscape and forest rings are proposed to surround the airport site creating the effect of an "airport in the forest".

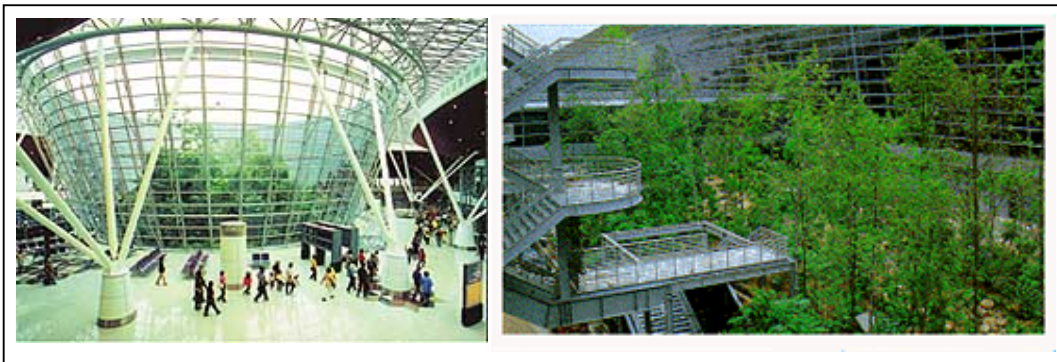


Fig.3 Kuala Lumpur International Airport

The current / planned initiatives for promoting SBC in Malaysia include:

- a) Malaysian-Danish Country Programme for Cooperation in Environment and Development (2002-2006) with a joint overall objective: "to assist Malaysia in achieving sustainable development, through the implementation of environment and natural resource management projects, in line with international environment conventions and agreements".

The initiatives are for the development of the energy efficiency regulations and the code of practice for energy efficiency and renewable energy in buildings. Demonstration of energy efficiency practices in government buildings are:

- i) MECM Low Energy Office (LEO) building
 - ii) PWD Public School Buildings
 - iii) Proposed Zero Energy Office (ZEO) building for the Malaysian Energy Centre (PTM).
- c) The national Solar, Hydrogen and Fuel Cells Roadmap 2004-2050, Malaysian Energy Centre, PTM, 2004.
- d) Implementation of Malaysian Building Integrated Photovoltaic Programme (BIPV) 2005.

6. Barriers and Challenges

Generally, the major barriers holding back the development of building and construction of sustainable buildings in South-East Asia are:

- the lack of awareness of sustainability issues in related professions and a lack of capacity amongst planners, architects, engineers, contractors and related stakeholders
- a lack of research and professional networks
- a lack of political motivation and incentive. It is very difficult to establish sustainable development as a national priority for areas in poverty and with economic problems
- a lack of well documented references, tools, techniques, case studies and demonstration projects which are relevant to local conditions.

There is a clear need for stimulation of activities to break down these aforementioned barriers in promoting sustainable building and construction in the region.

The Conference on Sustainable Building South-East Asia is being organised to address some of these barriers, particularly in raising awareness, in building capacity, in sharing and exchanging knowledge and in building partnerships, regional and international networks for the future.

7. Conclusions

The construction industry in South-East Asia faces its most serious challenge over the next two to three decades in finding appropriate solutions to overcome many environmental issues caused by its activities. Its mode of operation will need to change in order to significantly reduce its adverse impact on the environment in areas such as energy consumption, CO₂ emissions, use of non-renewable raw materials, water consumption, land use, soil degradation and waste generation. Although the awareness on sustainable building and construction is generally low, some progress has already been achieved on a number of fronts, with outcomes providing not only specific technological solutions but also a volume of new information useful for better understanding of the nature of the problem, as proven by existing projects. However, the problem is far from being resolved, in reality it is just beginning. The construction industry has a long way to go in order to adequately address pertinent environmental issues affected by its activities.

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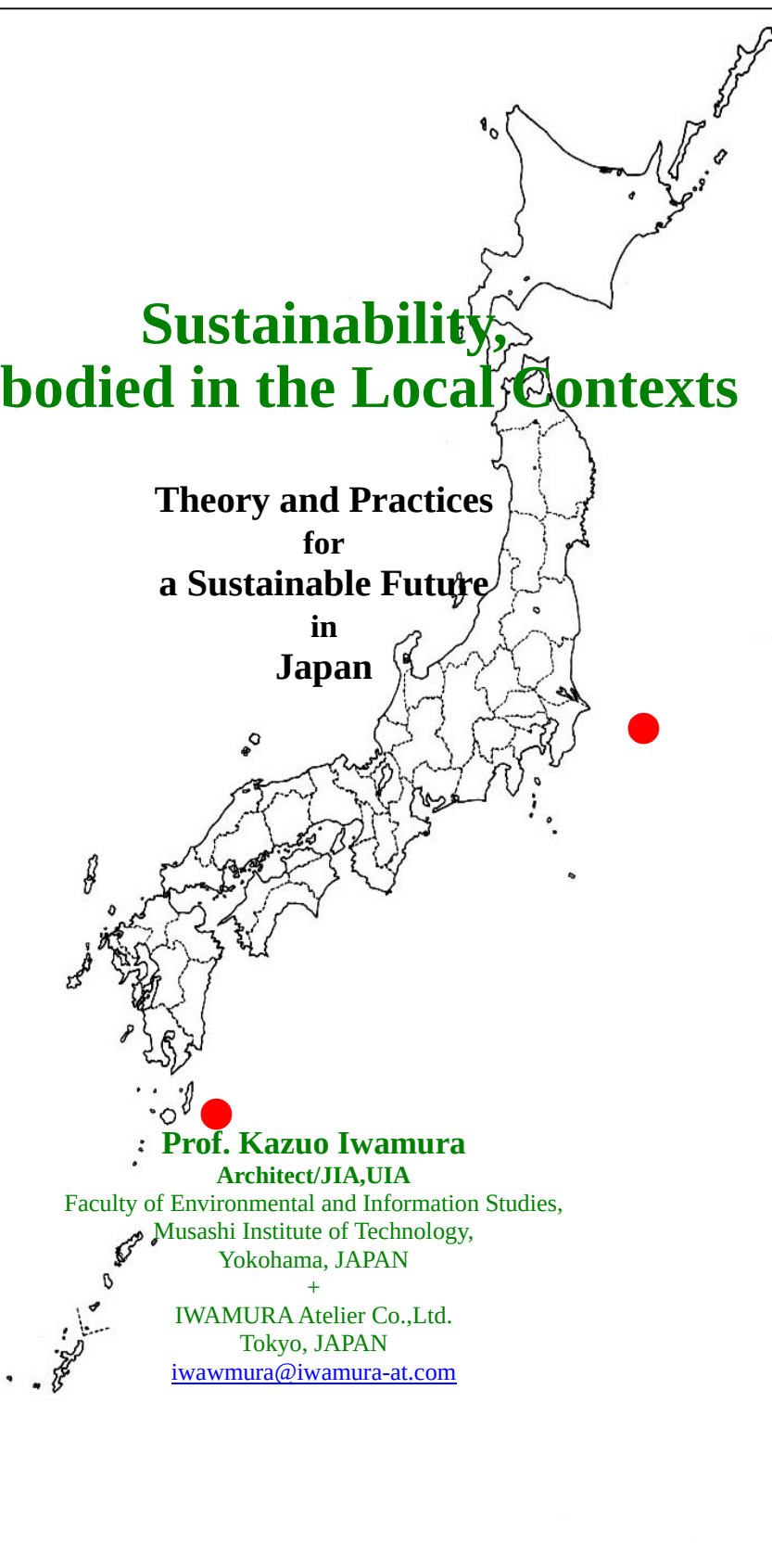
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Sustainability, Embodied in the Local Contexts

Theory and Practices
for
a Sustainable Future
in
Japan



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1. Preface

Post-war housing policies had always been one of major drive of improving social welfare and the economic growth of Japan through building industry. The author belongs to the baby-boomer generation, observing and enjoying the tremendous change and development during the last five decades. For us, one of the most impressive cultural transitions of built environment has been experienced in the housing. Although our ancestor created most sensitive and environmentally responsive housing culture of wood, earth and paper, general attitude of post-war Japanese put it lower value, in comparison with occidental image of houses, which seemed to us much more advanced "culturally".

This attitude was based somehow on a sense of shame deriving from the materialization gap between the winners and the loser. To catch up with this materialized level, therefore, became the clearest and simplest goal as political and social propaganda. But this catching-up efforts have been more or less concentrated on mass-production industries of textile, electric appliances, automobiles and the like, or on the construction of infrastructures such as roads, railways, bridges, dams and etc. Housing had been left behind except the mass supply by the public sectors according to the critical demand of post-war homeless people in urban areas destroyed during the war (Fig.1).



Through the very rapid materializing process of the country, housing became an object of speculative money game, not one that everyone can afford with reasonable price. Therefore, for many of people to possess one family house with a garden became a status symbol, even if they are obliged to commute every working day more than two hours. Such general attitude did neither create concerns on the performances of housing, nor considerations to the harmonious and attractive townscape, that have disappeared very quickly everywhere since the time of extreme economic growth of the 60's.

Fig.1 Tokyo in 1945

2. Environmentally Symbiotic Housing

2.1 Background

2.1.1 "Scrap and Build" Housing During the last decade, the Japanese building industry has maintained an average construction level of approximately 1,400,000 dwelling units per year (Fig.2). These homes have an average lifespan of 25 to 30 years (Fig.3), a quite short period of usefulness compared to European or American standards. This is however not surprising for us Japanese, because the lifespan of urban timber houses used be very short due to frequent fires or to the natural disaster caused by typhoons and earthquakes.

A historian reported that the expected lifespan of timber townhouses in Edo (former Tokyo from the beginning of the 17th till the late 19th century), the population of which had already reached to one million at the end of the 18th century, was as short as merely 3 years, according to accounting reports of carpenters. They had a very quick and prefabricated rebuilding system through forestry-timber manufacturing and supply industry within a cyclical eco-system. That could just happen due to totally

natural materials of houses, provided by the adjacent regions.

Such tradition could be a reason of the short lifespan of housing in Japan, however, other post-war social and administrative system, including housing loan, pricing and tax system on real estate, and high inheritance tax, were the major incentives to demolish the houses before they reach their potential lifespan. The result is the quite high proportion of new construction (55%) to renewal (45%) in terms of floor area per year (Fig.4). Therefore, the industry's massive output is largely dependent upon what has been called the "scrap and build" method.

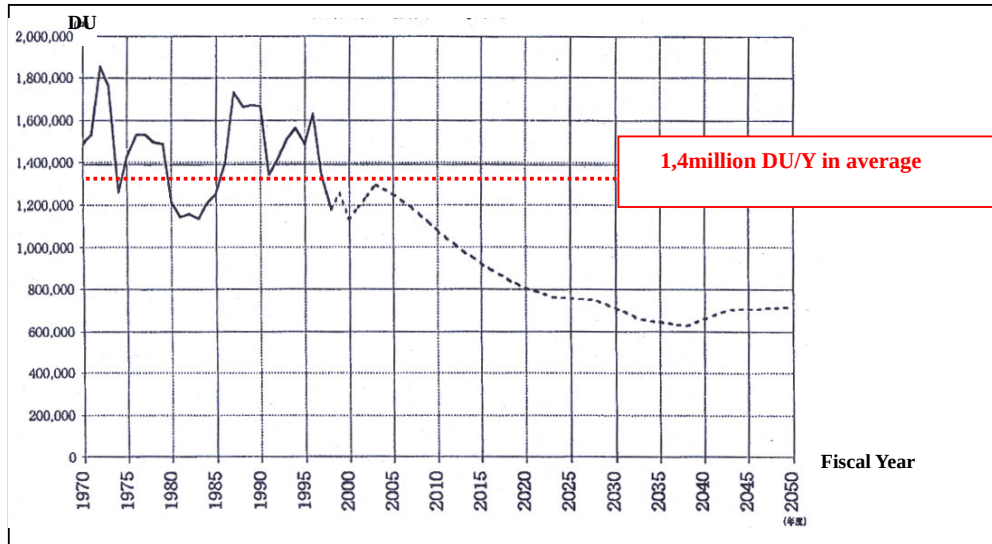


Fig.2 Annual New Construction of Dwelling Units in Japan (Mitsubishi Research Institute)

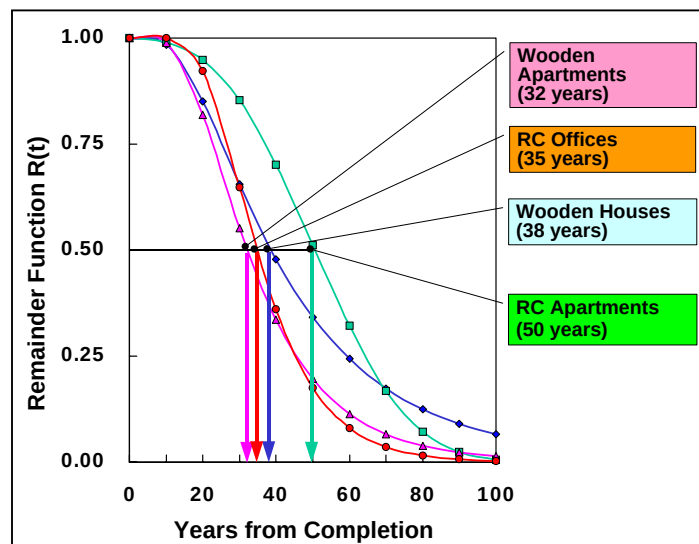


Fig.3 Assumption of Building Life Span
(T.Yashiro, University of Tokyo, 1999)

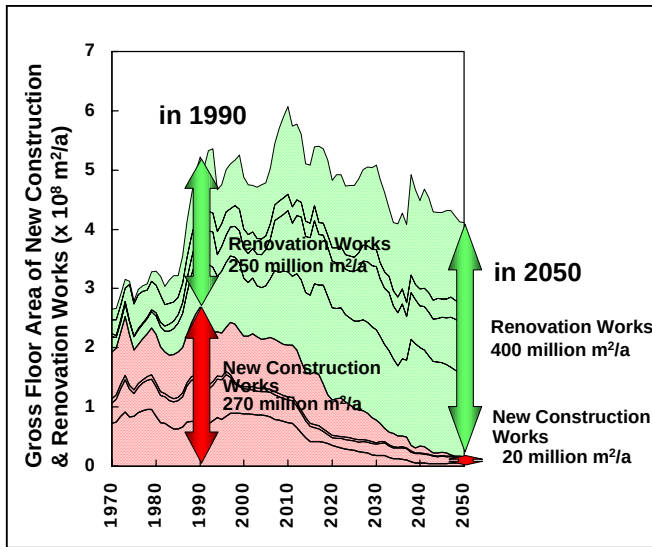


Fig.4 Decrease of new construction Works by floor area
(T.Ikaga, S.Murakami, University of Tokyo. 1999)

2.1.2 Housing and Global Environmental Issues in Japan While this rapid rate of housing production has been an indispensable propeller of the post-war Japanese economy, it has been a source of grave problems as well. These problems include the consumption of large amounts of energy and natural resources, most of which are imported from abroad, during the whole lifecycle of housing, and the resulting mixed disposal of demolished houses. Such issues were scarcely recognized as environmental issues, until the beginning of the 90's, when the global environmental problems became an internationally political issue, which Japan could not overlook anymore.

2.1.3 Problems of Housing Quality It is true that post-war Japanese housing production has developed very rapidly in terms of both quality and quantity. However, the following qualitative aspects of housing bring to light the many issues still to be tackled in Japan.

- the size of a dwelling unit
- the housing durability and adaptability to region and residents
- the appropriateness of housing techniques according to region and residents
- the health and comfort of its indoor and outdoor
- the overview of the townscapes and the natural landscapes
- the cost of measures related to the above

We have been facing a decade of economical recession, and the construction of new buildings in Japan is estimated to decrease drastically in the long term (Fig.4), high-quality housing that deals with such issues is in growing national demand.

2.1.4 Towards Sustainable Housing and a Sustainable Society It is the responsibility of all the stakeholders, involved in housing production, distribution, construction and use, to be aware of the environmental problems confronting housing and community development. At the end of the 80's, there arose a tendency of thoughts to recognize the necessity to come up with all these issues of resource, energy, immediate loadings, health & amenities as a comprehensive environmental issue to support for the creation of a sustainable society in Japan. The former Ministry of Construction took initiative to guide this tendency towards organizing R&D group, under the banner of "Environmentally Symbiotic Housing (ESH, hereinafter)".

2.1.5 Movement of the Environmentally Symbiotic Housing Having foreseen such a state of affairs, in 1990, a group of professionals and firms from public and private sectors joined forces, first functioning as a research body then as an organization for the promotion and realization of ESH from north to south in Japan. For six years it studied, from a wide variety of approaches, technologies and organizational systems that help address problems in housing and community development. National subsidy schemes set up during this period has helped to carry out over forty projects around the country. These are primarily projects by public corporations and independent groups, with the

completed works playing an important role in furthering the understanding and experiencing ESH. FUKASAWA Symbiotic Housing Complex (Fig.9, Fig.12) is the most successful and symbolic project that was planned and implemented during this early stage.

2.1.6 Development of the Movement This movement has already 12 years history and has been run by the Association of ESH since 1997, uniting member groups of diverse business types and conditions, design methods, construction techniques, marketing methods. Whether involved in the planning, design, production, marketing, or maintenance of housing and community, member groups share a common destination that is to investigate, propose, create, and evaluate ESH and related methods, systems and attitudes. In cooperation with the Ministry of Land and Transportation and its foundation, the labeling and evaluation guideline of ESH was established in March 1999 (Fig.5-Fig.6). Since then, more than 80 types of houses and housing complexes have been evaluated and labeled, and more than 3,000 labeled houses have been built (as of the end of 2003) nation-wide.

2.2 Objectives of ESH

According to the definition of the Environmentally Symbiotic Housing, set by the Ministry of Construction in 1991,

the Environmentally Symbiotic Housing refers not only to housing itself, but also to the surrounding local environment. It is developed from the standpoint of preserving the global environment by conserving energy and resources, while reducing waste at the same time. Its next goal is to exist in harmony with both natural and man-made surroundings, as well as to provide residents with amenity-rich healthy life, thus encouraging them to participate in construction process, and then taking care of the environment.

The following four themes (1-4) correspond to the three basic objectives (A-C:Fig.5) that must be realized to achieve Environmentally Symbiotic Housing :

- (a) Global Issue (Low Impact):
 - i. Energy Saving
 - ii. More Effective Use of Natural Resources
- (b) Local Issue: Harmony with the Surrounding Environment (High Contact)
 - iii. Compatibility and Harmony with the Local Environment
- (c) Residential Issue: A Healthy Residential Environment with Amenity (Health & Amenity)
 - iv. Health and Amenity – Be Safe and Feel Safe

Basic ideas of these objectives are as follows;

(a) Global Environmental Protection (Low Impact)

This includes energy and resource conservation and minimum waste production in various ways and upon various levels. Such activities already have some part in most people's daily lives, but they should be organized on a neighborhood and regional scale as well, and be thought about and practiced by everybody. The huge amount of concrete rubble produced when buildings are demolished, is an example of building waste that must be recycled. Such recycling should not be planned case by case; in order to achieve a significant difference, it must be established as a social system.

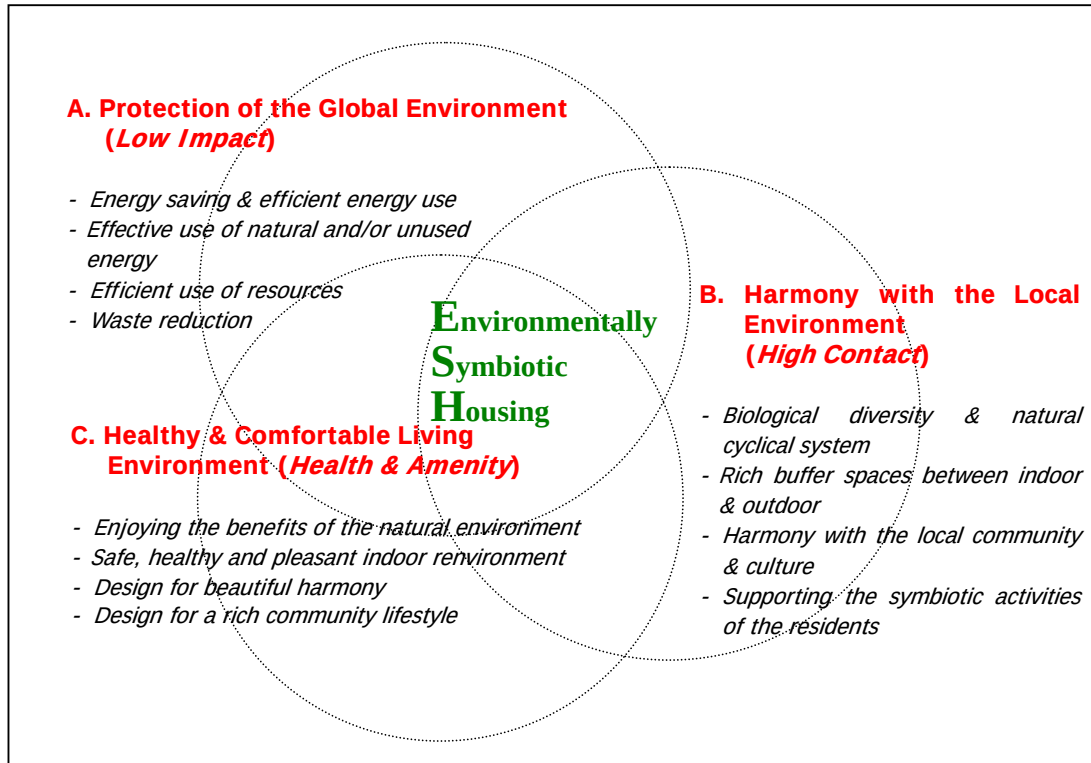


Fig.5 Three Objectives of the ESH

(b) Harmony with the Surrounding Environment (High Contact)

The etymology of the word "landscape" suggests not only the scenery of a location, but its condition in every sense, including its climate, its geography and the organisms that inhabit it. Therefore, it is essential to investigate environmental elements such as light, wind, water, earth, and organisms, and to apply the findings to development decisions. In other words, development should be appropriate to the history, landscape, and inhabitants of the site and its surrounding area. This will influence, too, the kind of community to be created there.

(c) A Healthy Residential Environment with Amenity (Health & Amenity)

In building each home, everybody wants to consider how it can be made truly healthy for the inhabitants. In Japan, the relationship between housing and health has become a serious social issue. In the past we have been too indifferent in our choice when choosing building materials, construction method, air conditioning and ventilation systems, and other elements. These have the potential to cause health problems to human and other organisms, especially within spaces that are increasingly airtight. This air-tightness of housing has never been the issue in the building history of Japan, where the openness for summer's hot and humid climate was the top priority, and the idea was brought from North America to cope with energy saving. Without actually noticing it, our homes may produce chemical substances, mold, and dust linked with allergic reactions as eczema. It is as if our bodies are protesting against this careless age. The elderly, the handicapped, infants, and housewives, who spent the longest hours at home, are especially at risk.

Closely related to health is the idea of "comfort", with light, temperature, humidity, and ventilation being some of the issues that need to be reexamined. Guidelines for such reform have been discussed and formulated by the Government after the intensive campaign of media and users.

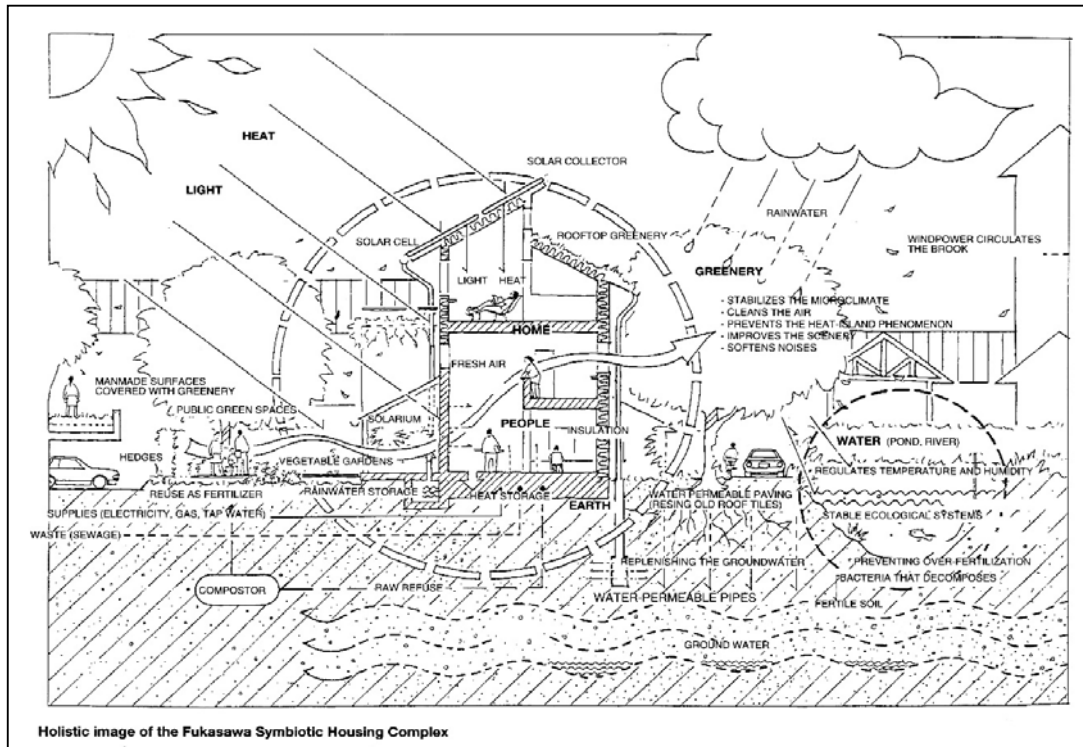


Fig.6 Holistic image of a Environmentally Symbiotic Housing (by K. Iwamura, 1995)

2.3 Major Topics of ESH

2.3.1 Energy and Daily Life In the past 100 years, while the global population has multiplied by four, our energy consumption has ballooned to 25 times the original level. It is true that Japanese energy consumption per household ranges from one half to a third levels in the US, and that it is the manufacturing, transportation, and business sectors which consume the dominant share of energy in Japan. However, we have not been aware enough of how our daily energy consumption affects national energy policy – and the global environment.

For, while the industrial sector, ever since experiencing the oil-shock of the 70's, has been doing its utmost to achieve efficient and low-level energy consumption, consumption in homes has been allowed to grow at an alarming rate, in the continual search for greater convenience and comfort. Clearly, our increasing use of electrical appliances and the widespread use of air conditioning and boiler for warm water supply will soon make us into high-level energy consumers in the world. The Government's "Global-warming Prevention Action Plan (1990)" warned of such a strong tendency, calling for the use of natural or untapped energy sources in our daily lives.

However, within the field of architecture and housing, a misguided convention dictates that "energy" is an issue, only related to the equipment planning and engineering. Thus, no matter what kind of form or space a building has, it has become normal building procedure to consider the creation of comfortable interior environment as a function specific to the equipment design. In the past, indoor environmental control was achieved through techniques based upon knowledge of climatic and geographical conditions of the site, independent of building machinery. Instead of studying and increasing this rich heritage, we have in recent years all but discarded it. Since the 70's, those advocating the "Passive Solar House", a house built to use the solar energy to supply the residents with daylight, heat and hot water, have been steadfast exceptions to this trend. Now, people have started to choose passive solar techniques again, as a sustainable and symbiotic alternative, although they still belong to the minority.

Nevertheless, at base the problem of daily energy consumption is intimately connected to how we, as individuals, think and act. This is perhaps why the ideas of ESH are often expressed in the language of lifestyle.

2.3.2 Resources and Wastes in Daily Life Inseparable from the problem of energy are those of resources and of waste disposal. We must consider these issues both in terms of the materials and equipment that make up the housing itself, and in terms of the resource consumption and waste production that occur within the occupied building. For example, houses built in and around Tokyo are said to have an average lifespan of twenty years. Most large housing complexes have become thirty or forty years old, and are reaching a stage where they must be rebuilt. But the terminal garbage disposal sites near Tokyo are filled to capacity, and the tremendous amounts of industrial waste materials caused by rebuilding will pose a serious problem. Nowadays, some of the discarded concrete is ground up on the demolition site and re-used as building material, but it is vital to start thinking at the planning and design stages, about the cyclical use of resources, taking into consideration the longevity, disposal and recycling of each material.

Also, now that there has been a move towards requiring those who produce large amounts of household garbage or sewage to cover the excess costs, people are beginning to realize that each individual must work for lower levels of resource consumption and waste production. The recent frequent shortage of water and other emergent situations have highlighted the need for using rainwater, gray water and other alternatives.

2.3.3 Locality and the Building Industry The relationship between a region's characteristics, climatic conditions, and the housing is important in urban and rural areas alike. This is the very basic premise of ESH. Similar to Feng-Shui philosophy, it involves studying the land's climate (Fig.9), topographical and geographical features, flora and fauna, and finding out what kind of effects these characteristics have upon the locality as a living environment. The qualities of a region are best brought to light by considering both the social and geographical viewpoint, with aspects of biology, geography, geology, meteorology, and sociology all contributing to the necessary fieldwork. This is a traditional way of designing housing, only recently being rediscovered.

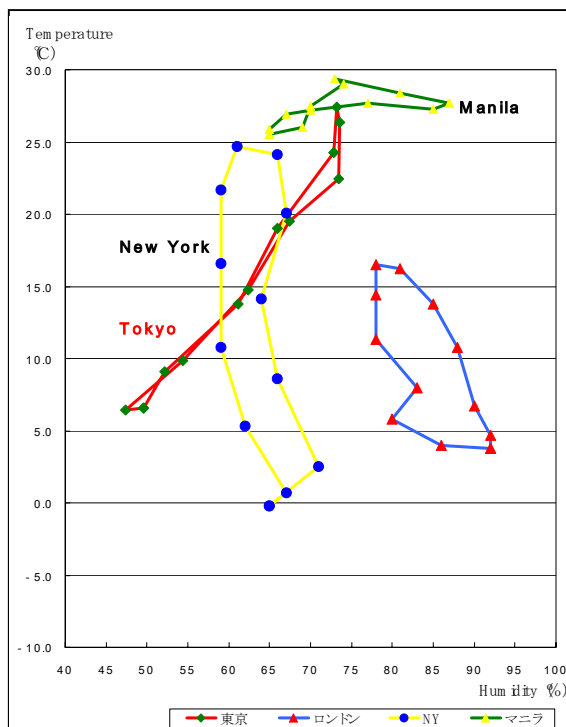


Fig.7 Climo-graph of 4 cities in the world
(Source: Annual Scientific Data, the National Meteorological Agency of Japan)

There is however a problematic gap between such an ideal planning process (Fig.8), and the present architectural production system that is called on to bring the plans into reality. The building parts and materials being marketed now are based upon mass production and mass sales, and even if the plan itself requires sensitivity to local social and economical structures, there are certain conditions that make it difficult to avoid using such products. For example, although timber is a renewable resource abundantly present in Japan (although ca. 75% of the land is covered by forest and the post-war policy had driven everywhere to plant Japanese cedar for timber industry), domestic timber cannot compete in the international market with cheaper import. Consequently, three forth of the lumbers used for house building are shipped from North America, Oceania, Russia and elsewhere, creating a cycle that only speeds the decline of the domestic timber industry. This creates also a critical ecological imbalance in forests and deteriorates the very important function as natural dam. To mend this absurd situation where wood is said to come from “the sea”, not from “the mountain”, not only must the Japanese timber industry rationalize its production and marketing systems, but also help to inform potential users about the related background and qualities of wood. People should not be choosing a veneer facing over real massive wood, for example, simply for the sake of its straight grain appearance. This belongs also to cultural issue that requires educational movements from the childhood of users.

2.3.4 The Site and its Local Environment Housing, like any other building, occupies a certain piece of land, i.e. the site: this obvious fact is allowed to determine much in the building of ESH. In other words, every site is connected to others, and is a part of a local space environment. It is therefore extremely rarely that something can be built based upon a single set of priorities and conditions.

Also, the greenery, soil, and water on a site are an integral part of a shared, regional ecological resource. Water, plants, and animals do not confine themselves to one plot of land, but flow, grow, and move about. The prevalent attitude that landscaping and gardening have been considered as “extra” or added aspects to architectural design must be changed. Regardless of whether the building site is in the city or in the suburbs, water, plants, and animals should be acknowledged altogether upon a wide ecological scale, and considered integrated into the architectural design to be symbiotic with the environment on all levels (Fig.6).

2.3.5 Technical Elements and Planning Methods The techniques necessary to build housing fall under a multitude of categories, from landscape, garden, and exterior finish, to the building itself, and the home units within. There is a multitude of passive architectural design elements, and active use of high-tech efficient mechanical parts, even counting only those elements that have to do with saving energy through insulation, air-tightness, and day-lighting for instant.

However, problems can occur, ironically, when these elements become too much effective in themselves. For example, when we achieved air-tightness associated with insulation as an energy saving technique, which was so far not familiar to housing design in Japan, we began to experience the problem of critical indoor air-quality and inside of the walls, because the need for ventilation was often ignored as usual. Till recently, too, not much attention was paid to the ill effects of certain chemicals such as volatile organic compounds upon the human body. When we forget to see technical elements as parts of the whole home, and concentrate upon making them individually successful, they tend to become statistically impressive ends in themselves, and harmfully removed from the very needs to be fulfilled for the sake of healthy daily lives and physical beings of the residents.

The technical elements must support the living environment in a balanced, holistic way, based firmly upon the residents' daily needs. Many fields of knowledge overlap in the conceptualization and design of a living environment, and a wide variety of those related knowledge should be incorporated in the design. It is vital, therefore, to learn from traditional and local building methods and materials, and to combine them with the latest technology appropriate to today's requirements of the residents' lifestyle. As was mentioned before, the determining factors are the zeitgeist, the characteristics of the society or the community, the land itself, and the residents as users, to be reflected in the design as a holistic and cultural action.

2.3.6 Housing, Health and Physical Life The above stated environmentally symbiotic technologies are designed to bring health and comfort to the residential environment of both indoor and outdoor. The question is, what is healthy and what is comfortable? The market of building materials and equipment has an incredibly wide variety, and they promise to create a “healthy and comfortable house”

irrespective of the user's individual needs or of the site's characteristics. Recently, however, the relationship between indoor air quality and residents' health has become a serious issue of the whole nation, especially as homes are built to be more and more air-tight, thus increasing the problem of indoor air pollution, caused by formaldehyde and/or volatile organic compounds, to cause allergic reaction like eczema.

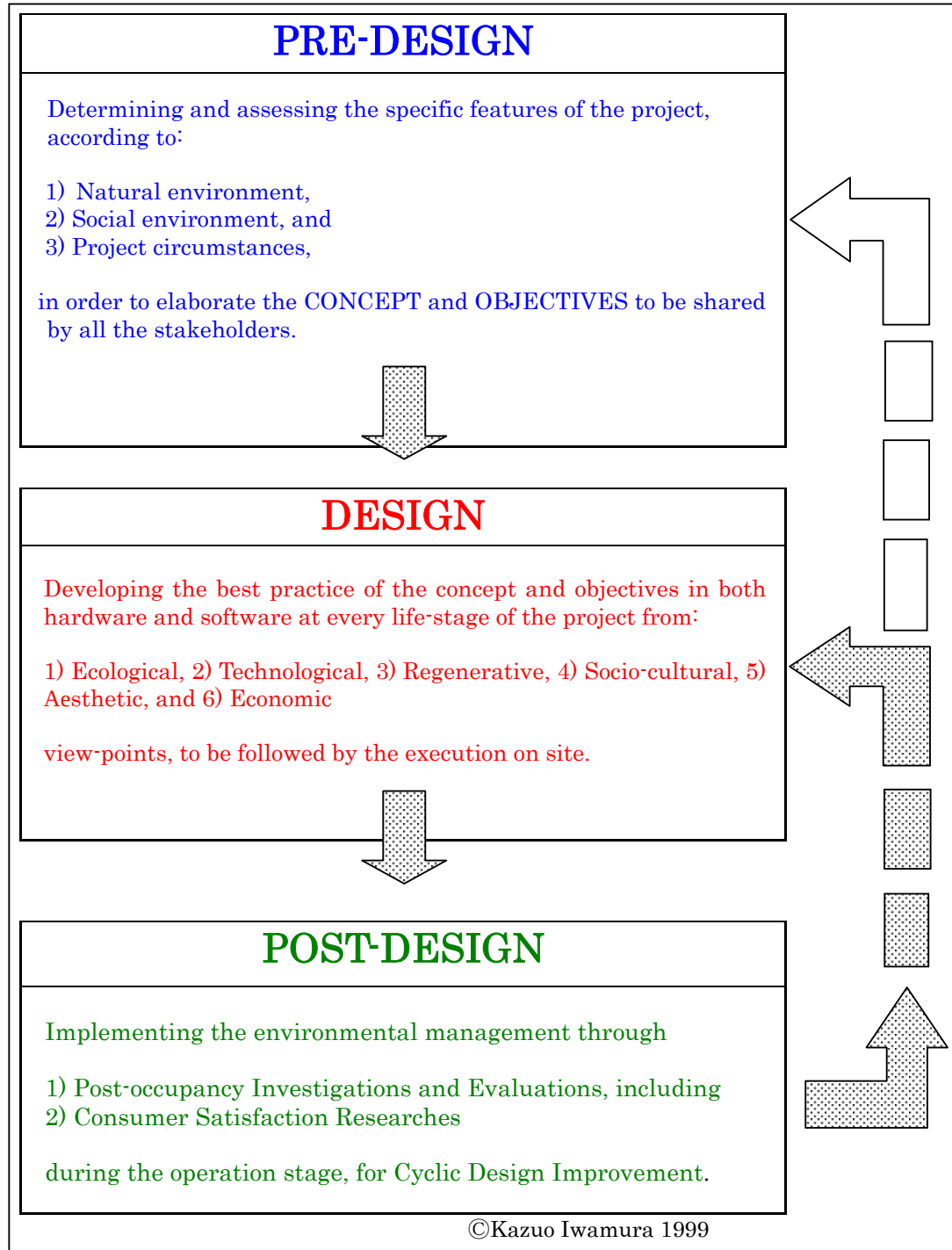


Fig.8 Cyclic Design Process of Sustainable Architecture

In terms of creating comfortable temperature and humidity levels, the modern technical elements, such as an air conditioner, used now excel, but the success is often combined with a harmful incompatibility

to the Japanese climate and lifestyles. Therefore, the problems of indoor air pollution have grown with popularity of such equipment. Toxic chemicals, microbes, and bacteria which exist in building, building materials and equipment, are among the reason why the design basics, including material selection, air conditioning and ventilation, must be reviewed from the vantage point of human physical well-being.

When testing building methods and materials for the energy efficiency, we should also remember the basis of our physical life, that are the five senses with which we human beings percept the world. Production, sales promotion, and design concerns must not eclipse the importance of the residents' sensory perception at home. On the other hand, the residents' concerns to share the awareness of such aspects have been very weak. What is needed right now is the development of building elements and materials, and of engineering and building techniques, that is sensitive to such "invisible environment" and to human physical life.

What people consider "comfortable" or "uncomfortable" depends very much upon individual physical characteristics (age, sex, or medical history), as well as upon childhood or recent experiences with houses, and even the person's mood of the moment. Especially in Japan, the "standard" of comfort is a complex one, for ever since the Meiji restoration of the late 19th century, lifestyles have been formed by inherited traditions on the one hand, and on the other by attitudes and architectural forms brought from the admired occidental countries of "advanced cultures". When different value systems are thus mixed, it is difficult to decide what comfort really consists of. It is, too, quite recently that the administrative housing policy has begun to shift its post-war emphasis on quantity, onto quality.

Another point is that residents are not a homogeneous entity, and their standards of comfort are varied and complex. For example, when trees are planted to create a pleasant green area, some people consider the job of sweeping up the fallen leaves an annoying bother, while others consider it a matter of course. Some dislike fruit-bearing trees because they attract wild birds which might dirty the house or laundry, while others enjoy this presence of nature in their lives. Thus, our ability to lead a comfortable life while being ecological, or while enjoying neighborhood relations, depends upon our attitudes towards what is "too troublesome". This is an age where large service industries such as door-to-door delivery services or 24 hours convenience stores offer to free us of the need to perform bothersome tasks. We city dwellers who have gotten accustomed to such systems need to change our own attitudes. Again, it is not enough to perform just techniques or administrative systems.

2.3.7 Cost and Lifecycle A cost analysis is indispensable within the process of realizing and popularizing the kind of systems and movements mentioned above. The alleviation of regulatory politics concerning building specification and the higher efficiency of transportation in recent years create corresponding adjustments in the initial, running and maintenance costs of building. In addition, as we run out of waste disposal space, the cost of recycling or otherwise dealing with dismantled building wastes has become a serious issue. The lifecycle cost of what we create has been already in the list of discussion. Tens of thousands of components and materials are composed to build a modern-day home. The initial cost of these products and their running and maintenance cost must be considered in conjunction with how their qualities will affect the lifetime of the home, and the cost of the home's eventual disposal. Only such a whole can the true cost of a home be evaluated.

The "environmental value" or "hidden cost" often talked about these days stem from the idea "value" of a thing is not simply the sum of its basic cost and profit, but that the environmental loadings the thing will cause during its production and distribution should theoretically be a part of the value analysis. True costs can only be determined and meaningfully compared with each other, when all these elements are considered together. Simply put, if someone, somewhere, is causing harm, the damage should be assessed and the perpetrator billed for it.

This way of calculating "cost" has not yet left the conceptual stage, since standardized guidelines have not yet set, but the underlying stance is one that should be generally adopted. It is useful to remember, once more, the fact that "ecology" and "economy" have shared etymologies.

2.3.8 From a Passive Maintenance to a Active Maintenance for the Sake of Maturing Process of a Building The life of a home begins with the initial construction is completed, In the course of time, residents' lives and neighborhoods grow, change and flourish. In the environmentally symbiotic housing, we are struggling to establish both conceptual and concrete frameworks that support such a

lifecycle through nurture and maintenance, while building a sustainable living environment.

For example, we depend greatly upon greenery to create a pleasant neighborhood environment. This tendency is quite far from the general attitudes that consider greenery as an annoying (i.e. expensive) liability, and where the classical problem is; who, whether in the public or private sectors, will carry the cost of maintaining it?

A basic step in solving this problem is for every resident to accept a part of the responsibility in carrying for the housing and its immediate surroundings. The residents should, with the help of the administration, cooperate in forming community rules that determine what needs to be done to what extent, and by whom.

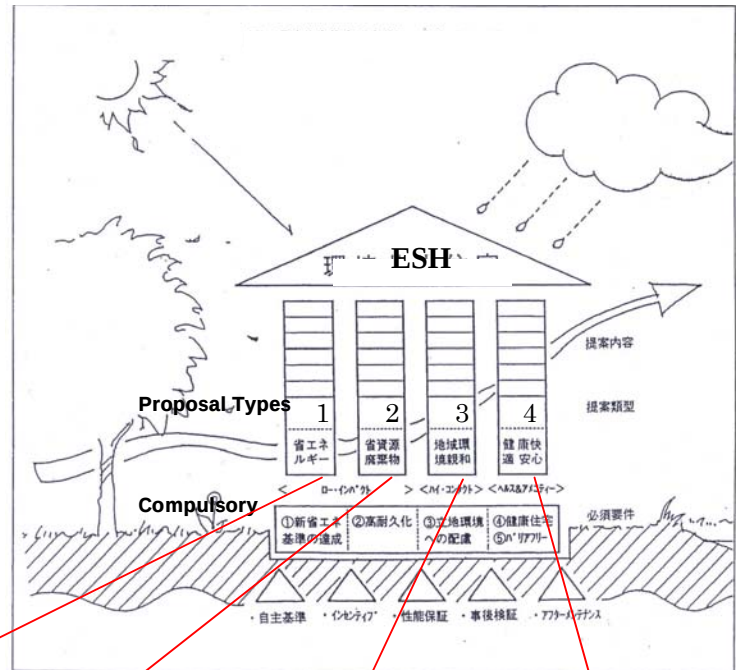
Architecture, and especially housing, is not “finished” simply when the building is completed. In a society of “stock economy” like that of the occidental countries, the real-estate value of a well maintained and matured home could be higher than that of a newly built home. This is not at all so in the case of Japan’s “flow economy” – a state we should be questioning and working to change. Facing the ten years economical recession, in which even the land price has generally dropped everywhere, it is time for us to answer the questions thrust to our attention by the Great Hanshin earthquakes in 1995, about the role of “stock” architecture and “stock” community-making.

Fig.9 Fukasawa Symbiotic Housing Complex in Tokyo
(K. Iwamura, 1997)



Fig.10, Fig.11 Yakushima Symbiotic Housing Complex in Kagoshima (K.Iwamura, 2001)

Fig.12 Structural Image of the
Environmentally Symbiotic Housing
Evaluation Guideline
(by K. Iwamura, 1998)



Proposal Types	1. Energy Saving	2. More Effective Use of Natural Resources	3. Compatibility and Harmony with the Local Environment	4. Health and Amenity – Be Safe and Feel Safe
Proposal Contents as Examples	1) Greater efficiency in reducing heat losses 2) Greater efficiency in controlling solar radiation capture 3) Passive use of solar energy 4) Active use of solar energy 5) Efficient use of unused energy 6) Use of highly efficient equipment 7) Miscellaneous	1) More durable skeleton 2) Structural and building methods for flexibility 3) Low emission 4) Active use of recycled building materials 5) Highly effective use of water resources 6) Sorting of household wastes 7) Miscellaneous	1) Better harmony with the local ecological system and environment 2) Greater consideration for the natural water system of the area 3) Greening efforts 4) Creating rich buffer spaces between indoor and outdoor 5) Greater consideration of townscape 6) Integration of the local culture and regional industry 7) Miscellaneous	1) Through universal design both indoors and outdoors 2) More suitable and adequate ventilation 3) Through choice of safe and eco-materials 4) High sound insulation efficiency 5) House performance guarantee though ongoing property management 6) Information services on housing 7) Miscellaneous

	Low Impact	High Contact	Health & Amenity
Compulsory Performances	(1) Conformity to the Energy-Conservation Standard as of 1992	(2) Long-life Durability; Conformity to the GHLC* Standard as of 1998	(3) Consideration regarding the surrounding environment
			(4) Conformity to the guideline for indoor air quality (5) Conformity to the barrier-free design standard of GHLC*

*GHLC=the Governmental Housing Loan Corporation

Source: Institute for Built Environment and Energy Conservation, 1999

Fig.13 The Basic Frame of the Environmentally Symbiotic Housing Evaluation Guideline (as of 1999)



Fig.14 Fukasawa Symbiotic Housing Complex

3. Conclusions

When we thus think about housing from the vantage point of symbiosis with the environment, the problems that plague modern housing – and architecture in general – become obvious. Along the path of progress, we have thought fit to discard or forget the traditional ways of living that were based on biological knowledge. These methods were in fact protecting the richness of the environment, supporting the continuity of peoples' lives through the preservation of ecological balance. While solving these problems in one sweep would be an overwhelming and difficult task, it is important to start with things we can do in our immediate surroundings.

In the aftermath of the Great Hanshin Earthquake, when we heard of how the victims reacted to this hitherto unthinkable disaster with spontaneous, local cooperation, we were made to recognize how important it is to build not only large-scale systems, but also smaller, independent systems of energy and water distribution. It showed us, too, in an extremely striking way, the true meaning of “living together” with our neighbors, and the importance of maintaining strong ties with each other. When a neighborhood is created through participation by all the residents, such relationships could develop and flourish. In order to realize a sustainable society and development, the element of human relationship is impossible to ignore.

The issues concerning ESH touched on above are not extraordinary in themselves. They are basic ideas from which most discussion on housing and neighborhood start. It is time to use these ideas, reconstructing our techniques, administrative systems, and attitudes accordingly.

Yes, sustainability is embodied in the local contexts.

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SUSTAINABLE DEVELOPMENT PLANNING & CONSTRUCTION IN PUTRAJAYA

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1. Malaysia's New Administrative Capital: Planning Framework



Fig.1 City of Putrajaya

Malaysia's new Federal Government Administrative Centre, Putrajaya (Fig.1) realisation of a vision to build a city capable of meeting the challenges of this millennium. It epitomises the coming of age of Malaysia as an independent and sovereign nation and as a dynamic and progressive member of the global community. Putrajaya is being developed as an intelligent city and a city in a garden within the context of sustainable development.

From the onset the planning of Putrajaya was based on the Total Planning Doctrine, which among others, recognizes the important relationship between man and his surrounding environment. This ensures that the issue of environment and sustainability is viewed holistically as part and parcel of the planning and design process.

This is consolidated at the conceptual level whereby the theme for development is 'The City in a Garden' (Fig.2) which further stresses the importance of quality living environment based on the principles of sustainable development.

In view of these factors, land use planning has particularly given emphasis to the following aspects of the environment:

- The preservation of trees, natural topography and environmentally sensitive areas such as hill land, natural water courses, flora and fauna.
- Influencing the micro-climatic condition by the creation of the lake system.
- Maintenance of the lake and river water quality by control of point source pollution and erosion management.
- Creation of the constructed wetland to further facilitate water quality control.
- Creation of green lungs to act as buffer zones against potential sources of environmental problems



such as vehicle emissions,

- Introduction of an integrated public transport system network,
- In terms of landuse planning, land area designated as parks and open spaces cover some 37% of Putrajaya land area.

Fig.2 Putrajaya core area

The proposal to relocate the Federal government offices out of Kuala Lumpur is not a new idea. It was mooted more than 20 years ago. The underlying objective was to provide an improved working and living environment and more particularly to ease the pressure on Kuala Lumpur's infrastructure. The relocation would give Kuala Lumpur City Hall the opportunity to undertake a review of the city's development and upgrade further its amenities. This would help the City Hall to realise its objective to

turn Kuala Lumpur into Malaysia's commercial and business capital while at the same time enhancing its attraction as the Federal Capital.



Fig.3 Putrajaya, the new Federal Administrative Centre

Furthermore, the relocation of the Federal Government Administrative offices (Fig.3) to Putrajaya would result in increased efficiency and productivity through improved and conducive working environment equipped with the latest technology.

2. A Model of Malaysia Incorporated

The approach adopted by the Government in the development of Putrajaya is unique. Putrajaya is a showcase of Malaysia Incorporated at its best. It is being developed through a partnership between the private sector and the government.

Putrajaya Corporation was incorporated on 1 March 1996 under the Putrajaya Corporation Act (Act 536), as a corporate body to administer and manage the city of Putrajaya. Putrajaya Corporation is responsible to formulate and implement Planning and Development Control policies and the Urban Design Guidelines to fulfil the objectives and vision of Putrajaya.

PUTRAJAYA FACT FILE		
Name	Putrajaya, the Federal Government Administrative Centre	
Location	25 km south of Kuala Lumpur, 20 km north of Kuala Lumpur International Airport (KLIA)	
Population	330,000 people	
Total Acreage	4,930 ha	
Land Use (%)	Government	5.3%
	Commercial	2.9%
	Residential	25.8%
	Civic & Cultural	0.2%
	Public Facilities	10.1%
	Utility & Infrastructure	18.2%
	Green Area	37.5%
Development Components	Core Area	1,069.1 ha
	Water Bodies, Wetlands & Lake	585.6 ha
	Central Business District	284 ha
	Periphery Area	2,925.3 ha
	Putrajaya Boulevard	100 m wide and 4.2 km long
Transportation Systems	Intra city – monorail, taxi, buses	
	Inter city – Express Rail Link, North-South Link	
	KL-Putrajaya-KLIA dedicated highway	
	KL-Seremban Highway	
Implementation	Statutory Authority :	Putrajaya Corporation
	Lead Developer :	Putrajaya Holdings Sdn Bhd
	Project Manager :	KLCC Projeks Bhd

Fig.4 Putrajaya fact file

It also acts as a local authority and is responsible for providing urban services and local public amenities. Maintenance of the infrastructure, parks and other landscape components will also be the responsibility of Putrajaya Corporation. Putrajaya Corporation was created to manage and administer the city for the general well being of the people and the nation.

To minimise up front investment, the physical development of Putrajaya is undertaken by a lead developer, Putrajaya Holdings Sdn Bhd; a company owned by Petronas (64.4%), Khazanah Nasional (15.6%) and the National Heritage Fund (20%). Incorporated on 19 October 1995, Putrajaya Holdings has been given a concession by the Government to government complexes / buildings, and the residential and commercial development projects in Putrajaya (Fig.4).

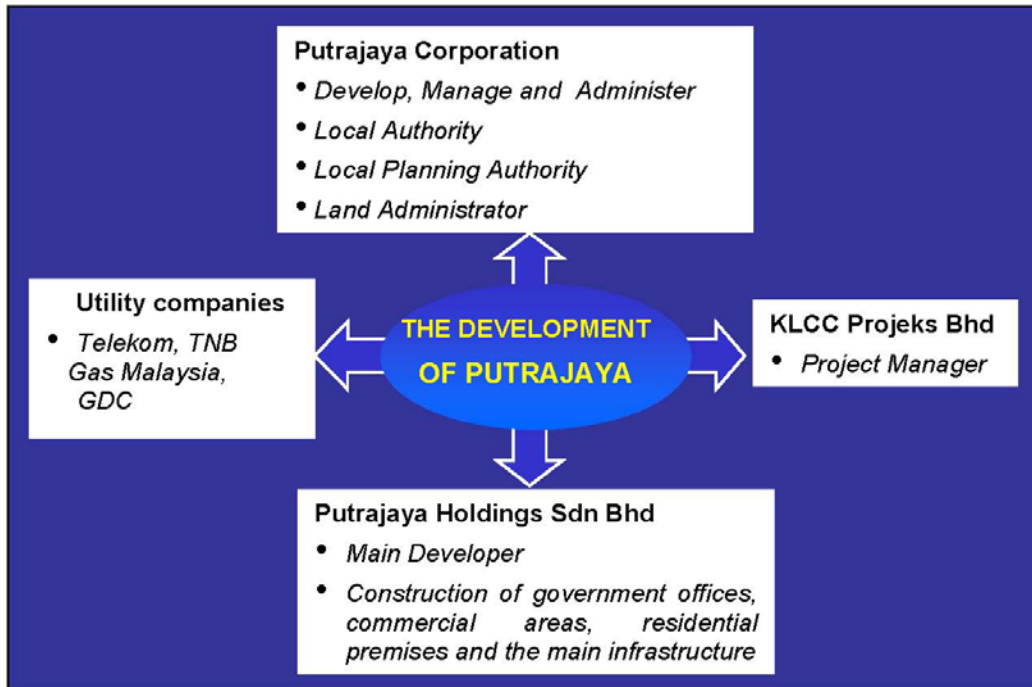


Fig.5 Implementation mechanism

As the lead developer, Putrajaya Holdings is responsible for raising the money required for the construction of Government offices, residential premises and the main infrastructure such as roads, drainage, bridges, lake and the wetlands. It forms partnership with eminent property developers in the nation in developing the residential precincts into a “garden city, intelligent city” as conceptualised by the Masterplan of Putrajaya (Fig.5).



By appointing Putrajaya Holdings as the lead developer, the burden placed on the government was considerably eased and the development could proceed quickly, hence meeting the need for off-budget funding while meeting the requirement to be transparent (Fig.6).

Fig.6 The Prime Minister's Office

KLCC Projekts Bhd with extensive expertise and experience in managing large construction projects (including the Petronas Twin Towers project) has been appointed as the consultant and project manager for both Putrajaya Holdings and the Putrajaya Corporation. The major utility companies in the country, namely Tenaga Nasional Berhad, Telekom Malaysia Berhad, Gas Malaysia Berhad and Gas District Cooling Berhad, have been investing in the development of Putrajaya's utilities and infrastructures as part of their business activities.

To date, this formula of teamwork and partnership between the government and the private sector has proved to be one of the major contributing factors in successfully building Putrajaya in record time.

3. Catalyst for Quality Development



Putrajaya is a mammoth urban development project by any one standard both in its scale and in physical development sense. Unlike many cities that grew organically, Putrajaya is being built to carefully structured layers of plans. The development of Putrajaya is plan driven. The scale and quality of planning has exerted a tremendous influence on many aspects of Malaysian life. For one, the fringe areas are benefiting from the massive investment in infrastructure and utilities that go into the development of Putrajaya. This is evidenced in the manifold increase in land value and economic activities already experienced by these areas (Fig.7).

Fig. 7 Putrajaya as catalyst of growth to surrounding area

What is more interesting is that the quality of planning, design work and development that we are witnessing in Putrajaya has set new standards and expectation for urban development in Malaysia. Quality, creativity and innovation are the key factors here. This is certainly a step in the right direction for a nation that aspires to be a developed nation by year 2020.

4. Malaysian Identity



One of the greatest challenges in developing Putrajaya is building a city that is identifiably Malaysian. Malaysia is a unique country of diverse cultures and traditions that have merged into a composite culture that is distinctly Malaysian.

Fig.8 Street lighting pole inspired by traditional 'Obor' design

The challenge for Putrajaya Corporation is to build a city that is relevant in the future but rooted in Malaysian culture and tradition. This is being achieved through several comprehensive guidelines inclusive Urban Design Guidelines to help the developers apply their creativity to achieve the desired character envisaged. The attractive ambience and quality of space of the city are the result of architectural and town planning efforts directed at creating a harmonious artistic environment and a distinct Malaysian character. Putrajaya has incorporated the latest in technologies to position the nation to face the future while at the same time it encourages values that would help in achieving sustainable development in very aspect – environment, economic and social.



The essence of Malaysia can be seen in the grandest buildings to the simplest street furniture. In Putrajaya, a national heritage is being created for the future generation (Fig.8, Fig.9).

Fig.9 Silhouette of Islamic architecture

5. Community Lifestyle



In the planning of the city, the Putrajaya Corporation strives to encourage a lifestyle that, revolves around a secure, caring and healthy community - strengthened by ties of tradition and spirit of unity (Fig.10). This approach is very much inspired by the Malaysian tradition of 'kampung' lifestyle where the well being of the community is the main motivation that drives its members.

Fig.10 Recreation area for community interaction

One of our objectives is to foster a more pervasive involvement of the residents in activities that would contribute to the enhancement of the well being of the community. In working towards achieving this, residential areas in Putrajaya are planned based on a neighbourhood concept where the layout of the residential areas and the public amenities are designed to encourage greater interaction and foster an abiding sense of neighbourliness among residents. Plazas, squares and recreational areas are essential and integral components of this scheme.



Barriers that inhibit community interaction are discouraged. Putrajaya has taken initiative in breaking down physical barriers that deter interaction in a community by limiting the erection of high and solid fences around dwelling units. Putrajaya's 'fenceless community' concept is aimed at promoting a caring society that accepts responsibility for the security and well being of the community.

Fig.11 'Permeable yard' connected by green network

Careful planning has resulted in a people-friendly city. Pedestrian walkways and bicycle lanes have been constructed to encourage the residents to take to walking and bicycling for short trips in their neighbourhood (Fig.11). Unconstrained by existing development, the planners of Putrajaya have been able to locate the public amenities close to the centres of population and within walking distance from the residential parcels.



Fig.12 Seri Saujana Bridge

Each precinct has its own community centre, a resource centre, a food court, a *surau* and a neighborhood commercial complex. Bigger complexes, including full-fledged shopping malls in response to demand for them, will later augment the neighbourhood commercial centres.

The layout of the residential areas and the public amenities are designed to encourage greater interaction and foster an abiding sense of neighbourliness among residents hence promoting sustainable community development.

6. Building Construction



Fig.13 Putrajaya Boulevard

Buildings affect our land habitats, the atmosphere, human health and quality of life. Building materials and design, construction methods and building operations and maintenance, have environmental impacts. Before any building is being constructed in Putrajaya, careful building design and materials selection are being considered so that it can substantially reduce or minimize these impacts.

Latest technologies and systems are also being utilized in Putrajaya in order to avoid environmental degradation and increase the comfort and productivity of building occupants. Systems particularly concerning energy consumption, low energy and efficient design buildings and supply, have always been considered at the early planning and design stage. One of the systems commonly being used in Putrajaya is Gas District Cooling system, a centralized energy plant using natural gas to generate chilled water for air-conditioning requirements of buildings. The system is environmentally friendly and practical. Architecturally the building designs also 'benefit' from it, as the building designs could make do without Cooling Tower at the roof top. As a result, the façade designs of the buildings in Putrajaya are more inspiring and appealing.

In Putrajaya, sustainable building construction has also saved the Government in operating costs. It has educated the people that with appropriate use of natural resources and with proper management of the buildings, it will contribute to saving scarce resources, reducing energy consumption (energy conservation) and improving environmental quality.

7. Environment Planning and Management

As a city being built on a green field site, Putrajaya presents an enormous opportunity for realising quality living environment and sustainable human settlement that many could only dream to achieve. Right from the outset, the planning of Putrajaya has been entrenched in a Planning Doctrine that places



Fig.14 Living amidst nature

emphasis on the relationship between man and his environment (Fig.14). Developing a city will eventually increase the impervious surfaces and the speed of runoff causes problems of erosion in water courses and oil from parking lots raises the pollution levels of water, which in turn affects aquatic life. Not only does the total discharge increase, but so does the speed of runoff, leading to erosion and the scouring of riverbeds.

The changes to patterns of vegetation and aquatic life diminish the ability of rivers to cleanse themselves naturally over time, causing the loss of aquatic and riverbank habitats and their native plants and wildlife populations. The Putrajaya planners have taken into consideration the need to work

in cooperation with the natural processes of the biogenic environment.

Putrajaya has been planned and developed to facilitate the attainment of sustainable development objectives through the preservation of its natural heritage, reduction of waste and pollution control at source that could otherwise threaten ecological sustainability, and minimum depletion and degradation of the natural and environmental resources. This is reflected in the care given to the preservation of natural topography and trees, control of quality and quantity of storm water and the creation of open space.

Water bodies have been used as a principal feature in many cities. It adds character and ambience and facilitates definition of space as well as functioning as a temperature-modifying element. Water elements will continue to be part of the designer's palette for creating interesting and pleasant places.

The Lake and Wetlands was planned to be a centre for human activities for relaxation, recreational as well as sports activities. The wetlands and the promenade around the lake are very suitable for passive activities such as walking, jogging, bird watching, and fishing. The lake itself is designed to be used for other recreational activities such as boating and rowing. It is also suitable for more active sports events such as Formula One Powerboat and high performance water sports competitions.

The 600 hectares Lake and Wetlands or 14% of the total area of the Putrajaya Development is not only meant for human activities. It is planned to be the place for creating the suitable habitat for fauna and flora including aquatic life.

The wetland now is fully grown with various wetland vegetation species and functioning effectively to filter and extract pollutants before the water flows into the lake system. This vegetation attracts insects as well as fish fries seeking shade areas. The wetland habitat is reversing the surrounding into a nature reserve attracting various kinds of insects, butterfly, amphibians, fish, and many species of local and migratory birds.



Fig.15 Green sanctuary

12 metropolitan parks covering an area of 1047 hectares were started several years ago and would provide vast greenery in the city. The metropolitan parks together with other urban green spaces create a rich and beautiful setting in the City (Fig.15). The natural green areas have in various ways been woven into the city's fabric may it be residential, government, commercial, recreational or the simple display of wildlife and nature. Putrajaya's plants collection display the rich flora indigenous to Malaysia.

Putrajaya adopts the partnership approach to environmental management in which all project stakeholders (developers, consultants, project managers and contractors) are expected to adopt a proactive and self-regulatory approach and provide sufficient resources for the environmental management of their project.

Cross boundary environmental management are managed through the close cooperation between the Corporation and neighbouring state as well as Federal agencies, such as the Department of Environment, Department of Drainage and Irrigation, Department of Town and Country Planning, Selangor Water Management Authority, neighbouring local government and land owners.

In line with the concept of Sustainable Development Index (SDI), Putrajaya Corporation is looking at the possibility of initiating an urban Quality of Life Index for Putrajaya which will be used to monitor sustainability performance over a period of time as the city develops, as well as, allowing for intercity comparisons (Fig.16).

STATUS OF THE DEVELOPMENT			Completed public amenities:
The status of the current projects completed is as follows :			Putra Mosque, Smart School, Hospital, Health Centres, Police Headquarters, Fire Services Headquarters, Police Marine Base, Food Courts, Multipurpose Hall, Educational Centre, Market, Surau, Bus Terminal
Type of Development	Target	Completed	Completed parks and landscaping works:
Residential	67,000 units	10000 units	Taman Wetland, Taman Putra Perdana, Taman Botani, Taman Warisan Pertanian, Taman Selatan, Perdana Walk, Promenade, Dataran Putra, Dataran Wawasan and Dataran Putrajaya.
Government office space	3,800,000 m ²	1,000,000 m ²	
Commercial	3,400,000 m ²	100,663 m ²	
			Completed infrastructure and utilities:
			Electrical supply - main intake substation, main distribution substations (25MVA), Telekom exchange (80,000 lines), Water supply (25 million gallon/day), Chilled water (27,500 RT), Sewer (100,000 PE), Bridges (1.4 km), Wetland and lakes (545 hectares), Road (30 km), LRT/Monorail (4.4km line + 5 stations),

Fig.16 Status of the development

8. Building for Posterity

Putrajaya is the outcome of the labour of love, love of nature, culture, people and human dignity. It reflects Malaysian growing self-confidence and their aspiration to give expression to their identity. Putrajaya is being built for posterity, a city for the millennium and beyond.

The invaluable experience of Putrajaya Corporation and Putrajaya Holdings in building the nation's administrative capital on a fast track basis – whilst at the same time setting out the basis for the sustainable city development, can actually serve as a model and an endeavour professionally executed

without compromise on quality and compliance to standards, rules and regulations.



In short, an important underlying theme throughout this endeavour has been the recognition that the new city has to be set out on the right footing. This entails planning and development towards achieving a sustainable human settlement, of which, sustainable construction is a paramount central consideration.

Fig.17 National Day parade in Putrajaya

SUSTAINABLE BUILDINGS : TARGETING EXISTING BUILDINGS

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Abstract

Much is written and spoken about sustainable buildings, yet there is no consensus on what constitutes a sustainable building, although some definitions do exist, e.g. ASTM defines such as a 'green building'. However, 'green' tends to confine itself to environmental aspects of performance, but not so much the social and economic dimensions of sustainability. Buildings have a significant impact on the environment; not least air-conditioned commercial and institutional buildings, in terms of life cycle resource consumption and environmental loadings. Whilst new buildings are most often the focus of attention in the sustainability debate, the stock of existing buildings offer great potential for immediate and cost effective measures to reduce environmental impacts. However, good indoor environment quality and other service provisions are very important, as they can have significant impact on health and productivity, and the quality of life generally. Voluntary labeling through building environmental performance assessment methods (BEAMs) can provide benchmarks for defining comprehensive performance, but the assessment standards for existing buildings need more thought when compared to standards set for new build, else take up by owners and the potential benefits to society will be limited. This paper contributes to the sustainable building debate by arguing the case for the use of voluntary BEAMs to enhance the performance of existing buildings, and thereby the building stock. The typical framework of a BEAM is first outlined, then based on experiences and application in Hong Kong describes some of the performance gains that can be expected.

Keywords : Sustainable buildings, Performance targets, Assessment.

1. Introduction

Almost two decades after the Bruntland report (World Commission on Environment and Development, 1987) highlighted the issue, sustainable development is now well within the focus of most governments, at least in the developed world. Unfortunately, the concept given in the report: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs", is somewhat ambiguous and very much a matter of interpretation, having maybe '87 varieties' (Willers, 1994)! For the Government of the Hong Kong Special Administrative Region (HKSAR), as for many other governments in Asia, the focus is very much on the economic and social dimensions (Fig.1(a)) with only an acknowledgement that the environmental impacts need to be reduced (Planning Department, 2003). However, at the global scale it has been well argued (Costanza et. al., 1992; Rees, 1996; Goodland, 1996) that the imperative is environmental sustainability, else without it, there cannot be economic or social development (Fig.1(b)). Measured in terms of the consumption of non-renewable resources, emissions and waste streams generated the construction and use of buildings; particularly large, heavily serviced buildings have a significant impact on the environment. For example Hong Kong's buildings account for over 50% of energy use, mostly for air-conditioning (Lee, et al., 2002a), with construction waste a major problem yet to be solved (Westwood, 2004). The quality of the indoor environments produced has significant impact on economic development and the quality of life generally. At the building scale, degradation of the external environment (solar gain, air pollution, etc) has impact on the servicing needs of buildings in order to maintain indoor environmental conditions. In urban areas, traffic, buildings, construction activity, etc. create heat islands and localised pollution, further exacerbating the situation.

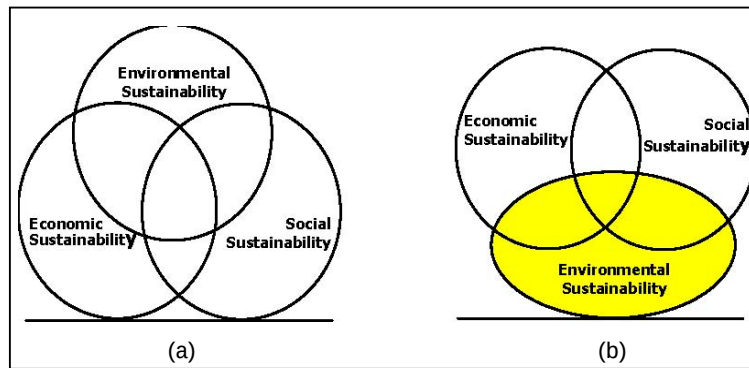


Fig.1 Facets of sustainable development

2. Sustainable Buildings

Much is written and spoken about sustainable buildings, yet there is no consensus as to what constitutes such a building. ASTM International (2001) defines such as a 'green building': a building that provides the specified performance requirements while minimizing disturbance to and improving the functioning of local, regional and global ecosystems, both during and after construction and service life. A green building optimizes efficiencies in resource management and operational performance and minimizes risks to human health and the environment. This may be interpreted conceptually:

$$\text{Life cycle efficiency} = \frac{\text{Indoor environmental quality} + \text{Service \& Amenities}}{\text{Non-renewable Resource Consumption} + \text{Emissions \& Waste}}$$

Essentially, the task for building professionals is to provide for safe, healthy, comfortable and efficient buildings whilst minimizing the consumption of non-renewable resources and the emissions and waste streams to air, land and waters. Even simplistic analysis demonstrates that consumption of energy and other resources during building use far outweighs that for construction. However, minimizing capital costs is usually the preferred option for developers, at the expense of operating costs and performance. This is the legacy of most existing buildings. If it is the case that at the global level mankind has already passed the point of 'sustainability', the targets for reducing environmental impacts need to be relentless. For energy efficiency, for example, the Factor 4 concept (Robert et. al., 2000) suggests efficiency gains need to be of the order of 75%. For the building stock in general, or a single new or existing building, sustainable targets are mostly unattainable even over an extended timeframe.

3. Greener Buildings

Realistic targets for buildings obviously lie somewhere between what currently exists, which will be somewhere just above the 'baseline' and below the sustainable building requirement (Fig.2). Practically the baseline is either the prevailing legislative requirements, or prevailing practices, dictated by building regulations that tend to cover only the basics for health (e.g. minimum daylight and ventilation), and energy efficiency standards at levels attainable by the majority (Lee et al., 2002a).

The emergence of 'building environmental assessment methods (BEAMs) in the last decade, such as BREEAM (Building Research Establishment, 1993, 1998), HK-BEAM (HK-BEAM Society, 1996, 1999, 2004), LEED, (US Green Building Council, 2001), GREEN GLOBE (Public Works and Government Services, 2000) etc., and more recently CASBEE (Institute of Building Environment and Energy Conservation, 2003) GREEN STAR (Green Building Council Australia, 2004), etc., have helped to set green building targets, at levels above prevailing benchmarks (baselines), but moving upwards over time.

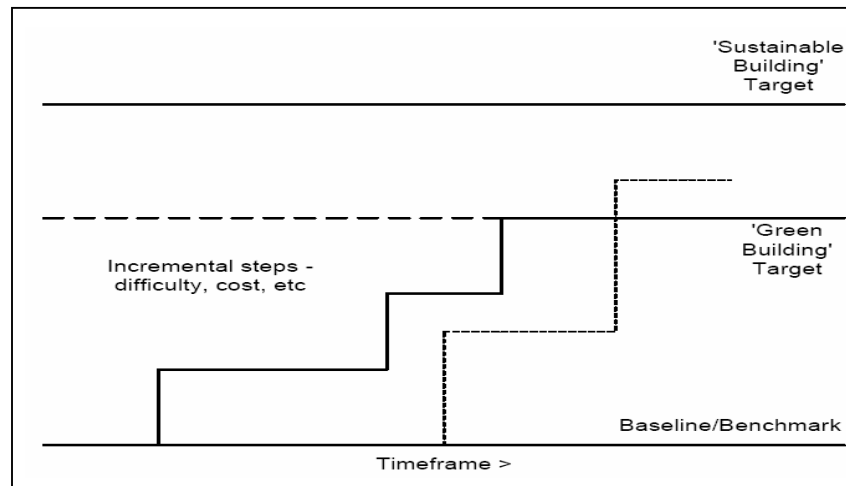


Fig.2 'Green Building' Targets

Considerations in the development of a BEAM generally include:

- **What** aspects of environmental (green) performance are included?
- **When** does assessment take place, e.g. at the completion of the design [e.g. LEED, BREEAM, etc], upon completion of the building [GREEN STAR, GREEN GLOBES, etc], during operation [HK-BEAM, BREEAM, etc]?
- **How** are the various aspects of performance assessed, and against what benchmarks?
- The **weightings** or scores given to each of the performance aspects?
- Aggregation of weightings to arrive at the overall assessment rating (**performance grade**)?

The 'what' will depend on which global, local and/or indoor impacts are regarded as the most significant, but which can be assessed in a reasonably objective manner. The issues included will be assigned a relative weighting in accordance with the informed opinions of stakeholders (Dickie, et al, 2000; Green Building Council Australia, 2004). Notwithstanding, a major consideration for a 'voluntary' BEAM is whether assessment criteria should be 'absolute' or 'relative'. Absolute performance would include, for example, building location and land used (Greenfield, Brownfield, reclaimed), which are often outside the control of the developer when, as for Hong Kong, land is in short supply. Location in relation to public transport and local amenities is an aspect of building performance that takes into account the impact of commuting using private vehicles. Absolute performance would also take into account emissions at power plants (e.g. CO₂), rather than GJ or kWh measured at the building intake, thereby penalizing a building's score if the supply authority burns coal or oil, or uses outdated plant. Relative performance that takes account of the efforts and achievements of designers, builders and/or operators, within prevailing circumstances, is more acceptable. In the case of HK-BEAM, for example, a survey of stakeholders was conclusive on three counts: that additional aspects of sustainability should be included (hygiene, amenities, etc), a mix of absolute and relative performance, as well 'features' was acceptable, and that the performance of the completed building should be assessed as far as possible.

Ultimately, the performance criteria set for a voluntary BEAM needs to take into account what criteria is considered achievable within reasonable effort and cost. Life cycle assessment and life cycle costing are now useful if still emerging tools to decide which assessment criteria should be targeted (Chau et. al., 2000; California's Sustainable Building Task Force, 2003). From its onset in 1996 the HK-BEAM scheme seems to have achieved a reasonable balance given the relatively high number of buildings assessed when compared to other similar schemes (Edmunds, 2004).

Clearly, many parameters define the environmental performance (greenness) of buildings, e.g. cubic metres of water per hotel room per annum, ventilation rate, kVA maximum demand, etc. In addition,

there are key 'features' of buildings and systems that help maintain performance, e.g. metering provisions, adaptive controls, complete commissioning records, etc. BEAMs now provide a more holistic if not complete assessment performance than hitherto, covering site impacts, use of materials, energy use, water use and indoor environmental quality, with a focus on the reducing consumption of non-renewable resources and environmental loadings, whilst sustaining workplaces and habitats (Table 1). More recently the assessment of building performance has expanded to embrace social and economic dimensions, e.g. access for disabled, security provisions, etc. An assessment under any of these schemes is voluntary, and the success of any scheme should be measured by the extent to which they contribute to improving the environmental performance of the building stock. Table 1 gives examples of performance-based criteria, as well as 'features'.

For existing buildings, whose performance is often compromised by changes in use, aging equipment, poor commissioning records, etc., and for which the cost of preparing for a BEAM assessment is often met from operating budgets, the assessment criteria set needs even greater care, else take up and overall impact will be inhibited. Notwithstanding, as building users become more aware of the relevance and value of a performance label, the marketing advantage in gaining performance related certificates increasingly drives the business decisions. However, some in Hong Kong bemoan the numerous certificates that are issued by various organisations covering energy use, water quality, indoor air quality, etc, and prefer a single all-embracing label. Consequently, HK-BEAM has been developed to incorporate the various assessment criteria and good practices under its 'umbrella' (Fig.3), thereby strengthening both the relevance and value of the label.

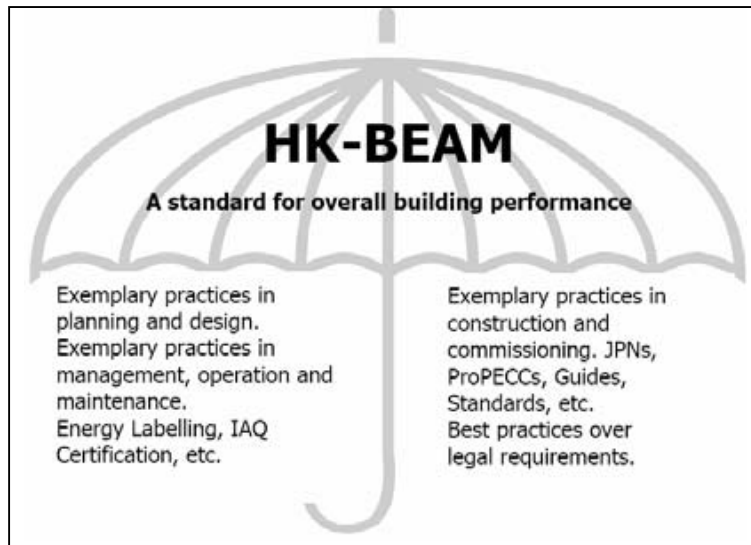


Fig.3 All-embracing performance label.

Table1 Examples of assessment criteria in BEAMs (HK-BEAM)

Section:	Credit Requirement:
2.1.3 Local Transport	1 credit if no car parking is provided other than provisions intended for use by company vehicles and/or any shuttle service vehicles. 1 credit for convenient pedestrian access to mainstream public transport.
3.2.4 Ozone Depleting Substances	1 credit for using refrigerants with a ozone depleting potential 0.03 or less and a global warming potential of 1600 or less. 1 credit for the use of products in the building fabric and services that avoids the use of ozone depleting substances.
3.3.3 Waste Disposal and Recycling Facilities	1 credit for providing facilities for the collection, sorting, storage and disposal of waste and recovered materials.
4.1.1 Annual Energy Use in Commercial Buildings	1 to 10 credits for a reduction in the annual energy use by 10% to 45%. 1 to 3 credits for a reduction in the maximum electricity demand 15% to 30%.
4.2.4 Hot Water Supply Systems	1 credit for installing energy efficient hot water supply system(s) and equipment that can save 20% or more energy.
4.2.7 Renewable Energy Systems	1 credit where 2%/4% of building energy is obtained from renewable energy. 2 credits where 4%/8% of building energy is obtained from renewable energy. 3 credits where 6%/12% of building energy is obtained from renewable energy.
4.4.2 Operation and Maintenance	1 credit for providing a fully documented operations and maintenance manual. 1 credit for providing fully documented instructions that enables systems to operate at a high level of energy efficiency. 1 credit for: providing training for operations and maintenance staff to the minimum specified; and demonstrating that adequate maintenance facilities are provided.
5.2.1 Annual Water Use	1 to 3 credits for demonstrating that the use of water saving devices leads to an estimated aggregate annual saving of 15% to 35%.
6.3.3 Indoor Sources of Air Pollution	1 credit for compliance with the appropriate criteria for VOCs. 1 credit for compliance with the appropriate criteria for formaldehyde. 1 credit for compliance with the appropriate criteria for radon.
6.7.2 Noise Isolation	1 credit for demonstrating airborne noise isolation between rooms, spaces and premises meets the prescribed criteria. 1 credit for demonstrating impact noise isolation between floors meets the prescribed criteria.
6.8.1 Access	1 credit for providing enhanced provisions for access for disabled persons .
6.8.2 Amenity Features	1 credit for providing amenity features that enhance the quality and functionality of a building to the benefit of building users. 1 credit for providing amenity features that allow for greater flexibility in building use and improved operation and maintenance of the building and its engineering services.

4. Green Buildings in Hong Kong

For the past few years 'green and innovative' buildings have been on the HKSAR Government's agenda, particularly through the activities of the Buildings Department (BD). Leung et al (2002) declared that BD was in the forefront of promoting green buildings in Hong Kong, ignoring the not inconsiderable efforts of the private sector, particularly those of The Real Estate Developers Association of Hong Kong who had funded HK-BEAM in 1995 and its further development up to 2003, as well as the initiatives of its sister departments, such as by the Electrical and Mechanical Services Department, and various construction related measures introduced by the Environmental Protection Department.

With the issue of two Joint Practice Notes (Buildings Department, 2002, 2004) the Government identified features of buildings it regarded as 'green and innovative' (Table 2). Incentives have been put in place for the private sector to include the features in buildings, although the key incentive, a

relaxation in the way service areas and building features are counted towards allowable Gross Floor Area (Buildings Department, 2003) apply mainly to new buildings. Clearly, as Table 2 demonstrates, some of the features relate to building quality, rather than environmental performance. In 2003 BD initiated a consultant to develop a Comprehensive Building Environmental Assessment Scheme (CEPAS), the draft of which claims to be an assessment of sustainable building performance, with similarities to the CASBEE scheme. However, some 90% of the assessed issues in CEPAS overlap with those in HK-BEAM but scoring and labelling of the assessment outcomes are significantly different. The choice that may confront developers and owners in the future is which scheme to embrace, maybe resulting in less take-up of either scheme than would be the if only one unified scheme existed. It is frustrating that an opportunity has been missed to join private and public sector efforts to develop one scheme for Hong Kong. For sustainable development, collaboration is the key, not competition!

Table 2. Green and Innovative Buildings (HKSAR Government)

Joint Practice Note No. 1	Joint Practice Note No. 2
The following green features may upon application and subject to conditions be excluded from GFA and/or SC calculations under the Buildings Ordinance	The following green features may upon application and subject to conditions be exempted from Gross Floor Area (GFA) and/or Site Coverage (SC) calculations under the Buildings Ordinance
Balconies Wider common corridors and lift lobbies Communal sky gardens Communal podium gardens Acoustic fins Sunshades and reflectors Wing walls, wind catchers and funnels	Non-structural prefabricated external walls Utility platforms Mail delivery rooms with mailboxes Noise barriers Communal sky gardens for non-residential buildings
(Criteria and conditions for exempting the above green features are listed in an appendices)	

5. Energy Use

Given the rapidly increasing concerns about global warming, energy use remains perhaps the most significant environmental aspect for buildings. Energy performance of existing buildings can be improved through energy efficiency measures and through energy conservation. Energy efficiency is about efficient conversion, efficient equipment such as boilers, motors, chillers, etc. sized to match load demand, and operate near optimum performance. All too often building design is by 'rule-of-thumb' plus 'allowances for contingencies'. Over sizing and mismatches between supply provisions and loads means operation well below optimum. For air-conditioned buildings much more care and sophistication should go into building design (through simulation) than is generally the case. Studies have demonstrated that if office buildings in Hong Kong met the current Hong Kong energy codes for air-conditioning and lighting they would be around 8% more efficient, and if they met the 1999 HK-BEAM criteria for energy use they would be some 32% more efficient (Lee et al, 2002a).

Energy conservation is about avoiding oversupply or switching-off when not required, or using natural substitutes (e.g. daylight). Lighting systems with occupancy sensors and daylight dimming controls are a good example where efficient equipment is provided with energy conserving controls (Chung et. al., 2001). However, a total performance approach would also consider glare, colour appearance, uniformity, etc. to ensure the productive needs of users. What goes for energy also applies to water and material use. Often, however, basic features such as meters, maintenance manuals and technical skills are limited.

Benchmarks for any consumable, be it energy, water, materials or land can be based on computed data, using baseline data for estimating performance of a 'baseline building', i.e., minimum compliance with legislation, or where non-exists, with the lowest acceptable levels that prevail, against which the 'assessed building', i.e., that having all the enhancements, can be compared. The variables in the analysis would only be those parameters over which the designer has control, and not parameters such as occupancy patterns, which would be set the same for both the assessed building and baseline model. This can be applied in existing building assessments, but if sufficient audit data is available for

buildings with similar characteristics, benchmarks can be derived using regression models (Sat, 2003).

6. Indoor Environments

In Hong Kong indoor environmental quality (IEQ), particularly indoor air quality (IAQ), has been the focus of attention for many years past. In Hong Kong, concerns and complaints from building users has lead to further Government initiatives to certify IAQ in air-conditioned offices and public places (Indoor Air Quality Management Group, 2003). This is part of the attention to IAQ which also embraces car parks and public transport interchanges. In contrast to EMSD's energy performance criteria, the IAQ criteria for air-conditioned buildings are rather strict (Chan et al, 2002; Burnett, 2004), not least in terms of the criteria for CO₂ set at 1000 ppm. It seems that the drafters of the scheme accept the view that CO₂ is not just an indicator of odour acceptability for visitors to a space (ASTM International, 2002), but also an indicator of the pollutants in the air. Nowadays, with increased awareness about IAQ, pollutant sources can be controlled through selection of materials and direct exhaust of sources. CO₂ levels in excess of 1600 ppm are recorded in occupied spaces without complaints, so to insist on 1000 ppm brings an economic cost through increased ventilation energy (significant in air-conditioned buildings) or reduced occupancy densities. Put another way, a pollutant free building could fail on account of 'excessive' CO₂.

Beyond the constraints imposed by building layout and system design indoor environmental conditions are dependent on the activities of users as well as the efforts of building management, so both parties need to appreciate that co-operation will be a mutual benefit. Educating and informed building tenants through 'tenant fit-out guides', as well as providing timely feedback on complaints have proven to be successful in enhancing building quality.

7. Targets for Existing Buildings

Existing buildings can be placed in three categories, those that, because of condition should only be redeveloped (reuse of Brownfield sites), those that can be refurbished (reuse of existing structural elements), and those that can be upgraded (to varying degrees). Refurbishment allows almost all the performance enhancements that are achievable with new build. The degree of upgrading depends on the quality of the original design and construction, but can vary between the extremes of replacement of main plant such as chillers, replacement of light fittings, etc. or simply through 'good housekeeping'.

Major upgrades includes retrofit of the building envelope to reduce solar gains, installation of energy efficient lighting, improvements to automatic controls, etc., but economic considerations based on energy cost saving tends to dictate the decision making. Replacing an oversized chiller with a smaller capacity chiller is viable if justified by the ability to improve overall system efficiency by matching supply capacity to variable summer/winter demand. Experience with auditing and tuning large 4-star hotel showed that the right knowledge and equipment can improve energy performance, as well as indoor comfort. The low-cost enhancements included 'tuning' and good-housekeeping. Recommissioning systems, calibrating thermostats, tuning boilers, resetting AHU controls, etc., were examples of tuning which, coupled with staff awareness to 'switch-off' when not required, led to 10-15% gains, as well as improved IEQ (Burnett, 2001). For places of work, what is difficult to assess is the extent that enhancements to a building's indoor environment bring to productivity gains, when thermal comfort, air quality, acoustics, and/or lighting quality are improved.

Performance targets for existing buildings can be formulated, based on the 'hardware', i.e. the measured performance of the building and the installed systems and equipment, and 'software', i.e. the quality and provisions for management operation and maintenance, appropriate to the building usage and condition. When a building owner seek a recognised label to mark performance so as to improve the marketability of a property, assessment of existing buildings can still include absolute and relative performance criteria, but with delineation between the quality of the hardware, and the quality of the software (management), which can be labelled separately. The performance criteria in a well-defined BEAM can be adopted as performance objectives and targets in an environmental management system (Burnett, 2002).

Be it energy, water or materials use, and/or reducing emissions to air, land or waters, a sustainable building seeks to maintain IEQ and other services at least to the minimum levels required by users. Faced with imperfect buildings and systems building operators need the skills and resources to improve. Improved performance is linked to remuneration and technical skills of operations and maintenance staff (Yik et. al., 2002), so investment in this area pays dividends. Water savings of some 20-30%, reduced waste by similar degrees, are achievable with relatively low investment of effort and capital, and without reducing the quality of services provided to users.

8. Conclusions

Much is written and said about sustainable buildings, often accompanied by claims that buildings are 'green' because they carry a few kW of photovoltaics, some greenery, use free cooling, etc. The focus is very much on new build because it is where most developers and construction professionals see the opportunities (and rewards!). However, greater focus on the existing building stock is likely to be equally beneficial in improving the total building stock, as shown by rough estimates in respect of energy use (similar figures apply to water and materials use). With a 1-2% increase in the building stock annually, over a decade the overall improvement, in say energy use, would be around 5%, even if the new buildings met the higher performance targets (30%+). If 30% of existing buildings could be improved 10-20% or more, without detriment to IEQ and service quality, the overall gain would be roughly doubled, and many more workplaces and habitats improved. Even though these targets hardly meet the demands of environmental sustainability, at least the building stock is somewhat greener. If the 'quality of life' and productivity dimensions are factored in then buildings will be somewhat more sustainable.

Legislation has not proven the answer to engender significant improvements to building design and performance. Where it is embraced by stakeholders and understood and appreciated by end-users, building performance labelling has shown to be a driver. Developers and owners who see labelling as an important marketing advantage with potential for improving financial returns, retaining staff, improving image, etc., will improve performance. Targets start at moderate levels, but the 'bar' can be raised over time.

Collaboration, between all stakeholders, government, private sector developers, building owners, designers and managers is a key ingredient in developing a building performance assessment (labelling) scheme that provides for a comprehensive assessment and is meaningful to stakeholders. As important is marketing of such a scheme to end users of buildings, so that they appreciate that good performance generally means safer, healthier and comfortable indoor environments, whilst reducing the impacts on the global and local environments.

Acknowledgements

This paper arises out of the author's work on the HK-BEAM scheme funded by REDA, the HK-BEAM Society and the Faculty of Construction and Land Use, Hong Kong Polytechnic University.

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PROJECT MANAGEMENT AND A MODEL FOR ACHIEVING SUSTAINABLE CONSTRUCTION IN SOUTH EAST ASIA

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Abstract

The aim of this paper is to propose a comprehensive framework for decisions in the form of a conceptual project management model that may be adopted by the construction industry to achieve sustainable construction throughout a project lifecycle. The paper explores and defines the concept of project management as a key vehicle to overcome inertia to change, and drive the change required to achieve ecologically balance, economically prosperous, and socially equitable outcomes within the building and construction industry.

The paper examines the key institutional, industrial and social changes that may be required to realise a sustainable construction industry and in doing so, proposes that sustainable construction will only be achieved utilising an assessment system based on absolute indicators of sustainable construction, in a supportive and directive institutional framework, with educated, skilled, motivated and unified human resources.

Keywords : Sustainable construction, Project management, Model, Absolute indicator, Marginal improvement, Assessment system.

1.0 Introduction

Earth is a single, quantifiable and unique system largely exploited by its human population. Humanity's negative impact on the environment has come to the fore in recent decades as nations in pursuit of social and economic development are increasingly being forced to recognise and embrace their reliance on a healthy natural environment.

Construction projects, by their very nature, impact upon the environment. They do this as a result of creating change, in the use of resources, and by creating waste and pollution. South East Asia and the world have recently entered a period of new environmental responsibility, currently aimed towards sustainability, the ultimate goal being the achievement of a sustainable human society. This goal, the driver of sustainable construction, is to move beyond the current practices and ways of thinking and achieve a result whereby human actions do not deplete or damage the earth's natural systems or resources, while simultaneously contributing to the well being and living standards of all human beings.

The achievement of sustainable construction is, however, proving to be a major challenge. In many instances political instability, poverty, a lack of established, comprehensive, and reliable institutional infrastructure, poor access to and utilisation of innovation and technology, as well as restrictive or inappropriate international economic policies, are all formidable barriers. These international and regional level considerations determine the capacity of the people of the nations of South East Asia to design, develop, and implement a unified strategy and action that will enable the realisation of a sustainable built environment. While domestic political reformation, such as decentralisation in Indonesia, may have positive outcomes for the sustainability agenda, corruption, mismanagement and inefficient natural resource extraction and use, limited access to health and education, and volatile economic conditions, further inhibit real progress.

The objectives of this paper are to;

- Review current trends, and the construction industry's approach towards achieving sustainable construction.
- Assess the concept of project management as a driving vehicle for achieving sustainable construction in the South East Asian context, at the project level.
- Develop and propose a project management model for achieving sustainable construction in South East Asia. This will include investigating all the relevant components of the model, and a range of reforms or strategies that would need to be implemented and encultured for such a model to be successful.

The model applies and makes more comprehensive the project management model proposed by Hyde (2003) with some of the many challenges unique to the South East Asian context.

1.1 Literature Review: Sustainable Construction and Project Management

Sustainable construction is a core subset of sustainable development. The construction industry is widely recognised as a major contributor to environmental degradation and resource consumption. It is estimated that thirty-two percent of the world's resources are consumed by buildings and the construction sector is responsible for between one third and one half of commodity flows in OECD countries (GBCA, 2003).

While in many developing countries these figures may currently be lower, developing countries are home to the majority of Earth's human population and as such, an increase in living standards will lead to massive increases in demand for the earth's natural resources. However, some argue that even current levels of resource consumption and environmental damage can only be sustained for a historically short time period and cannot be extended to all the world's people (Trainer, 1995). The solution is clear, yet difficult to achieve; accelerate human development, particularly in the poorest countries, and remove the gross inequities in the world today; while at the same time avoiding the depletion of the natural resources and biological systems of the planet (Spence & Mulligan, 1995).

Sustainable construction may be defined as 'the creation of the built environment that; increases the living standards of all those who work in the industry, as well as clients and users of the built environment; that returns sufficient financial gain to stakeholders and society; and one that, in its creation and use, does not negatively impact the natural environment, nor deplete the quality and diversity of natural resources. It includes all project types, throughout a project lifecycle from natural resource extraction through to adaptive reuse, deconstruction and recycling.

The ability to achieve sustainable construction depends on a number of factors that stem from two overriding requirements. Firstly, that there must be the institutional, scientific, technological, organisational and resource capacity to achieve sustainable construction (UNEP, 2002). Secondly, that people must not only have the capacity (education, skills and support) to achieve sustainable construction, but they are motivated and unified to do so. These two broad components determine the ability of a country to achieve sustainable construction, and sustainable development.

Approaches to sustainable construction frequently focus on innovation-led advancements that marginally improve the performance of the built environment. These often arbitrary 'marginal improvements', whilst being critical to the realisation of sustainable construction, are likely to have their benefits offset by the increase in building activity in the future. As such, another line of research supports the use of absolute indicators of sustainable construction. Absolute indicators were explicitly proposed by Uher, and have been integrated into a number of ecological evaluation systems, such as 'Ecocost' (Sainsbury, 1994). These assessment systems attempt to quantitatively assess what level of construction activity is within the carrying capacity of the earth, and measure a building's environmental impact accordingly. For example, while an innovation may marginally improve a building's environmental performance by reducing non-renewable energy use by 20%, this new level may still be well above a sustainable level, particularly if

every year aggregate global demand for energy increases. Absolute indicators attempt to assess a sustainable level of green house gas emissions, resource extraction, etc, and give a repeatable, comparable, numerical figure in line with that level.

Perhaps the most pressing issues facing the conversion to sustainable construction in developing countries is the change in individual and cultural value systems that will be required, and the need for far better integration of social goals with the manufacture of the built environment (CIB & UNEP-IETC, 2002). In all construction sectors, particularly the informal housing sector, an analysis of the theoretical background that is the subject of a number of motivational, team and leadership theories is required to understand this process of change. That is, what will motivate, and what is required to motivate individuals and groups to adopt sustainable practices and actively pursue a sustainable built environment? Particularly where sufficient, appropriate and enforceable regulatory authority may not be in place or effective. A detailed review of relevant motivational, team and leadership theories is synthesised by Hyde (2003).

Baldry and Golton (1994) state that an attitudinal shift is required within the industry to achieve sustainable construction, and examine the role of project management in leading this change. This is supported by Uher (2002, p156) who states 'A change of attitude towards sustainability will also [in addition to new knowledge and skills] be required considering that the traditional focus of project teams has in the past been largely on economic and commercial considerations'.

Project Management is proposed by a number of authors as being a suitable vehicle to drive sustainable construction (Uher, 2000; Baldry and Golton, 1994; Kilbert, 1994). It is foreseeable that, in its leadership capacity, the project management function may be instrumental in leading this change. There are a number of general business texts that examine change leadership and management and these are adaptable to suit project management led change to achieve sustainable construction. Included is the work of Kotter (1996), who proposes an eight step process to implementing organisational change, and Arnold (1998).

A project management model for the achievement of sustainable construction was first proposed by Kilbert (1994) who proposed a simple triaxial model that enables decisions based on the principles of sustainable construction to be assessed and made. The model connects a wide range of issues that had, in the past, been considered independently from each other. Based on this model, Uher (2000) proposed a conceptual project management model detailed through the project conceptual and design stages, incorporating absolute indicators of sustainable construction and the stipulation of measurable objectives at the very earliest project stages. Uher's model embraces the traditional project management process and enhances this with the integration of sustainable construction principles.

2.0 Project management in Sustainable Construction

The employment of practices that promote sustainability throughout the life cycle of the construction process may now be considered an integral part of the responsibilities of the project manager (Baldry and Golton, 1994).

As defined in the Project Management Body of Knowledge (PMI, 2000, p4) a project is 'a temporary endeavour to create a unique product or service'. Project Management is defined as 'the application of knowledge, skills, tools, and techniques to project activities to meet project requirements'. While this definition may be regarded as overly rigid, prescriptive and removed from the integral human resource component, Project Management is a primary method of project delivery within the construction industry. At both the strategic and execution level, the major functions of project management can be viewed as leadership and integration. Leadership involves unifying the project team and all stakeholders to achieve a set of desired objectives. Integration is the combining of all management functions, people, systems, techniques and technologies necessary to successfully achieve these objectives. The primary goal of project management is to deliver to the client a project of optimal value. That is, complete all project objectives specified by the client in the most effective and efficient way possible.

Baldry (1998) proposed a number of ways in which the project management function can positively contribute to the achievement of sustainable construction, including;

- “The provision of leadership and direction to the project process to establish a project team culture consistent with the intention to conduct a project in a sustainable manner;
- The articulation of clear goals and project outcomes in terms of sustainable construction processes;
- The identification, appointment, and assembly of a construction project team of like minded collaborators to further the realization of the sustainable objectives;
- The influencing of the project sponsor towards the opportunities and benefits of a sustainable approach and how this may promote enhanced value and user satisfaction;
- The establishment of the guiding principles by which a project may be delivered in a manner consistent with sustainability and ethical responsibility;
- The planning of a procurement and resource acquisition route based on equitable commercial relationships and the pursuit of efficient resource conversion”.

In the South East Asian context, the project management function will, at least initially, also have a large educatory component. That is, many project participants on major infrastructure, commercial and other public projects in the region will have had little exposure to any formalised training or education on the need to (and how to) undertake a project in a sustainable manner. In addition, while Baldry proposes the integration of like minded people into the project, this may not always be possible when the traditional goals of time, cost and quality have always been the prime delivery objectives.

The rise in project management is linked to the increasing size and complexity of modern projects. The diversity of project types in South East Asia ranges from projects of the grandest scale, through to numerous makeshift homes constructed from recycled waste and basic materials in the informal sector. Initially it is proposed that the benefits of project management will best be realised on larger scale infrastructure, institutional, and commercial projects. On these types, and all public projects, project management will be of benefit in two major ways. Firstly, to achieve sustainable outcomes on each project. Secondly, to educate and develop skills, so that participants may take away an enlightened sense of environmental awareness and responsibility, coupled with increased skills and knowledge so that all participants can be leaders and agents, to some degree, on future projects within which they work.

The informal sector is however a very significant sector of the regions economies, with a large social and environmental impact. Active programs to disseminate knowledge and expertise through all sectors will be critical if sustainable construction is to be achieved.

Implementing and sustaining the required culture change to achieve sustainable construction is perhaps the biggest challenge to be faced by project management. Various authors have described the culture within the construction industry by;

- Client's preference for maximizing economic objectives
- Designer's preference for adopting minimum regulatory compliance
- Contractor's preference for implementing conventional construction techniques, and
- Facility owner's preference for demolition rather than refurbishment (Uher, 2000).

The concept of project management is in a unique position to align project participants and the tools of project delivery with the greater goals of sustainable construction and in doing so, overcome the traditional industry culture. The process of change will require greater political, economic and social reform and development, discussion of which is beyond the scope of this paper, however, at the project level, the

project management function can be envisaged as helping to lead this change, through their skills in team building, motivation, leadership, and management of all project functions.

Initially, key responsibilities of the project manager to achieve sustainable construction will be to act as an educator and agent for change. To achieve sustainable construction requires the commitment of all project participants and thus, many stakeholders will need to be equipped with the appropriate knowledge and skills to understand and embrace this new approach.

3.0 A Project Management Model for the Achievement of Sustainable Construction

The value of utilizing a project management model to achieve sustainable construction is best described by Kibert (1994, p10). 'The model can serve many functions, the first of which is the articulation of the many issues of sustainable construction. It distils a wide range of complex issues into a simple graphic that allow us to grasp, at least in a reasonable fashion, the overall idea of sustainable construction. It allows the debate to be engaged over the appropriateness of activities meant to build or maintain the built environment. A second application is a decision making tool for use in examining the options that may occur during the creation, operation, or deconstruction of buildings. In this regard it can also serve as a checklist for the sustainability issues that should be considered by the construction professions in their activities.'

A construction project can be broken down into a number of stages. The model proposed (Fig.1) is based on six project stages; concept, design, tendering, pre-construction, construction, and commissioning where responsibility is handed over to a facility manager. The reason the model identifies the above stages is that this represents a generic project life-cycle. In addition, this break-down is to ensure practicality. That is, allowing enough information to enable sustainable construction projects to eventuate, but simple enough that it does not threaten, or attempt to authoritatively direct, or limit the freedom of project decisions.'

The model integrates the project management function into the construction project, through each stage of a project life cycle. The proposed project management model and a number of requirements and reforms for the model to be successful follow.

4.0 Conclusions

The models success will stem from the two overriding requirements, as previously discussed. These are;

- That there is the *Institutional, scientific, technological, organisational and resource capacity* to enable sustainable construction
- That there is the *Human Capacity* to achieve sustainable construction

4.1 The institutional, Scientific, Technological, Organisational and Resource Capacity Includes;

- #### 4.1.1 Local, Regional & Global Implementation of a Generically Applicable Quantitative Ecological Assessment System Based on Absolute Indicators of Sustainable Construction.
- Absolute Indicators are indicators based on the actual ability of the earth to support human development. They represent a move from arbitrary goals and targets, to use the earth as the frame of reference for assessing a sustainable level of human impact. Land, for example, is a finite resource that can be divided into different types, from primary rainforest to tundra and grasslands. Land types size, productivity and ability to recover from impact can all be calculated and this enables decisions to ensure its sustainable use for human development (Uher, 1999). Other examples include greenhouse gas emissions (the subject of the Kyoto Protocol), freshwater use, and resource mining and use, which can all quantitatively be assessed. A globally implemented assessment system based on such indicators enables the earths systems, which are not restricted by national

'boundaries' to be considered and 'budgeted' into allowable ecological impact. Such an assessment system can be implemented at a local level depending on local sustainability criteria, and should be performance based, not prescriptive, promoting traditional cultural solutions to local ecological challenges.

The parameters within such a system for construction impact assessment will include such things as; pollutant output from industrial processes, land degradation caused by raw material extraction, energy consumption and generation, pollution and land degradation due to transport, longevity of materials, resource scarcity, reusability and recyclability, and human toxicity (Sainsbury, 1994).

The major benefits of such a system are that it may allow repeatable, objective and quantitative assessment of building products and processes, based on the earth's actual ability to support life and development, taking into account the rate of recovery for various ecosystem types. In this way, the actual level of sustainable development per site, per catchment, and per nation can be assessed.

Implementing such a system is essential to achieving an actual sustainable level of construction. Only when people actually know the capacity of the earth to absorb human impacts, and its rate of recovery, can sustainability really be achieved. Such a system requires much further research.

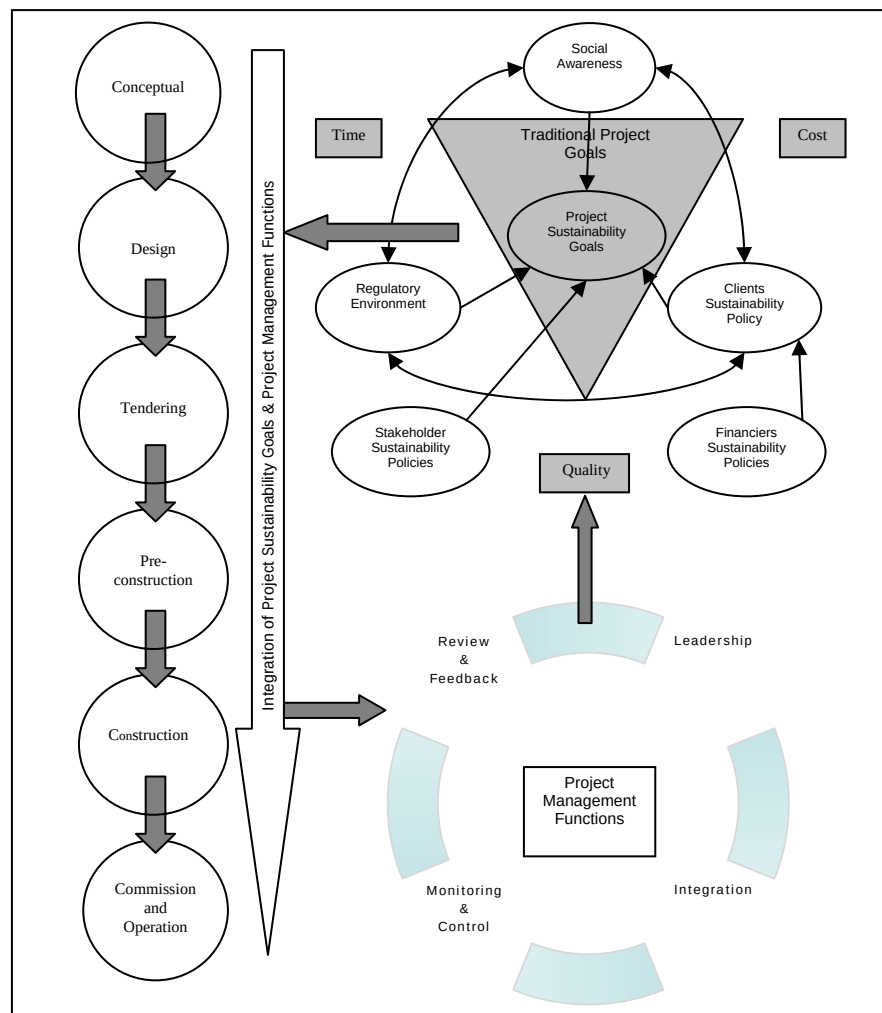


Fig.1 A conceptual model for achieving sustainable construction through Project Management

4.1.2 Commitment to Innovation The implementation of such a system, in the immediate present may be idealistic, and not practicable. As such, assessment systems, such as 'BASIX' in Australia, based on impact reduction through innovation and marginal improvements will be essential at least in the short to medium term. While arbitrary reductions in environmental impact may have any benefit offset by the anticipated increase in building production in the future, the commitment to innovation is very important for at least two major reasons. Firstly; because they reduce the construction industry's negative impact on the environment. In so far as they do lead to more efficient, environmentally friendly products and processes, marginal improvements are a key way in which the construction industry is able to move toward sustainable construction. Secondly; marginal improvements are important because they have helped lead to a changing industry culture that increasingly accepts the environment as an important concern. Regulation has pushed this, however through the influence of marginal improvements, environmental initiatives and products have become common place on many construction projects and this has raised people's awareness and comfort level when dealing with environmental issues. Marginal improvements are a bottom up method to achieve sustainability. They are a very important part in the attainment of a sustainable construction industry however; absolute indicators will need to be implemented if sustainable construction is to be achieved.

4.1.3 Regulation Sufficient, appropriate and enforceable regulation is another key component to enable the models success. The term 'sustainable development' is one of the key principles underlying environmental legislation and policy (Woolley et al, 2000, p93) and the concept has substantially infiltrated policy, legislation, regulation, and case law globally, its meaning generally accepted as defined by the Brundtland Report (WCED, 1987). The responsibility of the construction industry to address sustainable development stems from international obligations and responsibilities in regard to the broad principles of sustainability.

The impact of the construction industry on the environment, and the construction industry's reluctance to adopt sustainable practices independently has prompted action in regard to regulating the industry's compliance level. The level of compliance is currently relatively low, with legislation focused largely on the mitigation of environmental risks and land use and planning controls as opposed to real levels of sustainability.

Self regulation is the preferred way forward from a construction industry perspective, this being because it is perceived stringent environmental laws will decrease industry profitability. Certification to such voluntary standards as ISO14000 provides an opportunity for construction companies to demonstrate their environmental commitment. However, experience in other industries illustrates the concerns over the level of effectiveness of such voluntary codes in maintaining the desired performance standards.

4.1.4 Institutions and Social sustainability The importance of political, economic, health, education, legal and other social institutions in the achievement of sustainable construction is critical. While the complex and diverse issues related to these things is beyond the scope of this paper, it is necessary to recognise that only when a certain degree of social sustainability is achieved, will it be possible to achieve environmental sustainability. It is interesting to consider this using Maslow's hierarchy of human needs.

It is generally accepted that poverty is a major cause of environmental degradation, and a fact that poverty contributes significantly to rapid population expansion (Beder, 1996). According to Loosemore et al (2002), by the year 2034, 93% of Earth's population will live in developing nations, and, for at least the short-term future, a large proportion of these people will be classified as living in poverty. These people are therefore generally placed on level 1 or level 2 of Maslow's hierarchy of needs (Maslow, 1970)

People on level one are motivated to expend all energy and resources on survival. That is, satisfying hunger and thirst. Those on level two expend all their energy and resources on hunger,

thirst, shelter and security. While these people may desire a higher quality of life, they have no resources to actively seek it. In addition, and in most cases currently, pursuing environmental sustainability may be viewed as an activity toward the very top end of Maslow's hierarchy of needs. This is supported by Birkeland (1995, p4) who states, "Society's present course of action is not sustainable, and even worrying about sustainability is a luxury for the privileged in the richer nations".

While people exist on level one and two of Maslow's needs hierarchy, they will not actively expend extra energy on change for 'sustainable construction'. For this to occur, it is likely that people will require reliable access to nutritious food, access to fresh clean water, comfortable and permanent affordable housing, employment, and basic social services such as health care and education. This is because the broad goal of sustainable development is not viewed as being critical to survival of self and family, the base level of Maslow's needs hierarchy.

However, ecologically damaging and socially inequitable human practices and activities are increasingly being linked directly to significant disasters and humanitarian crises, such as landslides, global warming, food source destruction, and war. This increasingly obvious cause and effect link between human activities and ecological and social tragedy may help lead to change in human actions and value systems by linking healthy ecological and social systems with the very bottom level of Maslow's need hierarchy, survival.

The alleviation of poverty through job creation, better access to basic human needs and opportunity can only be brought to the people of a country through reliable and just institutions. Political stability, government policies that support appropriate development, absent of any inappropriate pressure from the international economic institutions, and a sound legal system are seen as key precursors to the achievement of real action, throughout a society, toward sustainable construction.

4.2 *The Human Capacity*

While the human capacity largely overlaps with the discussion above, achieving sustainable construction requires having committed, learned & motivated human resources. This will be a function of the institutional capacity, social awareness, leadership and personal choices that people make. In addition, it includes sound project management. The project manager's effectiveness is a function of their knowledge and skills, as well as their ability as a leader.

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SUSTAINABLE CONSTRUCTION – A NEW PROJECT OBJECTIVE IN HONG KONG

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ABSTRACT

Over recent years the importance of Sustainable Development has increased world-wide. Through several years of efforts by Hong Kong SAR Government to promote the concept, most of the local property developers and designers are now willing to incorporate sustainable designs in their projects. To achieve a Sustainable construction project, the contributions by the main contractor and sub-contractors are of equal importance to the design team, however, it seems that many local construction companies still hesitate to adopt Sustainable Construction methods. Time, cost and quality are the three fundamental measuring criteria traditionally used to quantify project performance. New criteria, such as environmental issues, are being introduced because rapid development in terms of the complexity and size of construction projects is gaining more public concern.

This paper analyzes how main contractors rank the objectives for their projects so as to evaluate their degree of intention of adopting the Sustainable Construction methods. As most main contractors in Hong Kong tend to sub-let most of the work to their sub-contractors, a survey was conducted to summarize the criteria that the main contractors are using to measure the performance of their sub-contractors. The survey results are therefore a good indication of how main contractors view the importance of different performance criteria.

Keywords : Sustainable Construction, Project objectives, Performance, Sub-contractor.

1. Introduction

Our living environment is being improved rapidly by advanced construction technologies. Unfortunately, construction work has the potential to adversely impact the nature environment and consume vast amounts of natural resources. The importance of Sustainable Development has thus increased in the recent years. The International Council for Local Environmental Initiatives (1996) defined Sustainable Development as development that delivers basic environmental, social and economic services to all residences of a community without threatening the viability of natural, built and social systems depends.

As a commitment to a better living environment, the Hong Kong SAR Government started to promote the Sustainable Construction concept in the last 1990s. Sustainable Construction is regarded as a way for the building industry to contribute to Sustainable Development (Bourdeau, 1999). The Sustainable Construction concept introduced by Kibert (1994) is defined as the creation and responsible maintenance of a healthy built environment based on resources efficient and ecological principles. In 2002, Hong Kong SAR Government permits the green features such as prefabricated external walls to be exempted from the Gross Floor Area and/or Site Coverage calculations under Section 16 of the Building Ordinance. As a result, most of the property developers and designers are willing to incorporate aspects of various sustainable designs in their new projects.

Collaborative efforts by all the key players including design team, main contractors and sub-contractors are essential supports to achieve a Sustainable Construction project. Prefabrication, an application of Sustainable Construction method, has already been extensively implemented in the construction of the local

standard public housing estates in the last decade and there are increasing private sector projects adopting this method in the recent years. However, other than this area, most construction companies still hesitate to actively implement the sustainable construction approaches into other site operations. This study reviews the reasons behind these decisions.

2. Aims and Scope of Study

The aim of this study is to establish whether or not Sustainable Construction has already become an essential objective for local building construction projects. The core part of this study is to identify the essential criteria that main contractors currently use to evaluate the performance of their sub-contractors so as to reflect how they set the goals for their projects and hence to conclude their willingness of adopting sustainable construction method.

Most of the well-established construction firms have already established their own systems to periodically review the performance of their sub-contractors. However, they are very reluctant to release the details of the system to the public. This survey was thus designed to collect the viewpoint from main contractors' staff as a reflection to the viewpoint of the companies.

In Hong Kong, main contractors of the building construction projects tend to sub-let almost all of their work to the sub-contractors. Many of these sub-contractors further sub-let the work to sub-sub-contractors. This sub-letting process may sometimes go down several levels and is referred to as a multi-level sub-contracting system. The workers actually carrying out the work may not even be the employees of the final level sub-contractors. This study only covers the building construction projects because the main contractor of the civil engineering projects would not sub-let too much of the work to their sub-contractors since the nature of work is not too labour intensive.

3. Project Objective

Time, cost and quality are the three most common fundamental project objectives for a building project from the client's point of view (Stuckenbruck, 1981; Bennett, 1983; Walker, 1990). In recent years, due to the rapid development in terms of the complexity and size of construction projects, broader project objectives are being introduced. For example, Ofori (1992) defined the environmental issues as the fourth dimension to construction project performance. Sustainable Construction is currently a popular topic in HK and many other countries, which could be considered as another essential objective for a project in the near future.

It is quite normal for clients to expect all of a project's objectives met, however, project objectives are not interdependent and, as pointed out by Ward, Curtis and Chapman (1991), trade-offs may have to be made between each objective. Also, during a project development process, a dynamic temporarily multi-organisation system is created that is continuously confronted with disparities between two levels of objectives: the temporary objectives of the construction project; and long-term objectives of the participating organisations and operational phase of the project (Mohsini and Davidson, 1992).

Due to business confidentiality, construction companies and their staff would not explicitly show their real intentions for a project. Sanvdo, Grobler, Parfitt, Guvenis and Coyle (1992) defined the success for a given project as the degree to which project goals and expectations are met. Client satisfaction is an important tool to gauge the success of a project (Yasamis, Arditi and Mohammadi, 2002). In this study, client refers to the staffs of the main contractors. Therefore, one possible way to trace out the goals that main contractor set for a project is to analyze the criteria that they use to evaluate the performance of their sub-contractors.

4. Research Methodology

Various publications have attempted different approaches to assess the performance of contract (Dainty, Cheng and Moore, 2003; Yasamis, Arditi and Mohammadi, 2002; Liu and Walker, 1998; Tam and Harris, 1997; Ward, Curtis and Chapman, 1991; Frisby, 1990). This study adopted an integrated research approach including a questionnaire survey to collect quantitative data and in-depth interviews to explore the possible causes for the findings.

After the consultations with the experience industrial practitioners, essential sub-contractor performance evaluation criteria for building construction projects were shortlisted. These were categorized into different objectives including time, cost, quality, safety and health, sustainability, potential for long-term development and company image. Respondents who had worked in main contracting firms were requested to rate the level of importance from 1 (very important) to 7 (very unimportant) to several short questions. They were permitted to suggest other factors that not yet included in the list presented in Table 1. The questionnaires were randomly distributed through private relationship to the industrial practitioners. One hundred questionnaires were sent out and 27 valid replies were received.

Table 1. Average Score for the Sub-contractors' Performance Evaluation Objective and Criteria

		Overall Score
Objective:	Time	1.58
Criteria:	Progress of work follow schedule	1.41
	Propose method to speed up progress	1.76
Objective:	Safety and health	1.93
Criteria:	Follow safety rules	1.88
	Propose method to eliminate potential danger to workers	1.98
Objective:	Quality	1.98
Criteria:	Quality of work comply with specification	2.04
	Quality of work comply with trade standard	1.91
Objective:	Cost	1.99
Criteria:	Amount of claims and backcharges	2.01
	Contributions on reducing construction cost	1.98
Objective:	Potential for long-term development	2.38
Criteria:	Application of advance technology	2.64
	Relationship with	
	a. Site representatives of the client/design team	1.73
	b. Other sub-contractors	2.48
	c. Your staffs	2.56
	Administrative issues such as submission of records, sample, shop drawings	2.54
	Availability of additional resources	2.31
Objective:	Sustainability	2.74
Criteria:	Suggestions to improve the design in terms of:	
	a. Buildability	2.69
	b. Durability	2.86
	c. Maintainability	2.86
	Amount of nuisance such as duct, noise, vibration etc generated	2.66
	Amount of construction waste generated	2.61
	Material wastage level	2.76
Objective:	Public image	3.32
Criteria:	Site tidiness	3.19
	Worker's working uniform	3.45

5. Data Analysis

The survey findings can be regarded as a manifestation of the common views of the industry as 44.4 per cent of the respondents have over eight years of working experience in construction industry. Table 1 above shows the mean of the scores assigned by the respondents to each criterion. This reflects the level of importance of these criteria in assessing sub-contractors' performance. In this study, it was assumed that all the criteria are of equal importance to their respective performance evaluation objectives. Thus, the score for the performance evaluation objectives is the mean of the score of the criteria in the same group. Three experienced construction managers of main contractor were subsequently invited to express their views on the survey data through well-structure in-depth interviews. The following section summarises the general observations of their views.

5.1 Time

Time was the most important sub-contractor performance evaluation objective among the short-listed criteria for building projects. Its average overall score was 1.58, indicating that most of the respondents considered this as a priority target for their projects. The main reason being that performance in relation to this objective can be easily quantified by measuring the variance between the contract and actual project completion date. Respondents in general adopted a conservative approach to the management of their projects, for example, they prefer their sub-contractors to strictly follow the project programme rather than propose new methods to speed up progress.

5.2 Safety and Health

The average score for the Health and Safety objective was 1.93. The importance of this objective is slightly higher than those for quality and cost because construction companies have to face litigation and the site managements may be liable for personal responsibility for serious accident. Safety and health issue for building construction projects is getting more government concern in the recent years, for example, the Buildings Department issued the Technical Memorandum for Supervision Plans to specify the safety requirements for different grade of construction work and request the contractor to submit a supervision plan at the time of application for consent to the commencement of works.

The questions for assessing the criteria of this objective were similar to those for time. Respondents displayed a similar attitude for this item. They request their sub-contractors to follow the basic safety rules and do not expect them to propose new construction method to eliminate potential dangers to workers. The survey shows that well-experienced respondents were far more ready to accept new method for site safety management. Perhaps, this may be a warning signal to voice out the dissatisfaction of the site management on the current safety management system.

5.3 Quality

The average score for this objective is 1.98: rated as only a fairly important factor because it is difficult to quantify the overall level of workmanship of a project. Construction projects comprise thousands of small jobs and it is impossible to review all of them so as to consolidate a final score to represent the quality standard of a project. Another reason for not to set the quality as the top priority objectives being that the property developers always set a very tight programme for the development due to high land cost. They need to make a trade-off to relax the demand on the quality of works provided that the project can be completed on time. Consequently, main contractor would spend most their efforts to push their sub-contractors to meet the tight project programme and the control on the quality of work would be of second priority.

One possible way to measure the quality of construction work is to assess the degree of compliance of the work to the agreed standards. Works Specification of the contract is the official standard of workmanship for a project. Respondents prefer to adopt the industrial trade standard rather than the Works Specification

of the contract as the quality standard for their projects. This is because most of the standards specified in the Works Specification are unreasonably high in view of current tender price.

5.4 Cost

As commercial companies, it is no doubt that the prime objective of the main contractors is to earn maximum profit in their projects. However, the respondents take any other view on assessing the performance of their sub-contractors. Excessive claims and backcharges may cause additional financial burden to the project. However, the survey shows that respondents do not take this as a very important issue because main contractors are always at the favourable side in assessing the claims from their sub-contractors. The average score for this criterion is thus only 1.99.

In Hong Kong, it is common for the main contractor not to pay their sub-contractors for the claims and backcharges unless they have got the payment for the respective variation order from the client. Final account preparation is a long process and it is also easy for the main contractors to find an excuse to reject the claims. Most of the local sub-contractors are small companies and would not initiate any legal action immediately even though their claims are supported with solid evidences. Their main concern is that the additional payment does not always cover the expenses. Instead, they would desire the main contractor to compensate their losses by awarding them high profit margin contracts in the future if long-term relationship is maintained.

5.5 Potential for Long-term Development

Long-term relationships are a key ingredient required to cultivate the mutual trust between main contractors and their sub-contractors, which can significantly improve their performances. Main contractor would evaluate the potential ability of their existing sub-contractors as this is one of the considerations to commit long-term co-operation plan with them. However, according to the survey result, this is not considered as a very important criterion as its overall average score is only 2.38.

Because of temporarily contractual relationship nature between the two parties and commercial secrets, main contractors would not expect to learn too much advance technology from their sub-contractors. On the reverse, they may allocate additional efforts to help the sub-contractors to build up good relationship with the design team/client's site representative. Sub-contractors are not demanded to have strong ability in handling general administration work.

5.6 Sustainability

The average overall score for this item was 2.74, probably because sustainability is a new concept to the local construction industry and is not easy to measure and quantify. Most of the experienced industrial practitioners did not learn about the Sustainable Development concept in their formal study years ago. They always equal this concept with prefabrication technique and green building design. They tended to claim that additional resources are required for arranging environmental protection provisions for the project. A set of questions under this evaluation objective is designed to review their understandings on the different issues in the context of sustainable construction technology.

In the local multi-levels sub-contracting system, almost all the production work of a construction project is actually carried out by the sub-contractors. They are therefore well-qualified to suggest alternative proposal to improve the design in terms of buildability, durability and maintainability of the construction work. Among these three items, buildability is most important one because a constructible design can significantly speed up the progress as well as to enhance the quality of the work. Durability and maintainability are less essential to contractors because these issues will be out their businesses after the property is handed over to the client. Main contractors are relatively more concerned about sub-contractors' performance in reducing the nuisances and wastes generated from the construction operations rather than on improving the design because they need to fulfill the stringent control imposed by local government.

5.7 Public Image

Marketing is a difficult task for construction companies. To upgrade the competitiveness of the company, they have started to allocate extra resources in this area. Apart from the development of company marketing plans, the efforts by the site staff should not be neglected. Tidiness of sub-contractors' site facilities and their workers' working uniforms are crucial factors that influence public's impression on a project. This subsequently affects the image of the company. The survey result shows that site staffs do not regard this item as an important criterion as its average overall score is 3.32. They think that public would not keep close view on their projects unless it is landmark building. They prefer to concentrate their effort on the production work and the company marketing work should be centrally organized by head office.

6. Conclusions

In Hong Kong, the role of main contractor has already been transformed from the actual production work to the management of the sub-contractors. This study has made an attempt to analyze the criteria that they are using to assess the performance of their sub-contractors, which are used to trace out how they set the objectives for their projects.

According to the survey result, time is the most important criteria to evaluate the performance of sub-contractors. With the increasing public concerns on the safety and health issues of the construction projects, this item becomes as important as the other two traditional indicators, cost and quality. Respondents in general adopted a conservative approach to manage the matters related to time, safety and health. They demand their sub-contractors to strictly follow their instructions.

Quality and cost are fairly important factors. Industrial trade standard is used to compare sub-contractors' quality of work. Sub-contractors are expected to make contribution in reducing the construction cost. Main contractors are not too keen to review the potential abilities of their sub-contractors for building up long-term relationship. Instead, they would like their sub-contractors to maintain a good relationship with the site representative of the client and design team.

Sustainable Construction is a new concept to local construction industry. Main contractor would not strongly request their sub-contractors to adopt the Sustainable Construction methods and to input additional resource for building up company image.

At the present moment, safety and health, not sustainability, becomes the fourth principal construction project objective in the local industry. However, it is expected that sustainability would be regarded as an essential objective that may be embedded within quality in near future when more and more local construction companies recognize the benefits they can gain from adopting the Sustainable Construction methods.

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THE MISSING LINKAGES BETWEEN DESIGN, INSTALLATION/CONSTRUCTION, MAINTENANCE AND SUSTAINABLE BUILDINGS

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Abstract

This paper is based on an unusual development and re-planning of a 20-year old teaching hospital in Hong Kong, which had been proposed to be torn down for reasons of inadequate design and maintenance. Based on this special case, the author discusses the missing linkages between the vital design, installation and maintenance of this highly serviced health care project in conjunction with the issue of sustainability. These linkages are often missing in construction debate – the relationship between the quality of building design and the requisite green issues.

Putting maintenance at the centre of the continuing post – Egan reform process is long overdue. Many people have not yet concentrated on the need for good planning of maintainability for building services systems in highly serviced buildings. Although considered important, the aspect of maintenance is seldom fully taken into account during the building process. The outcome: low quality of building and its M&E services and poor maintainability. This often leads to poor building and ultimately dissatisfied clients. Directly and indirectly, the quality of such buildings can have a significant impact on building sustainability. Case studies indicate that design strategies can have a significant effect on operation and maintenance, user satisfaction, client business, profitability and the sustainability of building and services. It is, therefore, necessary to have a critical appraisal of building services design together with the commonly neglected maintenance issue during the conceptual stage of a green building design to optimize the whole life aspects of building and its building services installations.

The aim of this paper is to provide a commentary on the ill-effect of inadequate maintenance of services in a 20-year hospital building. The author also offers his comments on the best management of design and maintenance that should be considered and pragmatic ways that can be used to improve building care and sustainability. This paper summarises the author's vision of sustainable buildings as a result of enlightened building services engineering that embraces design, construction and operation all are fully integrated as a seamless continuous process.

Keywords : Sustainable buildings, Building services, Design and maintenance, Whole life strategies.

1. Introduction

In recent years, much information has been put forth about the impact of the built environment on the natural environment, the concept of sustainability or green building issues and better design for our buildings. Vast amount of useful information is available for designing and constructing greener or better buildings. Nonetheless, study on maintenance of building and its building services and in conjunction with sustainable building care (i.e. use of building and the continuing maintenance) appears to be scarce. The industry apparently tends to focus too much on glamorous new construction, leaving maintenance aspect as a Cinderella of the design and construction process. Design for maintainability is little discussed and often ignored in industry. So it is difficult to get real green buildings, and many of these buildings still do not run efficiently, and very often, extra maintenance are necessary in order to continue the use of these facilities.

2. Building Towards More Sustainable

To begin with, we must have a mutual understanding of sustainability. There may be never be a consensus view on its exact meaning. However, one way of looking at sustainability is the ways in which built assets are procured and erected, used and operated, maintained and repaired, modernized and rehabilitated, reused or demolished and recycled constitutes the complete life of sustainable construction activities. Given this long definition it is vital that sustainable issues are given due consideration as early as possible during the procurement process. As seen from this definition, sustainability is not a building fashion, but a concept of good building design incorporating the best environmental management for the building, its people, the indoor and outdoor environment.

Building care is a part of sustainability issue. Building care is customer focused, and encompasses the management and maintenance of premises and its building services. The quality of maintenance or building care will definitely have a significant impact on the delivery of appropriate sustainability performance of a building. Obviously, to attain the highest building care and the best sustainability, the most effective way is to design maintenance out in conjunction with the development of a green building during the outset of a project. The reader will see that considerable emphasis will be placed on close coordination between members of the project team all seeking mutually acceptable solutions to green design challenge and maintenance issue (i.e. complex and innovative green designs may result in difficult maintenance later on and therefore good building care is unattainable, so the whole team must find another optimum solution). It will take both practical and innovative as well as synergistic designs that cut across design disciplines to achieve true success (i.e. both maintenance issue and green building requirements are of high quality). This will result in better sustainable building that achieves high performance, over the full life-cycle, in the following areas:

- Design attuned to use of building
- Higher sustainability in terms of energy air/water pollution and use of resources (i.e. energy and water efficient building with less waste and pollution)
- Higher building performance
- Low (or little) maintenance but higher reliability, availability and longer useful working life
- Low obsolescence and cost effective

The maximum value of sustainable building care is obtained by consideration the areas stated above at all stages of a project. However, spending time in researching and considering different solutions at the design stage has the greatest impact on achieving a sustainable building. Time well spent in preparation and design will enhance the effectiveness and efficiency of a sustainable project.

3. Sustainable Building Maintenance

A sustainable building (and its services) and sustainable maintenance are possible; indeed, the one presupposes requires the other. While zero maintenance may be striven for, it is ultimately unachievable in practice. Some maintenance will be necessary and, in deed, desirable if one wants to ensure the highest performance and reliability of the M&E building systems. In good design, a minimum maintenance model is to be pursued, in which the design of maintenance based on good engineering principles (e.g. simple design, functional analysis, reliability centred maintenance, fault analysis and risk identification, and combination of all planned maintenance techniques and conditioned based system) is carried out that will sustain the building and its building services in the best working conditions for a reasonably long period. If a green building is to be achieved, it is essential that the building and its M&E services are capable of being maintained to continue in the green performance conditions. Suffice it to say that any shortcomings in design and maintenance will not achieve a satisfactory green building as issues such as selection of materials, processes, systems, effective and efficient plant operation, maintainability, standardization, durability, health and safety – all these are (in addition to energy efficiency environment issues, waste reduction etc) significant components of the sustainability debate. They are whole life issues that need to be in the right context at the design stage.

Some designers jump on the energy and environmental band wagon without giving due consideration to equal or more important but less fashionable issues such as optimizing operation and maintenance, reducing design margins, minimizing redundancy, simplification of complex designs, improving standardization etc. these can all have a far more greater and long term impact on sustainability (over 50 to 60 years, the average life of a building) due to knock on effects such as extra energy consumption and waste all with extra maintenance costs and problems. Hence, the building services engineer has considerable influence on the environmental performance of buildings through involvement in design and operation.

Having outlined the basic concept of getting a better sustainable building care, it would be educational if the reader can see the missing linkages between the design, installation, construction and maintenance and the effects in a real life situation. A case study is helpful in this respect.

4. The Case

This case study is based on the \$4 billion (0.56 USD) rebuilding one of the largest teaching hospitals in Hong Kong, and the author's views on better design for maintenance together with green design sustainability. Its aim is to highlight some key issues that should be considered during the beginning of a project in order to improve the quality of a hospital building (as well as other buildings).

The Hospital Authority (HA) in Hong Kong released details of the plan of rebuilding a large teaching hospital which is only 20 years old, but it should have a long working life of 50 years or more. The plan was under fire, critics wanted to know why this 1400 beds healthcare facility could not simply be refurbished, and why it had to be torn down, especially when the (HA) would normally have an excellent repair and maintenance programme for its buildings in place. The HA argued that rebuilding the hospital was more economical than refurbishing it. The HA also declined to comment on whether the redevelopment plan was triggered by faulty design or substandard construction, but some of following comments had been given:

- Dilapidated state and accelerated deterioration of building finishes and other installations
- Serious water leakage problems due to building construction and building services installations
- Water damage to power facilities in basements/sub-basement as a result of flooding and the high moisture content within this sub-structure (it was a swamp)
- Never-ending maintenance activities/renovations
- Heavy usage of hospital and inflexible building layout
- Undesirable effect/inconvenience to users/patients
- Considerable age and insufficient capacity for future medical technology to be carried out

The HA defended the plan saying that the rebuilding plan would take less time to complete than renovation and refurbishment of this facility. The maintenance cost (\$37 million or US\$4.74 m for a five-year programme) would also be reduced after the completion of the redevelopment.

This case clearly illustrates that maintenance was not probably strongly enough addressed by the designers in any great detail at the design stage, otherwise, normal maintenance problems can be tackled easily, and the building can be used at least for another 25 years. The quality of this hospital design would have a considerable impact on:

- Reliability and durability of building and its building services systems (low in this case)
- Energy efficiency of the building services systems (less efficient as a result of difficult maintenance in this case)
- Use of resources, materials (will be more (including waste) due to more repairs, replacements or renovation of building and building services in this case)

- Sustainability and longevity of building and its building services (comparatively low and short in this case)
- Users and client's satisfaction (will be less satisfactory in this particular case and less value for money throughout the lifetime of the building)
- Use of funding (expensive maintenance cost is a big problem in this case)
- Building care (below expected quality as viewed by the HA)

If the building is to be torn down, the building will definitely produce more waste and pollution and the society will not have proper medical care for a few years time. The problems stated above are definitely related to the quality of design, construction and maintenance. As design is an exercise comprising a multiplicity of decision, maintenance should be a function of design and an important decision. Care at the design stage will give a care-free sustainable building. Unacceptable deterioration and breakdown are analysed, anticipated and corrected before they occur, thus avoiding many common maintenance problems. Maintenance problems can be designed out in many cases with both conventional and un-conventional design features, with resulting low cost of repairs, maintenance and better use of building. But how can this be done? There are numerous contributors to reliability, efficiency and maintainability: the original designer of the system, the manufacturer, the person who made the selection and installed the equipment and component, the users who use the facility and the persons who look after the building and its building services. However, the services designer can help reduce the maintenance problems by offering better design and maintenance together with the remainder of the design team in the design process. And the following paradigm for achieving a sustainable building is useful:

- No separation of design and maintenance
- Design for today and tomorrow (but must learn about the problems of yesterday maintenance)
- Provision of the right building and its building services by all professionals
- Use of common sense, wisdom as well as proven technologies

5. Close Look into Building Services Design

The combination of the escalating of building services installations and the increased rate of use of modern technology has resulted in the modern hospital (same as in other buildings) being the most complex of present day building types. It is important, therefore, that the subject of maintenance needs to be addressed much sooner in the design stage to ensure that the design of proper maintenance is fully integrated into a building design. The implications of building services installations on hospital design are many and varied with their inter-relationships complex. These implications not only influence the planning process of design but in many instances actually dictate the planning (not just two-dimensional, but three-dimensional considerations for the accommodation of services, etc.). The implications of building services permeate throughout every aspect of hospital design so that the resulting whole becomes an integrated matrix of building fabric and building services with elements interdependent on each other for function, support, protection, operation and maintenance.

The effect of the building services design not only encompasses the consideration of simply containing the various services, but also the parallel effects of the construction method, accommodation of services and the future maintenance needs. All in all, hospital design and building services are one which cannot be separated or considered in individual categories, without team effort, it is impossible to produce a useful, flexible and sustainable hospital.

It is crystal clear that in hospital engineering services terms the most important role is that of the designer. He has a range of equipment from which to select, he can dictate how it will be installed and how the components will be brought together to form the various systems to produce a functioning building. A multi-disciplined design team has professional responsibility to design out maintenance and/or make suitable provisions for maintenance. The building services designer should have a higher professional

responsibility to influence the remainder of the team in the decision making process in relation to the neglected maintenance of services after their physical installation.

It is appreciated that the maintenance of the equipment and the systems is only one of many considerations that the building services designer must consider when trying to satisfy a client's brief and working to produce an integrated building design with all the other professionals involved. However it is one facet that may not have received the degree of importance that it deserves.

6. Designing Sustainability

The primary consideration of a building design is the production of a functional facility. Since the functional requirement drives the design, there is a tendency to concentrate on this aspect of the design at the expense of other consideration, especially maintenance is the last thing on the designer's mind. However, the conceptual phase of a design is the single point in time at which there is total control over the future maintenance and operating cost of the facility. The ability to control or modify maintenance diminishes from the earliest step in the design process as shown in table 1 below.

Table 1 Ability to control or modify maintenance diminishes from the earliest step

STAGE	CONTROL
Concept	Total control – building and services can be tailored to any maintenance philosophy; designing out maintenance will eliminate most problems.
Design	Total control - flexibility remains to select systems which have low maintenance requirements.
Construction	Very limited control – design is fixed; difficult to change design but still possible at high cost; inspection will identify maintenance problems (not ALL).
Building in use (a life of) 50 to 60 years	No control – maintenance problems will develop and appear. Repair – very limited control, minor corrections to maintenance are possible. Replacement – still limited control, but can reduce on-going problems. Improvement/modification – control flexible is a little bit better, but may give good control (NOT TOTAL unless the whole system can be changed).

As stated previously and based on the author's understanding, good design will provide value for money of both total cost and cost-in-use and the energy and maintenance equations should be upper-most in the minds of the client and the designers. Therefore, the design team is in the best position to exert the greatest influence over the eventual maintainability of the building services installation. If all designers are fully involved in the integration and co-ordination of services in relation to the structure and architecture and the users' demands. It is not difficult for them to ensure that the appropriate requirements of space and accessibility are allowed for efficient building care.

Problems of maintenance will result in high cost penalties in terms of loss of service, high cost of repairs and, sometimes, unnecessary building damage. It is important, therefore, to consider the maintenance operational policy at an early stage in the design process to ensure that a maintainable building is possible.

Factors determining the approaches are:

- Capital costs
- Complexity of building design and intensity of engineering services in the building
- Use of simple technology, avoiding the use of special system, labour and material
- Level of reliability, durability and availability
- Future flexibility of layout and flexibility for changing client needs
- Consequence of failure or disruption of services and cost of failure
- Frequency of maintenance operations in conjunction with maintainability
- Health and safety aspects
- The acceptance of new design ideas with greater integration of building and its building services
- Maintenance with adequate access
- Obsolesce and quality of system/equipment to facilitate good use of building
- Impact on the environment
- A care-free sustainable building

The above-mentioned factors can greatly influence the future maintainability of the engineering services. We have to reengineer our practice (e.g. value analysis, risk evaluation and analysis, functional analysis and the process of continuous improvement such as design and maintenance audits) and give better designs to improve the requisite sustainability. With the increasing complexity of modern services, it is more than ever essential that the engineering and architectural aspects of a project are developed simultaneously from their inception. Most importantly, the types of services installation to be used should be identified before the overall architectural design is finalized and the necessary plant spaces determined.

Better design solutions can be used to enhance the maintainability of the lifeline of a building with or without necessarily increasing costs; where increased first cost cannot be avoided the increases can be demonstrated to have potential in more efficient O&M and longevity of the services systems.

7. The Need for Good Design

We have been using conventional design solutions for many years. Some work and some do not work satisfactorily. As an engineer, it is the right time to rethink about the use of innovative but practical ideas. Better planning of services do give better maintainability and lower whole life cost. As a responsible designer, it is our duty to incorporate the best solution in order to satisfy the client's needs. Again, working with other members of the design team is a must. To succeed, we have to put much emphasis on prevention/elimination of maintenance problem.

The engineering services needed to support the functions within a modern hospital (same as in any modern and highly serviced buildings) are vastly more complex and more sophisticated than they were ten years ago. With the increasing complexity and importance of the engineering content of hospital schemes, Services must be properly considered, coordinated, designed and analysed to ensure efficient operation and maintenance. The analysis should then aim to find out how the architectural and structural layouts will effect the engineer system and vice versa. The extent to which engineering systems affect building design cannot be over-emphasized. Blind adherence to standard hospital template (e.g. Hospital notes) without careful design of accommodation of services will no longer give good value for money to the client. Engineers and architect must rethink again the unusual hospital design and special considerations should be given to services with higher priorities than other static elements in a hospital. To the engineers it must be equally apparent that there is often a conflict of views on the part of the other members of the planning team, particularly in the relative importance of the clinical as opposed to the servicing, the answer must be better team work and the imposition of a strict discipline to all planning negotiations.

To leave the readers to find out the important details will not give a complete paper. The author feels that the following points can be very helpful when planning sustainable building:

- Consider all possible design solutions to cut down energy consumption which also give environmentally friendly buildings

- Design is fully integrated and coordinated and each services system can be installed and maintained with ease
- Use simple design solutions which can give better reliability and durability. At the same time, reliability centred maintenance should be used for services design and planning of maintenance.
- Check best design of services and maintenance and make sure that replacement or refurbishment is possible and without breaking the structure or building enclosure housing the services (this will save resources and also reduce waste)
- Check whether any plant and equipment provided may become obsolescent before the end of design life. Also think about the removal and replacement of this plant with the provision of suitable means of access for that work.
- Adequate attention is given to health and safety issue during the operation and maintenance

8. Barrier to Designing Maintenance

From experience, it is known that the ideal is very rarely attained and that bureaucratic procedures, inflexible decision making, in-cooperative culture in the industry and the unbalance of power amongst building designs as well as hard cash normally accounts for a large part of the difference between what we would have liked to have had and what we in fact get. The failings of inflexible building design, poor maintenance, etc. are mistakes which anyone of us might well have made and, for obvious reasons they are a general record of what has been found in a number of hospital buildings rather than the limited experience of any particular one.

9. Reconciliations

In today's building the engineering services may account for as much as 50% of the total cost and the engineer must be a full partner with the architect in any part of the design which affects the efficiency of all services. Maintenance should be considered as an integral part of the project during all phases of the design and, preferably, during the preparation of the brief. The larger the buildings, the more important early consideration of services design and maintenance becomes. Engineering services are a major cause of aggravation and tend to affect everyone in a building. They must be specified, designed, installed and commissioned correctly. Most importantly, the design should be sustainable and have sufficient flexibility and easy maintainability.

Maintenance problems (e.g. cramped services which are difficult to maintain) are mostly attributed to the failure of design co-ordination between architect, engineer and client. It is fair to say that the services maintenance problem is only one of the aspects of building design (even more important in a hospital) in which all project participants still have much to learn. If they can prevent the mistakes re-appearing they will have served their customers with better building care and the essential sustainability.

It cannot be emphasized too much that a highly serviced building (e.g. hospital) is one of the most complicated buildings calling for a team approach to design and the engineering member of the team must make sure that the services he is briefed to provide are permitted to do the job which is required. If not, the engineer must insist that he be given sufficient space to accommodate the services. The engineering profession can play a more positive part in any building design than in the past. Architectural and engineering design must go hand in hand and architectural features which create impossible problems for the engineering services to overcome must be firmly restrained, otherwise, we still have poorly maintained services and un-green buildings.

There should be a constant return to a fundamental simplicity in building design. There is scope for research in the integration of engineering services for better buildings. A fact finding survey of

design/maintenance in highly serviced hospitals could prove to be a valuable exercise, confirming as it would, the need for closer collaboration between designer and maintenance engineer. Research is needed to give greener buildings with better services and maintainability all are properly balanced to obtain the desired performance with minimum expense.

10. Conclusions

Modern buildings are designed to meet more complicated needs than those of previous time; improved space standards, higher environmental standards and new pattern of use of building can effect their design and construction. The natural result of these changes is higher building standards and more complicated buildings. This means that (1) increasing reliance is being placed on M&E services to provide the environment and the facilities needed, (2) there is a growing need to ensure services are available when required, operated at an expected level of efficiency, and (3) the design influence on the maintenance of all building is greater than ever before.

To get the best green building, all designers have to adopt a rational approach to the management of services design, installation and maintenance.

In conclusion, designers can greatly influence the future maintainability of our sustainable buildings. Designers should improve whole life performance through either simple or innovative design solutions. The consideration, during the procurement of built assets, of the influences of the factors discussed in this paper is a necessity.

It is hoped that this short paper will draw all project participants' attention to the importance of design for better building care.

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IMPROVING THE SUSTAINABILITY PROCESS AT THE HONG KONG SCIENCE PARK, PHASE I

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Abstract

The paper addresses the holistic sustainable design approach used for the Hong Kong Science Park phase 1. The master layout plan was prepared in 1998 with the requirement that the project be completed in three phases. Phase 1, recently completed in mid 2004, consists of one car park/utility building supporting nine innovative, adaptable buildings, connected and integrated on a reclaimed parkland site of 8 hectares facing the sea.

The paper describes the development of the design concepts in relations to the various aspects as follows :

- The setting of the project in the urban context, the environmental assessment of the site, the response to the planning and physical restrictions imposed by the site, the client needs, the use of semi basements, and elements that could be centralized including the central waste collection suction system and the service tunnel network.
- The overall design concept with the internal useable space grouped around central cores accessed through spacious atriums. Building services plant rooms are used as insulation space below the main feature roofs. Floor to ceiling height has been carefully considered and the raised floor system provides easy under floor adaptability.
- The innovative technical design of the building envelopes to maximize the use of natural daylight using insulated glass walls of different types designed to suit different locations and functions complying with the fire requirements.
- The use of photovoltaic panels for renewable energy as an integral part of the building envelopes in a variety of locations and components, façade elements, sun screens, and for roof shading on different buildings.
- The design for the interior comfort levels achieved through energy efficient systems including HVAC, lighting and management monitoring.
- The development of a glass building envelope sustainable design tool, tailor made for the Hong Kong situation with retrospective testing on one of the buildings. The results are briefly analysed to check if any improvements could have been made in the design or could still be made now, after completion.

Throughout the paper, the link between the developments of the design concepts in harmony with sustainability is made. The conclusion will reflect on the circle of future continuing improvement.

Keywords : Science Park, Building Envelops, Atriums.

1. Introduction

Hong Kong is a small country with very limited natural resources. Basically it has mountains, islands and the sea. In the past, there has been a double benefit cycle where mountains have been excavated to create flat plateaus for building and the removed soil has been used for reclamation from the sea, again forming new land. In today's projects, it is necessary to import all building materials from outside Hong Kong, therefore to become more sustainable, it is necessary for designers to focus on long life, energy efficiency, re-useable or recyclable materials, and minimizing waste.

2. Background

The Hong Kong Science Park is to be completed in 3 Phases on 22 hectares of reclaimed land at Pak Shek Kok near Shatin in the New Territories. The concept was first mentioned in the Chief Executives Commission on Innovation Report in 1998 and the first buildings in Phase 1 were opened in 2002. Phase 1 comprises of 9 buildings and 1 car park building, with roads and parkland providing 120,000 square meters of Research and Development (RD) facilities (Fig.1, Fig.2). The last buildings in Phase I

were opened in 2004, making the inception to completion period a very fast track 6 years.



Fig.1 Bird's eye view of Hong Kong Science Park, Phase 1

3. The Client Needs

The key client needs were:-

- to attract organisations to high tech modern facilities set in a park like atmosphere.
- to support small, medium and large organisations by permitting easy occupation and start up with excellent business back up.
- to provide flexible spaces and facilities, within nine separate fixed building envelopes, capable of taking different types of R&D functions and equipment.
- to create opportunities for human interaction/stimulation/innovation within the park.

4. The Urban Setting

The site was chosen for the following reasons:-

- Hong Kong always has a shortage of large flat sites. The site is on reclaimed land using public filling material from other construction sites and was becoming available at the correct time. An environmental impact study had previously been carried out and accepted for the site.
- Geographically, it is very central to the main population distribution. There are excellent road and rail links to the airport, China and the other major business districts in Hong Kong.
- The “sea in front and mountains behind”, environment is very attractive for prospective tenants and the development parameters suited the outline zoning plan designation.

5. Environmental Site Analysis

The very desirable site has green mountain views behind and sea views in front. The very busy four

lane Tolo Harbour highway and the Kowloon Canton Railway at the rear, generate noise which was taken into account in the design of the buildings. There is a good sun path, outstanding views, sea breezes and a pedestrian seaside promenade along the whole site frontage. No existing landscaping or vegetation existed. In summary, an excellent site for the project.

6. Site Constraints and Development Parameters

The site boundaries were fixed, as were the two vehicular entrance points. There is a large drainage box culvert dividing Phase 1 from the rest of the site. The development parameters of 30% site coverage, plot ratio 1:2.5 and a GFA of 120,000 square meters, dictated that the maximum site usage was required within restricted height limits. The end result is that the buildings are low rise in nature, maximum 8 storeys, but the opportunity for extensive landscaped parkland was very limited. The designers challenge was how to improve the environment.

7. Concept and Master Layout Plan

A master layout plan for the whole of the 3 phases was produced. It responded to the site analysis and environment by screening the noise from the rear, forming a feature entrance and providing vehicular and pedestrian access routes. The buildings were grouped around a large open central parkland space including a lake. Limited car parking was provided to encourage more pedestrianisation. Three specific zones, campus, core and corporate following the height restrictions of 40, 35 and 30 meters respectively, were planned to accommodate different tenant groups. This formed the basis for Phase 1.

8. Phase 1 Layout



Fig.2 Phase 1 layout

The campus buildings at the rear of the site are specially designed with glass walls to screen out noise. The Icon tower at the car park advertises the logo of the Science Park in fibre optic lighting to passers by and visitors alike. The core facilities in the centre provide the central business functions, restaurants and sense of arrival linking to the future phases. The stand alone corporate buildings on the waterfront are orientated to suite the available site sizes, therefore the design has to minimise heat gain. The Client added a late requirement for individual car parks for each of the corporate buildings therefore the necessary infrastructure and roads take up valuable landscape space. Sea views, mountain views and breezeways feature in the design layout.

9. General Shared Facilities

Due to the requirement of the buildings to be as far as possible stand alone to allow maximum flexibility, we were only able to share carpark facilities, the service tunnels and the central suction refuse system. This refuse collection system is innovative in this type of development in Hong Kong and is capable of serving the whole park in future. Sharing facilities is one aspect of sustainable design.

10. Building Design Concepts

As a result of the constraints and client requirements, it was recognised that there would be little space left for the landscape parkland. The building design concepts therefore contrived to bring the park into the buildings as far as possible. To do this, a variety of double height entrance lobbies, atriums, internal landscaped streets, bridges and external courtyards were used. These elements also helped to maximise the use of daylight within the complex whilst at the same time created interesting interactive arrival spaces and easy orientation for people visiting the complex (Fig.3).



Fig.3 Internal landscaped street of building 2

For each building, the project teams used a similar language of materials, consisting of metal insulated roofing and glass curtain wall building envelopes, to create a family of high tech buildings. For energy efficiency, the overall thermal transfer value (OTTV) needed to be less than 23W/metre square. The building structures were to be concrete due to the short fast track programme. Basement areas accommodating building service plant and car parking, are linked by a comprehensive tunnel network allowing easy maintenance and modification to pipe work without disturbing the landscape and tenants above. The overall result is that the buildings have spacious entrance areas, offices grouped around cores with views out, daylight usage is maximised and major building services plant is located at the roof level allowing ventilation, easy access for maintenance and providing additional insulation against heat gain.

A key requirement was to have an efficient floor plate of office space grouped around a central core of backup facilities, lifts, stairs, toilets, pantry stores etc. The window to core depth was to be less than 12.5 metres, as this maximises the use of daylight and is a normal tenant preference. To add to the

flexibility within the fixed envelope, a 4.5 metre floor to floor height is provided including a 200mm raised floor, a generous 2.7 metre floor to ceiling height and 1 metre allowance for building services.

The floor plan layouts were designed for easy subdivision to accommodate different tenants and are fitted out to a high quality of finish using long life materials to assist quick move in.

11. Landscape Design and Parkland Spaces

The overall landscape design aims for a subtropical parkland using species found in Hong Kong that have low maintenance and long life. Boundary planting encourages pedestrian entry at the main entrance and from the waterfront promenade. Roadside planting enhances directional flow and provides shading. Courtyards and node spaces including water features, provide immediate interest next to buildings. Roof terraces provide additional external spaces and more landscaping. The use of atriums and streets encourages the use of internal planting assisting the integration of the external and internal spaces (Fig.4). 4263 new trees have been planted in Phases 1 to add to the greening of Hong Kong.



Fig.4 Parkland view towards building 7

12. Innovative Design

The innovative technical design of the glass curtain wall envelopes is the use of a double skin on the southwest facades of some buildings. The main functions are to screen out solar gain and reduce noise whilst letting in daylight and allowing views out. The outer skin, which reduces solar gain, is made up of point fixed 19mm tempered glass with 5mm gaps on all sides supported on aluminium frames cantilevered from the main structures. There is a 1.0m space before the inner double glazed skin which normally uses a 10mm heat strengthened outer panel, a 6mm air space and a 6mm heat strengthened inner pane. The aluminium catwalk between the outer and inner skins acts as a sunscreen and is also used for access for internal cleaning and maintenance.

The chimney effect created in the void allows the warm air to rise thus reducing heat gain on the inner skin. The design required a fire engineering study approach to obtain Building Code approval. Heat gain is reduced by 1.56w/meter square and the anticipated energy consumption is reduced by about 7.5%. The noise levels are reduced by 6 to 7 decibels.

Integrated Photovoltaic panels have been used in different ways as sunscreens, on the outer skin of the double façade as sunshading, as a part of the spandrel panel of the elevation, on canopies and for roof shading elements (Fig.5). Currently the power generated is fed back into the grid or used for lighting. The integration ensures that the photovoltaic panels are serving double functions, therefore they become much more cost effective and therefore sustainable. The total amount of renewable energy is estimated at 260kW.

It is predicted that no other buildings will be built in the future which may block the solar path for the Science Park, therefore the panels will always be in use. It is also a fact that when integrated in the design, unlike traditional building services plant, no additional space is required for the equipment for the energy source. This is a useful sustainable design point.

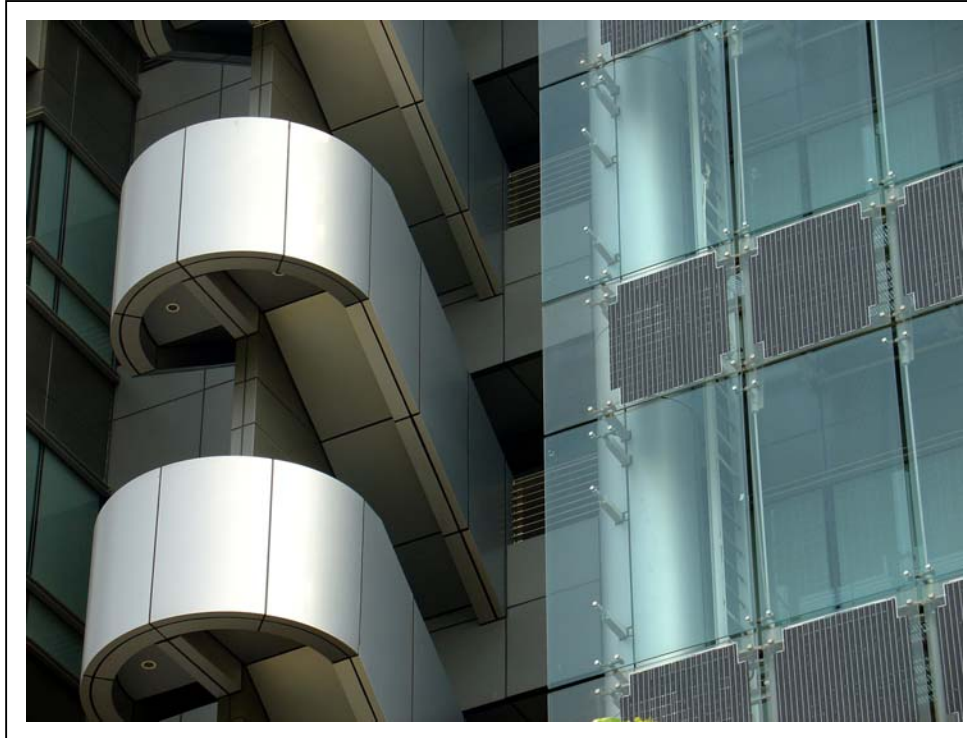


Fig.5 Double skin with integrated photovoltaic panels building 5

13. Interior Comfort and Energy Efficiency

With the building envelope design reducing heat gain, the building services are designed to the most up to date requirements to minimise the consumption of energy and water thus reducing recurrent costs. The maximum use of daylight is used and occupancy sensors automatically control or dim artificial lighting as required (Fig.6). Energy saving lamps are used with electronic ballasts. Zone lighting is on progressive reduction and fibre optic external lighting gives high impact visual effect with efficient recurrent costs.

The air-conditioning system creates indoor air quality designed to best practice with successive filtering techniques. Evaporative cooling is used as in Hong Kong this has about 20% lower running costs than other systems. Chillers have heat reclaim wheels to preheat the hot water supply and thermal wheels reduce humidity and recovery energy from exhaust air from air conditioned spaces. Zones in offices are subdivided using VAV's and variable frequency drives. All fan discharges are fitted with silencers. Exhaust emissions from kitchens are treated with electrostatic participation.

Saving in water usage is through use of bleeding water from the cooling tower being reused for flushing water in toilets. Electronic automatic sensors are used for controlling water flow for hand

washing and flushing in toilets. There is an automatic sensor which reduces water output after rainfall for the irrigation system for the landscape areas.

The Centrally Central Controlled Building Services Management System uses computer adjustments and scheduling for energy efficiency. Infrared sensors are used on escalators to minimise usage in quiet periods. The buildings are designed with very high IT backbone capability with the flexibility include through the raised floor system and spare vertical duct space. The intention was to allow for the paperless office in future, another sustainable design target.

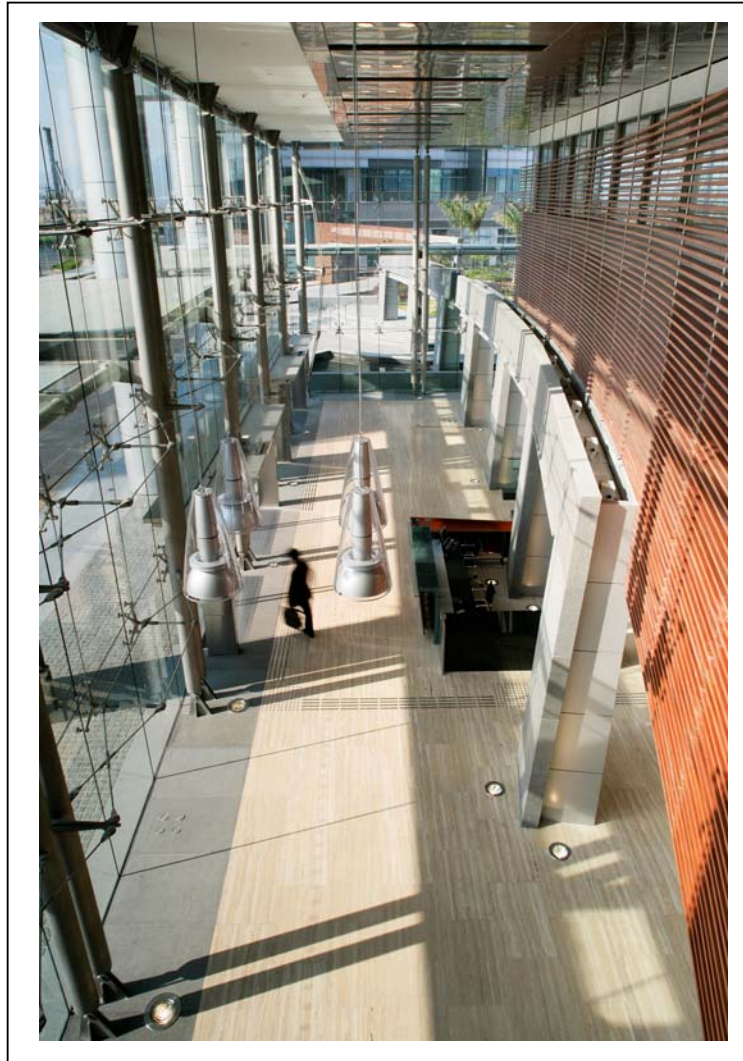


Fig.6 Use of daylight and integration of external and internal space

The central suction refuse collection system allows separation of waste paper from other waste through a double pipe system. It reduces odour and due to the compacting system, reduces waste and minimises the removal of the waste containers, thus saving vehicle trips. The reduction in waste also reduces the amount required to be taken to landfills.

All buildings have been submitted for a performance assessment grading under the established Hong Kong Beam System and they have achieved the highest rating "Excellent".

14. Materials and Construction

Because of the need to import materials and achieve a quality building, prefabrication and long life materials were chosen. Prefabricated concrete floor slabs, staircases and other elements were used in the structure. Metal roofs were supported by structural steel. Curtain wall and interior wall claddings were all prefabricated. The use of a 1.5m modular system reduced waste and minimised cutting of materials. Timber was not used in large quantities but was from sustainable sources. Road pavers had 70% glass content. Paints had low VOC content and environmentally friendly carpets were used.

15. Glass Building Facade Rating

The Department developed with the assistance of Ove Arup Partners Hong Kong Ltd, a sustainable design assessment tool for glass building facades. The main objective was to be able at the design stage to quickly compare the performance from broad sustainable energy efficient criteria. Some sample assumptions were made i.e. façade being open, (full heat gain) high rise location and the building using VAV HVAC system. The tool provides an analysis of the following:-

- Thermal Energy – predicts annual cooling and heating load with impact of external/internal shading and ventilation.
- Thermal Comfort – investigates outcomes of comfort conditions by different glazing systems.
- Energy Saving and Glare – tests the response of facades to different daylighting situation using simulation.
- Others – embodied energy, acoustic expectation and life cycle cost.

The fast rating requires only simple input from its pull-down menu on room properties (orientation, façade width & floor height), window properties and glazing details for full curtain wall systems. A test study on Building 9 demonstrates the results (Table 1). A summary report of North East Elevation generated from the system indicates that ratings in the elevation generally support the Hong Kong Beam Assessment.

Table 1. Facade rating for North East Elevation of Science Park Building 9

Summary Report of Fast Rating Results				Results Evaluation			
Title of Rating	SP9 NE						
Description	Test only						
User Name	TUM/4/23						
Date	11						
INPUT AREA	Variable(Unit)	Input Value	OUTPUT AREA (Per m ² of Façade Area)	Variable(Unit)	Estimated Range	Approximate value	Rating
Room Properties							
Orientation	(-)	NE	Annual Energy Consumption				
Façade Width	W _f (m)	1.50	Total Estimated Annual Energy Use (with daylight linking)		TEAE (kWh/m ²)	130	Good
Floor/Ceiling Height	H _c (m)	4.50	Overall Thermal Transfer Value				
Window to Wall Ratio	WWR (%)	66.67	Overall Thermal Transfer Value		OTTV (W/m ²)	18	Excellent
Window Properties							
Height	H _w (m)	3.00	Thermal / Visual / Acoustic Comfort				
Width	W _w (m)	1.50	External Visible Light Reflectance		VLR (%)	12	Good
Shading Coefficient	SC (-)	0.37	Thermal Comfort				
U value of Glazing Unit	U (W/m ² ·K)	0.37	with blind in summer		PPD (%)	PPD < 20	Rs 12 Excellent
Visible Light Transmittance	VL _T (%)	25	without blind in summer		PPD (%)	PPD < 20	Rs 11 Excellent
External Visual Reflectance	VL _R (%)	12	with blind in winter		PPD (%)	PPD < 20	Rs 10 Excellent
Number of panes	(-)	2	without blind in winter		PPD (%)	PPD < 20	Rs 11 Excellent
			Acoustic Comfort				
			Cellular Offices		PBU (%)	58 < PBU < 78	Rs 56 Average
			Open Plan Offices				Acceptable
External Shading Device							
Type of Shading Device	(-)	Façade	Embodied Energy				
Offset	(-)	1.30	Estimated Embodied Energy		EE (kWh/m ²)	EE > 1150	Rs 5124 Average
Lightshelf	(-)	No	Life Cycle Cost				
Type of Structure	(-)	No vented cavity	Estimated Initial Rate of Return		IRR (%)	0 < IRR < 20	Rs 10 Average
Type of Airflow through Cavity	(-)	N/A	(Compare to fully glazing glass system with metal frame)				
Solar PV as Façade Element							
Position of Solar PV Cells	(-)	0	Solar PV Energy Output				
Solar PV Material	(-)	0	Annual average Daily Output		(kWh/m ² ·day)	0	FALSE
Daylight Linking							
Daylight Linking	(-)	Yes	OUTPUT AREA (Per m² of Floor Area)		Variable(Unit)	Estimated Range	Approximate value
Glazing Acoustics							
Total Number of Panes	(-)	2	Total Estimated Mechanical Energy Use		ME (kWh/m ²)	163	
Pane mode	(-)	2 pane system	lighting		(kWh/m ²)	42	
Noise Exposure Category for Site	(-)	Low (65 dBL _{Aeq})	Made up of				
Glazing Type	(-)	Double glazed unit	equipment		(kWh/m ²)	67	
			HVAC		(kWh/m ²)	60	
			Total Energy Saved from Daylight Linking		DE (kWh/m ²)	-17	
			Total Estimated Annual Energy Use (with daylight linking)		TEAE (kWh/m ²)	146	Good

16. Conclusions

In the urban setting, the buildings are appropriate in scale and height, however the master plan layout once approved was very restrictive. Perhaps if the number of buildings could have been reduced or the heights increased slightly to reduce the site coverage, a reduction of hard paved areas and more parkland might have been created. The difficulty however was the phased opening requirements and different tenant types. The envelopes and building services exceed current local standards and provide quality finishes and good comfort levels. With a longer design time, more studies on the elevation treatments may have resulted in slightly lower future operational costs. On balance, the technical solutions do provide quality, sustainable buildings for the future. The Department and project teams were very proud to have been able to improve the sustainability process in Hong Kong on this unusual fast track programme.



Fig.7 Night view of courtyard and buildings

Acknowledgements

The author wish to thanks the Government of the Hong Kong SAR, the Hong Kong Science and Technology Parks Corporation and Simon Kwan and Associates Hong Kong Ltd.

ADELAIDE AND URBAN SUSTAINABILITY

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Abstract

Nearly 50% of the world's population lives in an urban setting and in many developed countries this proportion exceeds 80%. Modern towns and cities provide the setting for improved employment prospects, better housing and increased health care. However, the construction, operation, and renewal of the urban environment draw heavily on natural resources and there is increasing concern about the 'environmental footprints' of urban settlements. In a modern city large amounts of energy are consumed in operating private and public transport, maintaining comfortable conditions in buildings and constructing and maintaining the urban form. There are certain disadvantages to this reliance on an uninterrupted and increasing supply of energy. These include excessive financial costs, diminishing stocks of certain fossil fuels and environmental impacts from the use of these fuels. Increasingly, the question of sustainability is being considered as part of the urban planning process and this involves, in part, reducing our dependence on energy derived from fossil fuels. In order that energy consumption can be minimised, it is first necessary to understand the total energy usage of towns and cities. This paper explores some of the environmental and social aspects of the current dependence on fossil fuels. It uses the city of Adelaide as an example to highlight these issues and documents recent developments aimed at improving sustainable urban living. As part of this review, recent research work is described which suggests ways in which progress may be made in minimising the environmental impact of urban developments. Conclusions are drawn about the often-conflicting environmental, social and economic requirements of sustainability and about the importance of a multi-disciplinary approach to meeting the challenges of future development.

Keywords : Sustainable urban environments, Energy consumption, Adelaide city.

1. Introduction

Governments and councils of many towns and cities around the world are grappling with the concept of sustainability and attempting to find ways of applying sustainability principles. These attempts commonly have a focus on reducing energy and water consumption and waste production. The South Australian capital of Adelaide is a low density city with high energy and water demands. The challenges facing the city have been described in a number of recent studies and, in response, the South Australian Government and Adelaide City Council have introduced programs as part of a 'Green City' initiative aimed at reducing the demands which the city places on its environmental resources (Girardet, 2003). This paper uses the example of Adelaide to illustrate some important elements of contemporary programs to make cities more sustainable, focusing in particular on programs aimed at modifying energy consumption. Urban settlements depend on a constant supply of energy, but a number of recent initiatives have sought to reduce the energy required to operate buildings and infrastructure and the energy required for transport.

2. Background

It was the photographic images of the world taken by the Apollo space missions in the late 1960s that have been tentatively linked (Hajer, 1995) to a revised view of the global environment. These images showed the Earth in its entirety and isolation, suggesting a dependence of humankind on the well being of the planet to support life. Twenty years later, these revised views were articulated by the World Commission on Environment and Development in the publication 'Our Common Future' (WCED, 1987), also known as the Brundtland report. This publication popularised the concepts of sustainability and intergenerational equity. Sustainable development was defined as:

...development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Since then, there have been numerous definitions of sustainability embracing environmental, sociological and economic perspectives. The inter-relationship of these three elements of sustainability is not established or agreed and research continues to establish what it means to plan for more sustainable cities and societies (Mawhinney, 2002).

In developed countries, which have a disproportionate effect on the global environment in terms of resource usage and waste production, over 80% of the population lives in towns and cities. Hence, the construction and operation of the urban environment is central to the concern for sustainability. The Australian Model Code for Residential Development (AMCORD) has defined a sustainable urban environment (Department of Housing & Regional Planning, 1995) as:

...one in which there is a balance between what the community needs, and what it can afford and sustain, and the long term preservation of the environment.

The process of achieving improved environmental sustainability in the operation of cities requires identifying relevant indicators, setting benchmarks for performance and monitoring changes to ensure that progress is being made. There is a range of relevant environmental indicators which are commonly used, including materials consumption, energy usage, greenhouse gas emissions, water consumption, solid waste production, land and marine pollution, loss of biodiversity and habitat and degree of materials recycling. Energy and water consumption are considered to be key performance indicators in measuring the sustainability of Australian cities (Newton, 2002). Energy consumption is important as it is linked with the usage of diminishing fossil fuels and production of greenhouse gases.

In terms of industrial sectors, energy consumption in Australia is shown in Fig.1. Over two thirds of total annual energy consumption is accounted for by the transport and manufacturing sectors, with the combined residential, commercial and construction sectors amounting to nearly one fifth of the total energy consumption. It is often argued that the high proportion of Australia's energy consumed by the transport sector is related to the nature of Australia's settlement system – its widely separated and low-density cities, in particular. Just as transport energy and urban form are related, so a proportion of the manufacturing sector's energy is used in the manufacture of construction materials, contributing to the total energy input to the urban environment. About 94% of energy consumed in Australia is from non-renewable sources of fossil fuels i.e. coal, oil and gas.

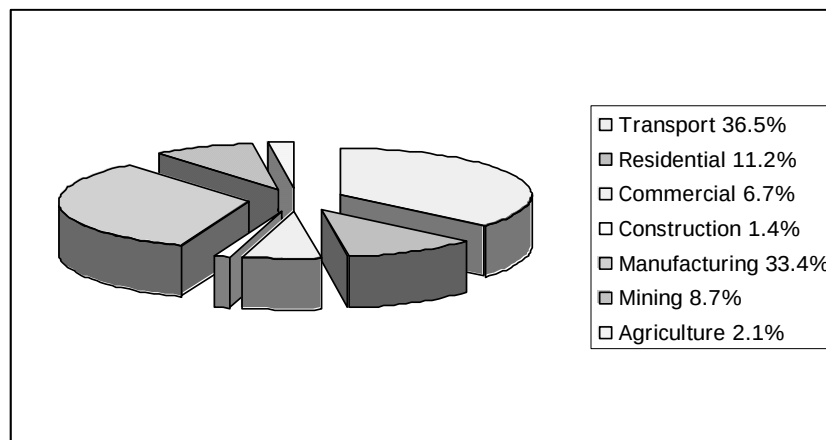


Fig.1 Energy consumption projections for industrial sectors in Australia for 2003-2004 (source of data: Bush et al, 1999)

3. Overview of energy dependency

Uninterrupted energy supplies are essential to modern cities, enabling the built form and transportation systems to operate and ultimately giving rise to improved employment prospects, better housing and

increased health care. However, there are some disadvantages to this reliance on a constant provision of fossil fuel based energy supplies. These include unnecessary financial penalties, the effect of supply disruptions, environmental impacts and possible health effects on urban dwellers.

3.1 Financial penalties.

Unnecessary financial penalties arise from two issues. The first is the cost of excessively high tariffs for energy supplies due to inefficient generation and distribution. The second is the inefficient use of the energy supplies once they have been purchased by customers. Both result in higher costs to industry, commerce and the community and loss of competitiveness in the marketplace.

To increase the choice of supplier, lower energy costs and increase the services offered by suppliers, many governments have deregulated the electricity generation and distribution markets over the last decade. In Australia, the Commonwealth and State Energy Ministers (known as the Ministerial Council on Energy) are proposing to extend this model to form a National Energy Market (Anderson, 2003) with a new national energy regulator which will have jurisdiction over both the electricity and gas markets. The ability of deregulation to reduce electricity prices in Australia has been complicated by some lack of interconnectivity between capital cities (EUAA, 2001) and increasing peak demand during hot summer weather. There are also continuing debates of an ideological nature about the extent to which governments should intervene in the energy market.

Extra costs arising from the inefficient use of energy have not been sufficiently severe in Australia to significantly improve energy efficiency in many sectors of the economy over the last 20 years (Tedesco and Thorpe, 2003). Over this period, the adoption of energy efficiency measures has been slow (Pears, 2002). A task of the Ministerial Council on Energy is to develop a National Framework for Energy Efficiency with the purpose of unlocking the significant economic potential associated with increased implementation of energy efficient technologies (Energy Efficiency and Greenhouse Working Group, 2003).

3.2 Supply disruptions.

The interruption of energy supplies can occur at an international, national and local level. Western economies are particularly susceptible to disruptions in the supply of crude oil as evidenced by the oil embargoes of the 1970s due to conflict in the Middle East and Iran (Mather and Chapman, 1995). Significant local disruptions to power supplies, common in less developed countries, also occur in cities of the developed world due to accidents, unusual weather conditions or major breakdowns – Montreal, for example (BBC, 1998) and Auckland (CNN, 1998).

In Australia, the hot summer conditions cause sharp peaks in electricity demand, well in excess of normal requirements, and there is a risk that this demand can exceed the supply capacity. These peak loads have been rising steadily over recent years as expectations of thermal comfort increase in both the workplace and the home. As an example, the summer maximum demand for South Australia in 1990/91 was approximately 1900MW, in 2000/01 it was 2800MW and it is predicted to increase by an average annual rise of 2½% to about 3500MW in 2010/11 (ESIPC, 2003). Clearly, a sustainable approach to managing future demand to avoid supply disruption is necessary and will involve a range of measures including energy efficiency in buildings, collective demand side response by consumers and different pricing policies.

3.3 Environmental Impacts.

The environmental impacts of energy consumption in towns and cities include adverse extraction effects, diminution of energy resources and the emission of greenhouse gases and their effect on global climate. Extraction of terrestrial based fossil fuels can result in land degradation, loss of biodiversity and disruption of water courses. Higher profile impacts arise from accidents involving the marine extraction and transportation of crude oil.

Reserves of crude oil are now considered to be over 1000 billion barrels (EIA, 2004) which is greater than the reserves identified in the 1970s despite the consumption in the intervening period. Current

concerns are less about the imminent exhaustion of oil supplies, therefore, and more about adjusting to the loss of a cheap and abundant supply.

A difficult problem for policy-makers associated with energy consumption is to unscramble the nature of the relationship between greenhouse gas emissions, global warming and climate change. As result of the consumption of fossil fuels and other mechanisms, an enhanced greenhouse effect is occurring which is described as radiative forcing and is believed to have given rise to an increase in the earth's surface temperature of 0.6 ± 0.2 deg C in the twentieth century. Apart from an increase in the earth's surface temperature, it is likely that there has been a reduction in snow cover of 10% since the late 1960s, a melting of non-polar glaciers over the last century and a reduction in the thickness of Arctic sea ice in late summer and early autumn over recent decades. During the twentieth century, it is claimed that the global average sea level rose between 100 and 200 mm (IPCC, 2001).

4. Transport Challenges

Over 80 per cent of journeys made each day for all purposes in South Australia are made by car. This percentage is higher than it was in the 1980s. The proportion of trips made by walking and cycling has fallen over the same period. Some major metropolitan roads are nearing capacity and are congested during peak periods, with resultant increases in levels of air pollution. However, public transport carries only about 5 per cent of total passenger travel on weekdays and can not offer a real alternative to the car for many people in the short-term.

Australia has high levels of per capita greenhouse gas emissions with the transport sector accounting for 16.1% of Australia's total emissions in 1999. To date, the Australian government has declined to ratify the Kyoto Protocol, the international treaty designed to limit global greenhouse gas emissions. In addition to greenhouse gas emissions and air pollution, increased reliance on motor vehicles also causes noise pollution and can lead to a decline in water quality, as well as having negative consequences for areas of conservation or biodiversity significance.

Current planning and transport strategies for Adelaide are based on the belief that more compact cities are likely to be more sustainable cities. At present Adelaide is a sprawling city extending nearly 100 kilometres from north to south. As urban areas sprawl, the cost to government of servicing these areas increases, travel distances increase and the reliance and dependence on the private motor car increases. Adelaide in recent years has seen a relative shift in projected population growth from the northern and southern fringes of the metropolitan region, to more concentrated growth within the inner suburbs. However, growth continues to place pressure on the urban fringes and this is further exacerbated by falling household sizes, leading to fewer people living in each dwelling. These smaller households reflect, in part, the ageing of South Australia's population. Current projections for 2051 indicate that, by then, South Australia will have a very significant proportion of older people in its population.

There is increasing evidence also that physical inactivity has increased as society has become more car dependent and this has led to a range of health problems, including rising rates of obesity and heart disease. In particular, the phenomenon of urban sprawl and necessity for outer suburb dwellers to use motor cars for most activities has prompted Frumkin (2002) to ask the question:

What approaches to urban planning, design and construction are most likely to reduce air pollution, reduce urban heat, encourage physical activity, reduce automobile morbidity and mortality, and promote mental health and a sense of community?

In South Australia, physical inactivity is now the most prevalent risk factor for heart disease. There are substantial health benefits to be derived from incorporating walking and cycling into daily routine. Concerns at the negative effects of car dependence and desire to reduce dependence on fossil fuels come together in a number of policies designed to bring about a shift towards more sustainable modes of travel.

5. Progress

5.1 Buildings and Infrastructure.

In May 2002, the South Australian government launched the Energy Efficiency Action Plan aimed at reducing energy consumed by government agencies. Within this plan is a commitment to reduce building energy use by 15% below 2000/01 levels by 2010. In the 2002/2003 period, government energy use in buildings was down by 2.4% and 9 out of 10 portfolios reported reductions.

At the beginning of 2003, the South Australian Housing Code was updated to include the new requirements of the Building Code of Australia with respect to energy efficiency of new houses and extensions to existing houses (Allan et al, 2003). Regulations relating to the energy efficiency of commercial buildings are currently being developed and will be enacted in the near future.

In the meantime, the 'Building Tune Ups' program is currently running, having started at the end of 2003. This is a joint initiative between the South Australian government and the Adelaide City Council as part of the Green City Program. Ten large office buildings have been selected for improvement in their energy and water consumption. All of the buildings are located in the central business district, three are occupied by government departments and seven are privately owned. Over the 18 month program, the energy efficiency of all the buildings will be improved by 'one star' of the Australian Building Greenhouse Rating (ABGR) scheme. A one star improvement corresponds to a reduction of greenhouse gas emissions of approximately 30 kgCO₂/m²/annum. The purpose of the scheme is to show that best practice in energy (and also water) efficiency can be cost effective and to encourage other building owners to follow suit.

A further initiative under the Green City Program is the BASEline project, the purpose of which is to promote energy efficiency in small businesses such as retail outlets, hotels and workshops. The first phase of this project has just been completed and the preliminary results from the energy auditing of 19 businesses show the potential to reduce energy use by an average of 10% with a payback of 3.3 years.

The State government is encouraging the use of abundant solar energy by means of the South Australian Solar Hot Water Heater Rebate Scheme which provides up to \$700 for residents who purchase and install a new solar hot water system or retrofit kit for domestic purposes. Cash rebates are also available to assist in the purchase of photovoltaic systems for generating electricity for the sun. The Photovoltaic Rebate Program is funded by the Commonwealth Government and South Australia has one of the highest per capita uptakes of the scheme (Rossetto, 2004).



Fig.2 Starfish Hill wind turbines, near Cape Jervis, Fleurieu Peninsula, South Australia

The Strategic Plan for South Australia was launched at the beginning of 2004 (SA Govt, 2004) and makes commitments to reducing energy consumption in Government buildings by 25% within 10 years and to leading the nation in solar power and wind generation in the same period. The proportion of the State's power generation capacity that is powered by renewable resources has increased from 0.1% in 1998 to approximately 4.6% when the wind farms that have been approved over the last two years are completed (Nicolson et al, 2003). Cape Jervis is the site of the first wind farm of 34.5MW capacity and

known as Starfish Hill (Fig.2). Other developments include the commissioning by Origin Energy of a manufacturing plant for Silver Cell solar panels in Adelaide in early 2005 and the exploration of geothermal energy from underground hot dry rock (HDR) technology in outback South Australia. The State Strategic plan aims to increase the proportion of electricity generated by renewables to 15% within 10 years.

The hub of the broader Adelaide metropolitan area which is administered by the Adelaide City Council has its own sustainability targets within the Green City Program. The city aims to be greenhouse emission neutral in the building sector, emitting zero net greenhouse gases, by 2012 and in transport by 2020.

All of the initiatives described are aimed at reducing costs or reducing greenhouse gas emissions or both. In an attempt to map total energy consumption in the Adelaide metropolitan area, a pilot research project was undertaken at the end of 2002 (Troy et al, 2003). The purpose of this project was to depict total energy consumption in a spatial manner so that informed decisions could be made about minimising energy consumption and greenhouse gas emissions in the development and operation of the built environment in the future. The project attempted to capture all forms of energy consumption, that is transport energy of vehicles, operational energy of buildings and embodied energy of the materials forming the buildings and infrastructure, in six selected areas using currently available datasets. It was demonstrated that the mapping of energy was feasible and could be used to compare different styles of development such as dense inner city residences with outer suburban low density housing. The advantage of this type of analysis is that it considers energy consumption from a life cycle perspective. Fig.3 shows the annual energy consumption of one area known as Hindmarsh. The segments of the chart relating to buildings, roads, water supply, sewers and vehicles are the embodied energy of those parts of the urban environment expressed as a per annum energy expenditure i.e. total embodied energy of the component divided by the expected life. The segments for electricity, gas and transport refer to annual energy expended in operating the built environment. The chart provides a useful perspective on total energy to construct and operate an area of a city which can be considered when evaluating alternative planning policies. This work is continuing so that the method can be refined and is also being extended to other Australian cities.

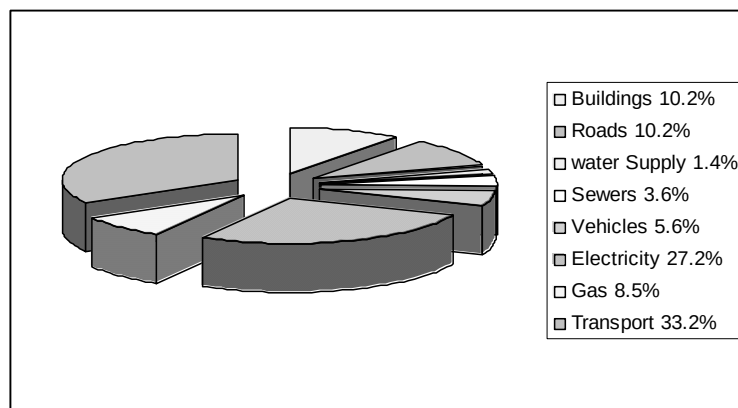


Fig.3 Distribution of annualised total energy consumption in case study area.

A very recent initiative by the Australian federal government (AAP, 2004) has selected Adelaide and Sydney to trial solar suburbs that would use solar power equipment to put unused power back into state power grids. An amount of \$75 million has been allocated to equip new and existing homes with solar generation technologies.

5.2 Transport.

Providing people with better information about their travel choices has the potential to reduce the dominance of the car. School-based education programs are receiving particular emphasis at present to try to counteract the growing trend for children to be driven to and from school, rather than walking or cycling as they did in earlier times. 'Green Travel Plans' form another strand in the effort to change

travel behaviour. These are plans developed in conjunction with employers to help staff get to work and conduct business travel in a more sustainable way. They can include organising car sharing or 'pooling' or practical steps such as providing better facilities for cyclists once they reach their place of employment.

As well as changing people's behaviour, there are also technological possibilities. The technology for more fuel efficient cars is available. While this technology is not yet in the mainstream, there are now some cars which use considerably less fuel per kilometre travelled than others. Tighter Australian Design Standards for vehicles have been introduced in recent decades and have resulted in a substantial improvement in the efficiency of new cars and trucks sold in Australia. All new cars sold from 2006 will need to meet current European emission standards and trucks will need to meet stricter emission standards that are to be implemented in Europe from 2005. New technologies such as fuel cells offer the opportunity for even more substantial reductions in emissions and energy consumption.

Labelling of the fuel consumption of cars is being introduced in Australia. This will enable people to make more informed decisions when purchasing cars. The government is a major purchaser of cars in South Australia and is in a position, therefore, to influence innovation through its purchase of vehicles which are designed to meet best-practice environmental standards and take the lead with hybrid and electrically-powered cars. Traffic signal technology is also becoming more sophisticated and has the potential to reduce energy consumption and pollution by smoothing traffic flows.

At present, 29% of the public transport bus fleet in Adelaide uses natural gas for fuel. This is amongst the highest percentage of any Australian city. It is planned that over the next 15 years public transport will become carbon neutral. This is to be achieved primarily by increasing the share of the public transport bus fleet that uses greener fuels such as natural gas and bio-diesel; trialling innovative technologies such as dual-fuel buses (using diesel engines to generate electricity) and fuel cells. It is also intended to plant more trees to absorb any residual carbon dioxide output from the public transport fleet.

The provision of better information to motorists was referred to earlier in relation to enabling them to make considered travel choices. Information about the *cost* of motoring can be especially influential. At present, motorists do not accurately estimate the actual cost of motoring when they make their travel decisions. This occurs in part because fixed charges such as registration and insurance fees do not vary with the amount of use made of the road system. The government intends to provide information that better informs the community about the cost of transport. Some argue that they actually need to go further and to make motoring more expensive through, for example, higher car-parking charges, especially in the Adelaide city centre. The State Strategic Plan sets a target of doubling the use of public transport to 10% of weekday travel by 2018.

There is also a spatial planning strategy which translates the government's social, economic and environmental priorities into spatial terms. This spatial planning strategy brings together state government policy for guiding and co-ordinating land uses and development, construction and the provision of services and infrastructure. It indicates directions for future development to the community, the private sector and local government. A central theme of the latest version of this spatial planning strategy is the integration of transport and land use planning. This involves shaping the pattern of development and influencing the location, scale, density, design and mix of land uses with the intention of reducing the need for motorised travel; reducing the *distance* that people need to travel; and providing a choice of travel modes, especially walking and cycling. These ideas are widely accepted now in Australia and were recently enshrined in a 'National Charter of Integrated Land Use and Transport Planning' (2003).

6. Discussion

The concept of sustainability has been taken up in Adelaide somewhat later than in some other capital cities but the extent of change required is possibly greater, necessitating more innovation and modification of attitudes and behaviour. A large number of initiatives have been undertaken at federal, state and local government level in a relatively short time and there is a need for close monitoring of programs to ensure the desired effects are achieved.

Many of the solutions to sustainability problems can be modeled on experience from elsewhere in the world but there are factors peculiar to climate and locality which require special consideration. For instance, the trend towards higher density housing to minimize travel can have additional benefits in a cold climate arising from lower heating demands. This is because the close proximity of dwellings and the sharing of boundary walls and floors creates a mutual insulation effect. In a hot climate, there is a risk that higher density housing can create a higher cooling energy demand. This is because the shift in design from single storey to two storeys often necessitates the installation of full air conditioning to create comfortable sleeping conditions in first floor bedrooms in hot weather.

There will be some reluctance to accept changes which may be seen to be counter to the current advantages of the South Australian life style. For instance, many migrants from more densely populated countries value the uncrowded environment, large housing lots and open spaces for leisure and more dense housing may not be welcome. The trend towards fully air conditioned houses may be difficult to reverse, particularly as houses with passive heating and cooling features require management and participation by occupants to vary ventilation levels and adjust shading devices. The relatively low rate of population growth in Adelaide also means that pressure for urban redevelopment is not as intense as in other cities and change to the urban fabric occurs only slowly.

In terms of transport, there is the challenge of making smaller cars as acceptable as the current large engined sedans and of encouraging a significant proportion of the traveling public to give up their cars and use public transport, cycling or walking for journeys to work.

The transition from being heavily dependent on fossil fuels for the operation of buildings and infrastructure to the situation where there is a mix which includes substantial renewable energy input will require a range of instruments. Education plays an important part in explaining the need for this transition but will need to be used in conjunction with economic levers, such as increases in the price of energy, and some government regulation.

7. Conclusions

The dependence of modern urban living on a constant supply of fossil fuel based energy sources is undesirable from a number of commercial, practical, environmental and medical perspectives. Responding to this challenge, many governments are taking initiatives to make the construction, operation and maintenance of modern towns and cities more sustainable. The city of Adelaide is no exception and is currently attempting to bring about significant and relatively rapid changes in electricity generation, energy efficiency and a variety of other sustainable practices.

Modification of the behaviour and attitudes of urban dwellers is necessary for this transition to occur. Education, price signals, government leadership and regulation all have their part to play in the modification of travel behaviour and in the modification of the existing building stock to improve energy efficiency in heating and cooling.

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STRATEGY FOR PROMOTING SUSTAINABLE DEVELOPMENT IN TAINAN COUNTY, TAIWAN

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Abstract

Many renowned international and regional organizations have placed sustainable development as the highest tenet. Regional governments have played critical roles on implementing the task to promote sustainable development commitments and action schemes. In accordance to the executive mechanism of cooperation between regional governments and private organizations stated in the 28th article of UN's Agenda 21, this study took Tainan County in Taiwan as an illustrative example for proposing a strategy planning process for promoting regional sustainable development. The visions of sustainable development of Tainan County, its strategic analysis, the establishment of strategy elements, detailed action programs, the sustainable indicators for feedback evaluation and the participation mechanism will be presented and discussed in the paper.

Keywords : Sustainable development, Regional government, Strategy planning, Sustainable indicator, Participation.

1. Introduction

The quality of the environment has rapidly deteriorated, and abnormal changes of global climate are taking place around the world. To solve these environmental problems, a summit meeting was held by some developed countries, to formulate measures to save the environment. The outcome of this summit was the establishment of the "Rio Declaration" issued at Rio of Brazil in 1992. The topic of Agenda 21 was discussed in the meeting and the concept of sustainable development be given a greater consideration in any action plan. The schedule of undertakings was submitted, and the "Sustainable Development Committee" was established to take charge in promoting and implementing the Agenda 21 in various countries. The commitment towards a "sustainable development" has gradually become the world consensus. The plans related to sustainable development have been promoted internationally and many renowned international and regional organizations have placed "sustainable development" as the highest priority.

Without exception, Taiwan also established a "global environmental changes task force" in 1992 and it was upgraded in 1994 as the "Executive Yuan policy guide panel of environment changes". The guide panel as expanded to be the "National Sustainable Development Committee, Executive Yuan" in 1997 and reshuffled

in 2002 to have the Executive Premier as the convener. At the same time, taking into account the local environment and the economic development attributes, the committee includes eight task sections to accomplish the "Agenda 21 – the sustainable development strategy of Taiwan". Major implementation strategy was brought up with four visions of sustainable development in Taiwan consisting of sustainable ecology, satisfactory living environment, safe society and liberalized economy.

Regional governments have played critical roles on implementing the task to promote sustainable development commitment and action scheme. The subsequent transition and adjustment strategy for the government, including reviews and modifications of relevant laws, organization changes, new systems and flowcharts shall be set up to concretely achieve sustainable development.

2. Research Method

The executives in the cooperation between regional governments and private organizations as in the 28th article of UN's Agenda 21, had agreed to take Tainan County in Taiwan to illustrate the proposed strategy planning process for promoting regional sustainable development.

Works in this process are described as follows.

- (1) Establish a partnership with experts, academics and regional private groups to form the executive organization (sustainable development committee).
- (2) Seminars and forums were held to exchange and compile opinions from the county government and the public and thus establish the sustainable development vision for Tainan County.
- (3) Strategy analysis inclusive of internal and external factors that are likely to have great impact on the future of the Tainan County, were carried out. The results from these analyses formed the strategies for Tainan County's sustainable development.
- (4) Action programs, which represent the major actions, required to carry out the strategy and then accomplishing the vision.
- (5) Review the results through the participation mechanism proposed in 3.4 and sustainable indicators proposed in 3.5, and feedback to examine the elements of strategy.

3. Results and Discussions

3.1 Vision

Tainan County located in the center of Chia-Nan Plain, has forest mountains in the east, deep ocean in the west and broad plain and farming land. This county is located in the south of the Tropic of Cancer, with subtropical climate all year round. Since its ancient times, agriculture had been their people's livelihood. Nevertheless, the development of traditional farm villages could not survive by the rampage of the industrial and commercial development. Therefore, Tainan County government has themed the concept of sustainable development in recent years and encouraged the public to participate. It is envisaged that the plan to preserve the county's natural features and striving forward for technology, culture, tourism and industry. In the hope that it will become a green silicon island in the future. The following are the visions of a sustainable development aimed at by the Tainan County government:

- (1) A good place for cultural development and nature
- (2) To highlight the development of technology frontline and new vision civilization
- (3) To brace for the paragon of new life civilization.
- (4) As a role model for a green silicon island.

3.2 Strategy Analysis

In terms of “natural ecology”, six major issues are as follows:

- (1) The exploitation and destruction of forest ecology
- (2) The dysfunction of hydraulic resources, such as reservoirs, ditches and rivers
- (3) Diminishing of biological habitants
- (4) Desolation of vast coastal salt pan
- (5) Wet lands are vanishing and being destroyed
- (6) Coastal ecology is under development pressure

With respect to “environmental protection of daily life”, seven crucial issues and their counter strategies have been proposed.

- (1) Emission and pollution of industry's waste water
- (2) Sewage discharge system has not met the requirements
- (3) Insufficient water resources with inefficient utilization
- (4) Crowded and ruined living environment
- (5) Daily environment protection and sustainable ecological concept are not effectively promoted
- (6) Level of environment protection and restoration approach is not sustainable
- (7) Depletion of historic culture and traditional festivals

In the aspect of the “green industry”, six major issues and their counter strategies have been submitted.

- (1) Traditional industry is fading away
- (2) Agriculture products have not met the standard for environment sustainability and human's health
- (3) Tourism has not achieved the standard for sustainable environment
- (4) Gap and misunderstanding between producers and consumers
- (5) Development bottleneck encountered by medium and small enterprises, and the decline of competitiveness
- (6) Competitiveness decline of traditional agriculture and fishery products

Regarding “green construction”, the major issues and their counter strategies have been submitted.

- (1) Construction of transportation, river bank revetments, dikes and bridges do not meet the standard for ecological sustainability
- (2) Construction materials do not conform to the requirement of ecological sustainability
- (3) Too much resource and energy consumption
- (4) Withering of old buildings and the large idle space left from the traditional industry
- (5) Various buildings do not confirm to the local climate attributes
- (6) Deterioration of traditional historic streets/zones/villages

3.3 Action Programs

With the survey made through relevant academics, experts, and members of sustainable development committee by “open-end experts/academics questionnaire”, the results of the action programs with high priority are described as below.

- (1) A campaign to encourage the public to plant trees
- (2) To apply ecological engineering on public construction projects
- (3) Sustainable construction of the sanitary sewer
- (4) Originality design of public space and green embellishment
- (5) Green construction of the public building
- (6) Resource recycling for solid wastes
- (7) Develop the sustainable communities from the sustainable campuses

3.4 Participation Mechanism

The operation methodologies for promoting sustainable development and establishing the participation mechanism of private groups are proposed as shown in Fig.1.

- (1) Concept promotion
- (2) Experience sharing
- (3) Mutual exchanges
- (4) Implementation
- (5) To think of the domestic generation perpetuity at any time and any place.
- (6) To establish the database of participating partners, continue interactions, sustain on-line indicator, update periodically, follow up with evaluation and assessment for the sustainable strategy and action programs and assure the source of law.

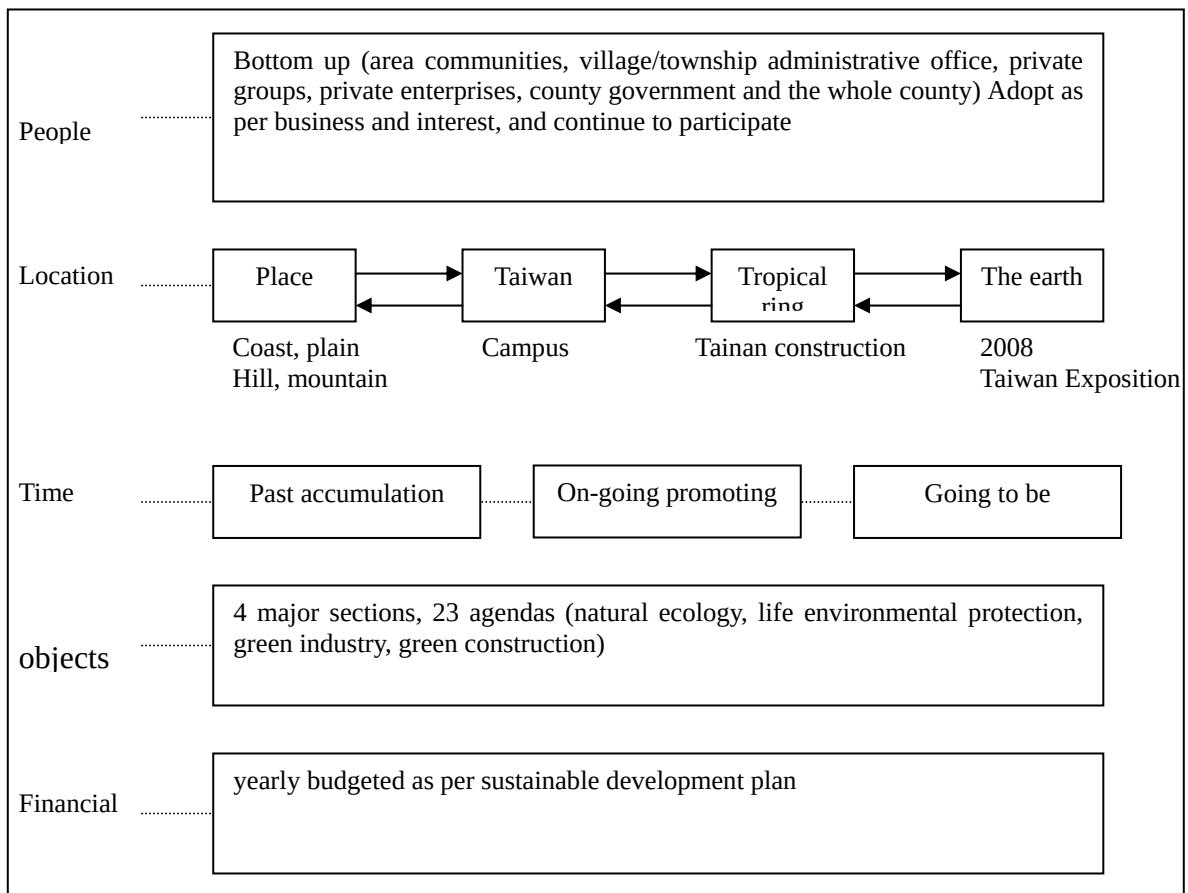


Fig.1 Participation mechanism of promoting sustainable development in Tainan County

3.5 Sustainable Indicators

The sustainable measurement system of Tainan County is based on the "sustainable Taiwan measurement system" and took reference of United Nation's Agenda 21 to bring out the status of regional sustainable development and the international sustainable development indicator. According to Tainan's ecology, economic development and environmental attributes, the measurement system will be modified to make it adapt to the development vision, so as to establish a regional sustainable measurement system as the reference for policy assessment.

Design of measurement system in accordance with local environment, objective, representation and feasibility. Therefore, Tainan County has conducted many seminars, international forums and symposiums, to conclude four major strategic issues namely, natural ecology, environmental protection in daily life, green industry and green construction.

Both the indicator of for Taiwan sustainable development released by Executive Yuan in Taiwan [4] and the four strategic issues (refer to 3.2 Strategy Analysis) will be used as the reference, to develop the sustainable indicators Tainan County's sustainable development. The result are shown in Table 1.

Table 1 Measurement indicator of Tainan county's sustainable development

Aspects	Indicator
Environment pollution	1.The volume of factory waste not being well-handled (tons)
	2.Qualification rate of drinking water (%)
Ecological resources	1.Ratio of road(river) section implementing ecological engineering
	2. Number of black-faced spoonbills
	3.Length of roads where trees are planted on both sides (m)
	4.Ratio of green area of Taisugar and Taisalt (%)
	5.Ratio of eco-flood detention pools among reservoirs and ditches
Society sector	1.Daily water consumption per person (m ³ /person)
	2.Daily electricity consumption per person (kw/person)
	3.Crude divorce rate and single parent rate (%)
	4.Density of motor vehicles (%)
	5.Average life span
Economy sector	1.Annual output of the piggery industry (head)
	2.Unit production of orchard (NT\$/km ²)
	3.Idle rate of plants in the industrial zone (%)
System sector	1.The number of buildings with green building mark
	2.Organic agricultural accreditation
	3.Development quantity of sustainable teaching materials
	4.Number of activities related to sustainable seminars and number of their participants.
	5. Number of legitimate home-stays in Tainan County
	6.Number of spots to receive recycling waste

4. Conclusions

Taiwan officially unveiled the era of “the first year of sustainable development” in 2003 and signed up the declaration of Taiwan's sustainable development to fulfill the vision of a green silicon island. The “regional sustainable development plan” for 11 counties was passed in December 2003 and the process of carrying out the task for sustainable development will be a direct issue for those counties. The strength required for achieving sustainable development can only be achieved through the partnership of the central government, regional government, private sectors, academics, business enterprises, and the public.

Acknowledgements

The author with to Acknowledge the Tainan county government and Archilife Research Foundation for their assistance.

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THE INITIATIVE FOR SUSTAINABLE LIVING –A TRANSDISCIPLINARY APPROACH TO SUSTAINABLE DEVELOPMENT

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Abstract

A range of academic institutions world-wide would now nominate sustainability as a specific area of research and educational interest. To date, however, many of these activities have focused on bringing together existing activities, perhaps with insufficient attention to where the sustainability agenda is going across industry and the wider community. This paper discusses the vision and objectives of the 'Initiative for Sustainable Living' launched by the Queensland University of Technology, Brisbane. The Initiative, which will be developed into an Institute in 2005, will engage the whole of that University in a collaborative framework to deliver sustainable development solutions. This is to be achieved through research partnerships, experiential learning and transdisciplinary education.

The issues and opportunities in bringing together diverse professional disciplines, skill sets and approaches are discussed.

Keywords : Research collaboration, Sustainable development, Sustainable living, Transdisciplinary scholarship, Triple bottom line.

1. Introduction

Schumpeter (1950) observed that a common characteristic of growing economies, knowledge development and innovation was the continual challenge and break down of existing approaches and the rebuilding, from those, of new methodologies and structures that better address changing demands. He called the process "creative destruction".

Schumpeter could never have imagined the contemporary environment of rapid and compounding change, nor exponential increases in knowledge. Similarly, he could not have envisaged the enablers now available to collect and apply that knowledge.

We may want to use Schumpeter's rather dramatic terminology or wish to consider contemporary changes in terms of evolutionary processes. In any case, the underlying parameters are the same. Any institution or structure - government, firm, university or, indeed, an entire community, now exists in an environment where change is continuous and profoundly non-linear.

Sustainability, in its broadest context, provides us with the classic example of this environment. It is a pervasive and contentious issue and yet, even though the disciplines of built environment and science have long addressed its components, its characteristics are being redefined. Nobody would suggest that the way forward, or even the limits of the debate, is settled.

In the midst of this debate are research institutions and universities. Like others involved - governments, industry sectors, businesses and communities - they have a reasonable understanding of the sorts of issues

that are involved. They are, however, still formulating their individual and collective responses and are attempting to find a position where they are value adding, relevant and recognized now and into the future. This paper provides some update into the sustainability debate and the role of research institutions and universities in addressing its component parts. It draws examples from the current situation in Australia. As with the entire debate, however, these examples must be seen not simply in a local context, nor indeed focused on single disciplines. Such approaches would represent the antithesis of the entire sustainability agenda – that it has global dimensions and that it will only be solved with transdisciplinary, holistic solutions. By way of example, the paper describes a proposal, the Sustainable Living Institute, that is being developed at the Queensland University of Technology in Brisbane, which that University believes is a unique, focused response by a University responding to the demands and concerns of its community and stakeholders.

2. In the Macro

The sustainability debate remains eclectic. There is debate even to the extent and seriousness of the problems involved, let alone their solutions.

It is also an area that is full of contradictions. On the face of it, a considerable advantage here is that the issue is so well recognized across the whole of the community – from heads of government through to individuals and their households. Ironically, however, that can also be seen as a detriment. Whilst the issues are indeed complex and multifaceted, the community-wide interest remains at a very superficial level, often not advancing far past the perfunctory recycling of waste etc.

Governments within this environment have been successful in responding in a similarly superficial way. It is interesting to note, for example, that, in state elections in Australia in 2004 and in the federal election in November of that year, sustainability issues were not rigorously pursued and even environmental issues were isolated (in the case of the federal election, logging of old growth forests in Tasmania).

Emerging sustainability issues were identified in such landmark documents as the Brundtland report (WECD, 1987). Industry, however, has overall been slow to respond to these new challenges. This is despite the evidence that there are a number of issues that need immediate attention. Oil provides a case in point. Campbell (1998) reports that the present production of oil worldwide will fall from 27 billion barrels in 1998 to 13 billion barrels by the year 2030. In 2003, the number of major oil field discoveries has fallen to zero (BBC, 2004).

Another associated issue is the widespread deterioration of transportation systems in practically all urban areas with the incumbent waste of energy and human resources, and adverse effects on pollution and lifestyle. Highway statistics (1994) in USA point out that in one state alone (Minnesota), the residents drive about 43.3 billion miles per year, enough for about 465 trips to the sun! Our travel distances continue to grow by 2% per year, a growth trend that is supported by the continued provision of new roadway capacity. The social cost associated with all this amounts to about 1.6 trillion per year in the US alone (Deluchi, 1996). Emissions from transportation now contribute about 75% of all greenhouse gas emissions in developing countries (UNCHS, 2001) with reductions in sunlight penetration up to 5.3% (Chameides et al., 1999). This has the most profound and immediate effect on flora, but the flow-on effects on animal and human communities are obvious (Tickle et al., 1995).

It would be reasonable to think that, with such ominous signs, business and government would focus on addressing obvious causes. There is only limited evidence of this in Australia. Prompted by shareholder activity and in some cases, by corporate positioning, large corporates are increasingly reporting on a Triple Bottom Line (TBL) basis or, at least, are providing some level of environmental reporting. Deegan (1999) identifies that within Australia there are organizations such as Shell, WMC, RGC Ltd, Rio Tinto, BHP Ltd and Body Shop which collect data on financial, environmental and social aspects and present them publicly. For example Placer Pacific's Ltd's 1998 document 'Taking on the Challenge' states: 'We need to adopt sustainability, not at an added extra, but as a core aspect of our business strategy' and Shell's report 'Profits or Principles- Does there have to be a choice?' reflects the departure from the traditional approach

that only focuses on economical reporting. Whilst these are positive trends, TBL reporting in Australia is still in its infancy as only 11% of the Australian top 500 companies produce any type of environmental reporting. This is compared to an average of 23% of the top companies in other OECD countries and 45% of the Global Fortune Top 250 companies (Minister for Environment and Heritage, 2003).

Australia, like most other countries, has an economy based on small to medium firms (SMEs). Half of all businesses have 20 employees or less (ABS, 2001). For those, viability – keeping the order book full, month to month – is the overarching priority and they normally lack the scale, capital, time and methodologies to address sustainability issues in any cohesive way.

Further, for the communities, firms and governments (particularly at local levels) that wish to pursue a sustainability agenda, the way forward is anything but clear and one cannot be too critical of such organizations being reluctant to strongly commit to a sustainability path where the political and / or financial risk and opportunities are not well defined or understood.

Unfortunately, because of the unsettled and immature nature of the debate, the whole agenda can often become distracted and, indeed, de-railed. Clear examples of this exist in the sustainability initiatives of the federal government in Australia. In the first instance, the policies sometimes confuse sustainability with environmental issues. Whilst they are obviously complementary and, in areas, overlap, they are not the same thing and much of the sustainability debate is not currently included in the national agenda at all.

The generalized geographic and demographic characteristics of Australia belie serious long-term sustainability issues. Whilst population densities over the entire nation are amongst the lowest in the world, about two persons per square kilometre, the fact of the matter is that 61% (ABS, 2001) of the population live in five major cities. In those cities, population densities, growth management and the provision of infrastructure are as critical to sustainability as practically anywhere else in the world. Nevertheless, for over 20 years, the federal government has had no definitive policy as regards urban growth and the support of cities, leaving it instead to the under-resourced state and local government systems. This is despite the indisputable fact that these matters are of national importance and, in Australia, are at the heart of sustainability.

The debate in Australia has also been distracted by infighting between federal and state governments' (which are of different political ideologies) and the Commonwealth Government's near obsessive defence of its decision not to sign the Kyoto Protocol on Global Warming. There are indeed sound (though of course debatable) arguments for Australia not being willing to sign that protocol. Australia's overall physical impact is small by comparison, its infrastructure is based on cheap and available fossil fuels and this cannot change quickly over time, and thirdly, much of its energy usage is embedded in materials, particularly light metals, which are exported overseas. Kyoto aside, the point here is that the federal government has, for some years, been distracted from really addressing other sustainability issues which are equally pressing and where Australia can have considerable impact.

In considering these issues in an overall sense, we need to recognize that the major challenges still lie ahead. In capitalist societies, the primacy of self-interest rightfully dominates. Our responses to sustainability issues to date have been often small-scale and certainly have not challenged in any serious way, costs nor benefits to the current generation. The recycling of waste, for example, has practically no cost for the individual and we achieve some level of satisfaction from it. Likewise, our efforts in energy management normally have quite short payback periods and provide us with recurrent savings. Therefore, we would be financially imprudent not to pursue them. These initiatives, however, are relatively small-scale compared with the efforts and costs that will be required to secure sustainability into the future.

As energy prices and infrastructure costs rise, communities and individuals may soon find that they will have to change existing behaviours and benefits. Further levels of capital investment in projects may have to be increased, certainly beyond normal commercial horizons, so that sustainability will be secured for future generations. This is a paradigm shift from the existing 'micro' approaches and challenges the

primacy of self-interest. As we all know, upfront cost (in whatever form) and deferred benefits will never be politically or financially palatable unless based on very robust arguments and innovative solutions.

3. A Changing Debate and Changing Solutions

Sustainability has in the past been addressed as a physical concept –largely about the built environment and resource and natural sciences. That will remain the mainstream into the future. However, sustainability is not the exclusive domains of those disciplines. As communities evolve and mature, issues of social capital, human resources, governance, ethics, education and communication become overlays and linkages across that physical environment.

Based on research over the last decade, we can produce sustainable development and sustainable buildings. It goes without saying that more research is always necessary to refine and better adapt these but perhaps the debate here has moved on. The key questions increasingly relate to what can be afforded by owners, occupants and communities and what are they willing to pay in the short, medium and long term to secure those sustainable environments.

The lesser known areas in sustainability relate to the human and community dimensions – how we encourage the changes in behaviours and of social organization and governance to ensure that sustainability is not only “designed in” and accepted in the built environment but is continued and advanced over time. As the issues of energy costs, availability of services, convenience and socio-economic dichotomies become more obvious, governments and businesses will increasingly focus on these aspects of sustainability and that trend has already begun.

They will also look to logical, innovative and politically acceptable solutions to compensate for the disturbance and changes that must inevitably occur as part of development and growth. Environmental banking and transferable rights offer real opportunities here.

Finally, we should not be too pessimistic and have faith in the human ability to research, problem solve and be innovative in the face of new challenges.

Perhaps parallels – and, to some degree, comfort – can be drawn from the manner in which the internet and e-commerce debates developed over the last decade. One will remember that, in their early years, ICT systems were expensive and clumsy, protocols almost non-existent and there was real potential that the whole advent of e-commerce would collapse existing systems, regulation, intellectual property and taxation. In the intervening period, we have seen these systems quickly become manageable – not that all problems have been solved or that new problems don't emerge - far from it. However, from what seemed to be chaos, a platform was created that has produced arguably the most effective enabler for business that has ever been created. We can hope for a similar future path for sustainability – both in regulation and practice. As the problems become more obvious in sustainability over the next decade, we can anticipate that, as with ICT, agreed protocols and methodologies for addressing the issues will emerge.

To begin this process, some clarification of our starting point and approach is called for – though the difficulty and risk of that is recognized!

We put forward a definition of “sustainability”: “the strategies, methodologies and activities that optimize current function and use of physical, economic, human and community resources, whilst ensuring that options for, and the use of, those resources into the future are not prejudiced or compromised and, where practical, are enhanced.”

Flowing from that is the overall belief that each generation should be considered as a user, custodian and potential enhancer of humanity's common natural, generic and cultural heritage and must therefore leave for future generations at least the same opportunities that it enjoyed (WECD, 1987). There is a balance in all of this, however, and, particularly as regards the introduction of legislation, regulation or other attempts

to modify behaviour, it must be recognized that today's individuals, businesses and communities are part of the continuum that we call society and, as such, have legitimate rights and expectations also.

Lowe (quoting Meadow) notes: 'If the present growth in the world resource depletion continues unchanged, the limits to growth on this planet will be reached some times with in the next hundred years'. Whilst this is a matter for obvious concern, Lowe believes the situation is recoverable and not beyond control. "It is possible to alter these growth trends and to establish a condition of ecological and economic stability that is sustainable into the future, designed so the basic material needs of each person on earth are satisfied." (Lowe, 2002).

In the past, engineers and other built environment professionals have carried the responsibility to respond to these demands. However, the problems to be addressed now and into the future require engineering and "built" solutions that also fully respond to social, community and political challenges, not just function and efficiency.

There is a need to consider an integrated way, the wider economic and environmental implications for our decisions and actions within Australia, the international community and the biosphere: and we need to take long term rather than short term view when making decisions (COAG, 1992). There is now a real need for sustainability leadership in government, industry and academia. The community is ready for it and will increasingly demand it of us.

4. Queensland University of Technology- Case Study

The balance of this paper describes the philosophy, strategy and operations of a particular initiative in sustainable living (ISL) at the Queensland University of Technology (QUT) in Brisbane, Australia. This initiative has been under development for about one and a half years and will soon to become one of four Institutes within the University.

As discussed above, sustainability implies a new, broader set of criteria in contemporary decision making. In particular, it requires a wider view of the transformation of resources into goods and services that meet human needs and wants (Hodge et al, 1999).

QUT's Sustainable Living Initiative acknowledges this reality and has been working hard to the move 'up and out' from the University's existing strengths. It is particularly keen to develop research links with other institutes within Australia and overseas.

There is no suggestion here that the model being developed and applied is suitable for all situations – of course that is not the case and even at QUT the model continues to evolve. However, it does represent a conscious effort by the University in the area of sustainability (broadly defined) to better structure its research, education and learning activities to better align with the contemporary environment and with the demands of its stakeholders.

QUT is one of the largest universities in Australia and the second-largest in Queensland, with about 4,000 staff and about 40,000 undergraduate and postgraduate students. It is a city University, proud of its "real world" approach and strong links with industry in applied research and problem solving. It has nine faculties with particular strength in Built Environment and Engineering, Science, Law, Business and the Humanities.

It is important here to place ISL in a strategic context in the University. Two years ago, the University announced what it called a Blueprint – a summary strategic plan committing itself to new arrangements with its stakeholders in the public and private sectors and to re-aligning its research, teaching and learning activities to contemporary demands.

It then looked for areas in which to concentrate its efforts – the criteria used being existing strengths, competencies and networks; areas of growing demand; and market / niche opportunities.

Four such areas to be developed into Institutes were identified. One was in sustainability.

That choice was not without risk. Whilst it was an area of developing interest across government, the private sector and the wider community, it was also well populated with research and other related organisations – approximately 60 of them across Australia. On investigation, however, it became evident that most of these were highly specialised organisations, often dealing with one esoteric area of the entire topic. There appeared to be nobody who could offer the more holistic solutions that government, business and the community now sought.

In this environment, clear points of differentiation were essential. For QUT and its Institute, these became:

- focusing on the public and private development sectors;
- leading with foundation strengths of built environment and science, but now integrating these with human sciences, law, IT and education;
- developing some new enabling skills – in this case, the integrated use of IT for sustainability modeling and in decision-making processes;
- developing an outcome-focused framework through research partnerships with large-scale private and public organizations that would not only service domestic demand but also be applicable into the Asia Pacific region;
- developing a culture that was not overly reliant on grant funding into the future; and
- developing a true transdisciplinary and learning organization that, in combination with other international institutions as necessary, provided full solutions to real world problems.

On the face of it, there may seem to be some contradiction between the concepts of “holistic solutions” and “focus”. In fact, there is no contradiction – in areas where QUT has significant expertise (such as subtropical design, regional development or natural resource management), the University will now provide a more comprehensive response. Certainly, in each project, this will be led by a particular discipline (be it design, engineering, natural resource science or whatever). However, using the Institute as a vehicle, that response will also include the components of law, human sciences and whatever other disciplines are needed, not just in a token manner but to ensure innovative, comprehensive solutions.

The Institute is being developed with a small core of academic, teaching and business leaders who could act as the interface between the University and its external clients. They will also be the translator, coach, coordinator and facilitator of major initiatives in sustainability within the University. As major initiatives are identified in this area, they will be properly established and project managed, drawing required resources from across the nine faculties. Management is through a committee of Deans with an Industry Advisory Committee also established to advise on direction and priorities.

Education programs are also being revised and upgraded with electives and later postgraduate programs being developed on a cross-faculty basis. Experiential learning with outplacements will be encouraged. To assist lecturing staff, the Institute will develop subject modules and case studies, so ensuring the highest content quality.

Certainly, support from the executive of the University has been essential as was the level of trust and confidence through the management of the various faculties. It soon became obvious to all that opportunities did exist out there and that they could only now be secured by collaborative and transdisciplinary activities. Several early successes exemplified the approach.

To date at QUT, the key areas / themes from which such expertise has been drawn have been Sustainable Buildings and Built Environment, Natural Resource Management, Industrial Ecology, Cultural and Social Landscapes, Urban Forms and Structures and Resource Use, Re-use and Conservation.

Importantly, too, the University had a stated objective and clear performance indicators on the need to increase total levels of research and consequently Deans, other executives across faculties and individual researchers were very open to the opportunities of transdisciplinary activities to secure more long-term projects.

Perhaps most important and interesting has been the reaction of individual researchers. Research management requires a special relationship with individual researchers. They need to be attracted, stimulated and held by the nature of the research. In the case of sustainability, this was a comparatively easy task as all recognised the growing interest and concentration of effort into the area. The transdisciplinary nature – to learn from other disciplines as well as their own – was also attractive to many.

The model used in the Institute gives all within the University a level of confidence that the hard negotiations with the external public and private sector partners are normally well advanced by the Institute itself, and the individual researchers from within the University recognise that the Institute provides a trusted and predictable working environment with good levels of continuity.

Again, it has been our experience that a lot of time can be wasted in establishing abstract protocols and working relationships, revenue sharing models etc between faculties. It is much more important to get some significant, current and truly transdisciplinary projects secured and educational programs initiated. These provide practical examples of the new, interesting and innovative activities that could not have otherwise been secured. One does not have to convert the whole of a university to these new operations. What is needed, however, is overt support from the highest levels of the University, combined with the strong commitment of a relatively small number of opinion leaders and decision makers across the faculties involved.

Though all of this is in its early days, the good news is that it appears to work. It would be our observation that research partners have been very comfortable engaging through a single, high-level point of contact which is committed to delivery of a timely, quality product. The response has, in fact, been so strong that real issues emerge in the prioritisation of the research partnership opportunities. We particularly seek those which are larger scale, longer term and in line with QUT's particular expertise.

Finally here, QUT recognises its role in research input and leadership as the public debate into sustainability advances and gains more clarity and focus. A university brings with it a level of credibility that can truly assist in stripping away the build-up of media generalisations and misinformation that has occurred over some years. It can act to replace that with factual data and logical, innovative and realistic options for the future.

In the high-growth South East Queensland region in which QUT is located, a major draft Regional Development Plan has recently been released by the State Government. QUT has had significant input into the development of this plan and intends to take a major role in its further development and implementation.

In a similar "public domain" area, QUT and this Institute observe that, for all the discussion about sustainability, it is still very difficult to truly define what constitutes a sustainable region, what are its component parts, how do governments, firms, communities and individuals move towards that, and how do we measure success. To increase its profile and contribution, the Institute intends to pursue research in these areas over the next 12 months. Clearly, its work on IT modelling will be very relevant to all of this.

5. Conclusions

Shriberg (2002) notes that, in order to get to the true bottom line of sustainability, institutions - be they government, corporate or research - do require a natural, social and economic balance sheet.' Through its proposed Institute for Sustainable Living, QUT believes that, in its own way and from its core expertise, it can significantly contribute to such a broad balance sheet approach.

This can never be achieved on a faculty-by-faculty basis. New environments demand new solutions and that is true of research institutions as well as business and government. There is no suggestion here that a transdisciplinary institute model would be suitable for all research organizations. What we can report here, however, is that, provided that such an Institute remains as a small, leadership and coordinating body that effectively links the University with its stakeholders, then it does hold promise to become a model in sustainability and potentially into other areas of research interest.

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SUSTAINABILITY OF THE BUILT ENVIRONMENT: A TEACHING PERSPECTIVE

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ABSTRACT

As a result of the Rio conference of 1992, the School of Architecture Construction and Planning at Curtin University, Western Australia adopted, as one of its values in the strategic plan of 1994, a commitment to engender environmental responsibility in students and integrate responsible sustainability principles and practice in all courses. The implementation of this commitment translated into a unit of study, Ecologically Sustainable Design (ESD), in the second semester of the first year architecture program. This was not intended as a design unit, in spite of the nomenclature, but rather an introduction to general topics of sustainability such as environmental biology, embodied energy of construction materials, operational energy in buildings and waste management. Over time, in the development of this unit of study, it has become apparent that two aspects of study need to be addressed. Firstly, students' philosophical and personal involvement is necessary for the principles and application of sustainable thinking to become an integral part of their design practice and secondly, the unit needs to be perceived as directly relevant in the teaching of architecture. Factual data and predictions of impending disaster are not enough to sustain a student's interest and commitment. In this context the teaching of ESD now seeks greater student direct involvement and action through projects. One project involves tree planting. Students are required to calculate their annual carbon dioxide emissions using a web-based measurement tool and then plant sufficient trees to compensate for one year of their carbon dioxide emissions. Another project explores waste recycling. Students are required to examine the life cycle of a material used in construction and make an object from water material found on construction sites. This paper, while tracing the evolution of teaching ESD at Curtin University, this paper describes the current initiatives towards 'action' projects together with the expected outcomes.

Keywords : Architecture, Education, Ecologically sustainable design, Action project.

1. Introduction

In 1992 Curtin University of Technology (CUT) established the Curtin Environment Committee. This Committee was charged with the responsibility for coordinating activities that would enhance CUT's reputation in the field of environmental management (CUT, 1993). Very broad terms of reference were adopted for that Committee. These terms of reference included recommending action related to environmental issues on campus as well as encouraging greater environmental awareness in the wider community and in Curtin's teaching and research programs. In 1994, one of the values explicitly expressed by CUT was a commitment to promote ethical practice, social justice and environmental responsibility (CUT, 1994). In support of the values expressed by CUT in the 1990s, the School of Architecture, Construction and Planning established, in 1997, an undergraduate unit entitled Ecologically Sustainable Design (ESD) to support an objective of the School's Strategic Plan "*to extend the School's commitment to ecologically sustainable design and integrate environmentally responsible principles and practice in all courses*" (ACP, 1994). Although the word 'design' was included in the title, ESD was intended to provide students with a broad introduction to general topics of sustainability.

ESD is compulsory for all first year students studying architecture. However there has been no explicit policy decision nor any systematic progress towards incorporating sustainability matters in the teaching of architectural design, the major stream in the course. Consequently a significant proportion of the actual design projects produced by architecture students during their five years of study pay little or no attention to the question of sustainability of the built environment.

A number of reasons may have contributed to the lack of integration of the ideas of sustainability into the general curricula in the architectural course. One reason may be the lack of commitment by CUT to the sustainability agenda. Symptomatic of this lack of commitment was the removal in 2000 to a reference to sustainability in the CUT vision, mission and values statement (CUT, 2003). Another reason may be the lack of commitment to the sustainability agenda by those teaching in the Department of Architecture. A third reason may be the difficulty of engaging with the breadth of topics introduced in the unit ESD. The introduced topics include environmental biology, embodied energy of construction materials, operational energy in buildings and waste management. Although each of the topics is identified as having a relationship with built environment decision-making there is difficulty in imaging design solutions for the problems raised. This paper does not explore the broad questions related to the attitude of CUT to the sustainability agenda that may reflect the conflict between sustainable behaviour and the traditional infrastructure of tertiary institutions as discussed by Martin (2000). Nor does it analyse the motives behind the low commitment to the sustainability agenda by the Department. Rather it focuses on the environmental issues raised in the unit ESD in the architecture course with particular consideration given to recent moves towards 'action' projects, their expected outcomes and ideas for the future. 'Action' projects in this context refer to projects involving students in both a physical activity as well as analysis of the activity.

2. Teaching and Learning about Sustainability

2.1 A Philosophical Position

In order to discuss ESD and overcome the multiple ways of understanding the term sustainability, the ideas of John Passmore, a highly regarded Australian philosopher, are introduced. Passmore (1974) postulates that to effectively respond to the natural world, man must explore the notion of what can be done to conserve the natural environment and how this fits in to the paradigm of relative thinking, as opposed to pure science. In this regard he establishes the meaning of 'ecological problem' in order to find a common language to discuss potential solutions. He refers to an ecological problem as being a social problem, arising from man's dealing with nature, that society would be better off without but not "*an inevitable consequence of an otherwise desirable state of affairs*" (p.44). In other words ecological problems are perceived as alterable consequences of what is good in a particular society. They are social problems that can be managed in ways to reduce their severity. This particular view of an ecological problem provides a rational approach for examining the impact of building construction on the environment.

2.2 Structure of the Teaching Program

Using the idea of a social problem as presented by Passmore (1974), the unit ESD introduces a number of areas related to building design and construction where there are significant undesirable consequences of socially desirable activities that could be managed in a more sustainable manner. The objective of the unit is to provide students with some understanding of the complexities that the design and construction professions must deal with to contain some of the irreversible damage caused by human settlement.

Weekly lectures cover such areas as the ecological impact of land clearing, embodied energy of building materials, energy and water consumption in the occupation of buildings and waste production in construction of buildings. The lecture series examines the topics beyond the strict discipline of architecture. For example environmental biologists are invited to discuss the subject of land clearing and land degradation. Extending beyond the strict discipline of architecture in ESD should not be considered unusual as it is recognized (Leal Filho, 2000) that matters related to sustainability do not fit neatly into one particular discipline.

In addition to the lecture program, a series of tutorials have typically sought to engage students in research and discussion. These tutorials appear to provide the greatest opportunity for students to develop a personal commitment to the practice of sustainability in design.

2.3 Tutorials

When ESD was first developed the tutorials involved students carrying out research in a chosen area of study, provided the area in some way connected sustainability to architecture and construction. Consequently topics ranged from an analysis of the pros and cons of nuclear energy to an exploration of native plants suitable for residential landscapes in the local climate. The students were required to make both an oral presentation to their colleagues and to submit a fully referenced paper on the topic. This tutorial plan was abandoned after a number of years for two main reasons. The first was that student feedback indicated that students did not see the relevance of the theoretical research to their study of architecture. Secondly the oral presentations proved to be very time consuming as a result of a significant increase in student numbers in the architecture course.

A different rationale for tutorials was developed to try to make use of CUT's expanding web-based teaching potential. CUT have adopted WebCT, a software package that can be adapted to teach entirely on-line or to complement a class-room based course. With sustainability in mind the idea was that students could participate in tutorials on-line via WebCT. Greenhouse gas emissions could be reduced as students would not need to drive to CUT for just one tutorial session, they could reduce the use of paper by submitting work on-line and they could participate in tutorials at times to suit their personal schedules, particularly as approximately 70% of students have part-time employment while studying. Tutorials were set up as private chat rooms for each tutorial group with a tutor monitoring the discussion and contributing as necessary, particularly with information related to sourcing reference material. Students were required to make a minimum number of postings that both introduced new referenced material and responded to material posted by other students. Discussion topics were set for different weeks of the course, starting with students assessing their own ecological footprint. Other discussion topics included the profligate use of energy and water in the industrialized world, particularly in relation to building construction and building occupation and the life cycle of construction materials. Students were assessed on the quality of their discussions on-line and on an electronically submitted paper relating to the life cycle of one building material including the material's potential for reuse and recycling.

When students taking tutorials on-line were surveyed at the end of the semester, approximately half the students found that tutorials on-line were a useful medium for learning but the other half commented that it was alienating and difficult to become involved with the subject matter. Tutorial staff also were burdened with an extremely time consuming process. A pragmatic decision was made to reintroduce face-to face tutorials, albeit with an amended set of goals. WebCT became exclusively a repository for lecture material, communication between staff and students and a means of providing feedback on student assignments.

2.4 Action Project

In mid-2004 one of the authors of this paper attended an international conference entitled Environmental Management for Sustainable Universities (EMSU 2004) where some 40 papers were presented related to teaching and learning to create environmentally aware citizens. The conference papers and informal discussions highlighted the need for an innovative approach for engaging students with ideas of sustainability. At the EMSU conference many speakers recognized that students needed encouragement to accept multi-disciplinary inputs so they could start to understand sustainability as an issue outside a particular discipline. Further, some form of personal experience with an environmental issue appeared to provide a successful mode of teaching. For example one conference paper described the development of a multi-disciplinary perspective for both law students and non-law students taking a course related to environmental law (Connolly, 2004). Importantly, that course included an 'advocacy in action' component where students were required to attend some environmental advocacy event outside the university and submit an essay describing their experience and reflecting on the event. Another paper described the recent approach towards environmental education promoted by the Centre for Environmental Education in India. That approach recognized that it was not just the information transfer that was important. Equally important was student involvement as active partners in practical, hands-on activities (Boojh, 2004).

In the light of the experiences reflected at EMSU 2004, tutorials in the ESD unit were reconsidered. The tutorials were developed around two assignment topics.

The first assignment topic required students to examine their patterns of consumption, calculate their current ecological footprint and predict their children's ecological footprint. An explanation of how they had determined the input data for themselves and for their children was required. Students were then required to calculate their annual carbon dioxide emissions using an on-line measurement tool such as that developed by Men of the Trees (www.carbonneutral.com.au). They were also required to consider practical ways of neutralizing the negative impact of their carbon dioxide emissions. A multi-disciplinary approach to action was then introduced through cooperation with a local authority's environmental program.

The local authority that manages the area adjoining the university campus is required to maintain public land much of which has been degraded through careless public use, invasion of weeds and neglect. As the local authority has very limited resources for this land maintenance, a program was developed whereby the local authority would provide trees for students to plant in degraded areas and supervise the planting. The local authority would also provide experts to discuss the impact of building development on local land degradation and the benefits of maintaining local flora and fauna. After the planting students were required to submit a paper reflecting on how the activity of tree planting and land restoration would help the environment and how their actions as future participants in the construction industry could contribute to minimizing land degradation.

The second assignment topic revolved around the idea of '*muda*' which is Japanese for 'waste', 'futility' or 'purposelessness' as defined by Taiichi Ohno, the developer of the Toyota Production System (Hawkins, Lovins & Lovins 1999, pp.125-143). There were two parts to this topic. One part required students to carry out a basic examination of the life cycle of one traditionally used construction material and discuss how or if that material was currently being recycled or what they could imagine as possible scenarios for recycling in the future. The other part involved making an object from found waste material that made a statement about the natural environment under stress. Two of the made objects are shown below in Fig. 1.



Fig.1 Objects from found waste: Left side – 'Strangling the planet through domination', Right side – 'Man-made flowers only'

3. Student Feed Back

After the conclusion of the first assignment a student survey was carried out asking 6 questions as shown in Table 1. Forty-one students (66% of the students enrolled in the unit) responded to the survey.

Table 1. Survey questions for students after completing Assignment 1

Where 1 = strongly disagree and 5 = strongly agree	
You learned something you consider valuable when involved in tree planting	1 2 3 4 5
You are more aware of the environmental consequences of your actions since considering your ecological footprint	1 2 3 4 5
Your interest in sustainability has increased as a consequence of this unit	1 2 3 4 5
You now feel confident in discussing the idea of ecological footprint with friends	1 2 3 4 5
You feel more empowered to effect the sustainability of our environment than before taking this unit	1 2 3 4 5
You believe that TAKING ACTION is as important as CONSIDERING PRINCIPLES when studying issues of environmental sustainability	1 2 3 4 5

The results of the survey showed that a majority of students (61%) agreed or strongly agreed that taking action is as important as considering principles when studying issues of environmental sustainability. Thirty-nine percent considered that their interest in sustainability issues were heightened while 42% felt they were empowered to effect sustainability of the environment. A high number of students (68%) agreed or strongly agreed that they were made aware of sustainability issues through computing their personal ecological footprint although a low 27% indicated a confidence in discussing the idea of the ecological footprint. However only 32% of students agreed or strongly agreed that they learned something of value when involved with the tree planting exercise. Thus the tree planting exercise was shown not to be as valuable a learning experience as might have been hoped.

Of concern is the large number of students that voted neutral to all the questions. This could indicate that, as first year students, they were reserving judgment until they saw how or if the tree planting exercise appeared more relevant with hindsight in later years of the course. Alternatively it could indicate that the students were not engaged and/or did not care about the issues. Can these results be used to help redesign the tutorials and/or lectures to improve architecture students personal involvement with issues of sustainability and assist students to see the relevance of ESD to building design?

4. Acknowledging Precedence

New areas of study only slowly seem to become incorporated into the main stream of architectural education. In considering the uptake of ESD in architectural design it is perhaps useful to compare the adoption of sustainability principles with the history of the use of computer drafting in architectural education. This may assist in ascertaining what may need to be undertaken to avoid current frustrations while incorporating strategies that may bring about high levels of acceptance.

From the advent of computers in the early 1970's the potential for application in architecture was quickly seen. The realization of the potential though seemed, for many years, just around the corner. Significant developments in computer modeling enabled representations of 3-dimensional models of buildings, multiple views, sections and walk-throughs together with colour renderings using raytracing and radiosity further whetted the appetite for more general extended use. However it was only with the advent of the personal computer in the early 1990's and development and availability of affordable drafting software such as AUTOCAD that the potential of computers could be exploited. Having been adopted in the work place, the design stream in architectural education also began to support and encourage the use of computers for design and drafting.

It may be that the take-up and application of sustainable principles in architectural education needs a similar catalyst. The analogy with the use of computers in architectural drafting may well be the development of user friendly, affordable software that helps to assess sustainability of projects at the

design stage. Some software is currently available but it is still on the fringes of architectural practice. When such software becomes readily available for a designer to call on and if such analytical tools become integrated into CAD programs so that the consequences of design decisions can be assessed during the design process, ESD as a unit of study may appear more relevant to both the teachers and students in architectural education.

5. Discussions

A number of questions emerge from the experience of instigating the tree planting project in teaching ESD in the architecture program. Three questions are discussed below.

The first question considers whether the tree planting project was an unfortunate choice as an education tool to demonstrate sustainability as on one hand it appears as a simplistic task but on the other hand requires an understanding of complex social, environmental and economic interactions. The student survey results may provide some clues. A significant percentage of students (29%) did not feel they learned something of value from the tree planting project. Presumably this could be interpreted as meaning that they did not see the relevance of this particular project to architecture. Thus the linkages between tree planting and such matters as greenhouse gas emissions from use of buildings, soil degradation from land clearing for construction or mining for building materials and the heat sink effect of urban centers were not recognized by students. As highlighted by Boyle (2004) in her discussion of teaching sustainability to engineering students, not only do students need to have a basic knowledge of engineering but they also need to have a wider understanding of the effect of technology on human life, society and the environment in order to recognize negative effects and sustainable solutions. Boyle (2004) claims that in engineering, where the education program traditionally looks at end product rather than the impacts of process, a major shift is required if students are to be asked to consider the environmental and social impacts of designing and making a product. Architectural education suffers from a similar end-of-the-line approach where the factors that effect ecosystems, employment, community relationships, waste production and the like are rarely even mentioned when developing an architectural design brief. Thus it should come as no surprise that the first year architecture students did not see a link between tree planting and the concepts of sustainability. In fact Boyle (2004) suggests that most first year students entering university do not have sufficient understanding of the complexity of systems to comprehend how sustainability can be applied to their discipline. A lesson learnt from the tree planting project is that students should be able to see a direct link between the 'action' project with the discipline of architecture. Further, in the architecture course, the lecture series should cite examples which demonstrate the system linkages between the 'action' project and social and/or environmental benefits to human settlement.

A second question asks if the tree planting contributed to *"an understanding of the linkages among the issues of sustainable development and develops the knowledge, skills, perspectives and values which will empower people of all ages to assume responsibility for creating and enjoying a sustainable future"* as stated in the UNESCO objective for education regarding sustainable development (UNESCO 2002). A high number of students (68%) recognized that they became more aware of their personal impact on the environment through computing their ecological footprint. However less than half the students (42%) equated tree planting as a form of empowerment to compensate for some of their negative impact on the environment. It seems that the tree planting project has the potential to contribute to the UNESCO objective in that it intertwines practical action with reflective thinking. The challenge is to enable university students to recognize the potential and begin to understand how tree planting is associated with the role of the local authority and the community in general and contributes towards a sustainable environment.

A third question is associated with the mainstreaming of sustainability considerations in the teaching of architectural design. It could be speculated that students would not consider any 'action' project valuable unless it was directly related to architectural design. Perhaps, as the architectural profession embraces sustainability principles through more readily accessible information and regulatory requirements so the teaching of architectural design will also embrace ESD as a fundamental area of learning in a similar way to

the take-up of CAD drafting over the past decade. Consequently the value of 'action' projects in ESD may depend on a cultural shift in the Department of Architecture and in the architectural profession.

In summary, the tree planting project can be seen as a small incremental move towards a greater absorption of sustainable thinking in the teaching of architecture. Although the particular project did not sufficiently engage the students to indicate a lasting change in values or heightened sensitivity to issues of sustainability of the built environment, it has raised some important issues that provide directions for the future teaching of ESD 'action' projects. Consequently a number of measures are planned for the immediate future that may improve student engagement. These include:

- Clearly relating the 'action' project to the lecture series by citing examples where social and/or environmental benefits have accrued to human settlement as a result of similar actions.
- Establishing the system linkages between the 'action' project and the design profession.
- Developing a process to explicitly incorporate sustainability matters in each year of the architectural design stream.
- Amending the name of ESD to encapsulate more clearly its place in the teaching program.

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ACOUSTICS EDUCATION FOR SUSTAINABLE BUILDINGS: METU EXPERIENCE

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Abstract

Design for sustainable buildings must consider acoustical concerns from standpoints of efficiency productivity, functionality, health, comfort and environmental impact. This paper focuses on acoustics education in architecture at Middle East Technical University (METU). Several courses in room acoustics and building acoustics at both undergraduate and graduate levels have been designed to provide much needed acoustical information for the design of sustainable buildings like concert halls and convention centres at the extreme. Two graduate level courses BS 575 and BS 576 Acoustics in Architecture I and II are discussed in the paper. The former course deals with room acoustics and the latter with building acoustics where special emphasis is placed on reverberation control. With the help of commercial software, students can get an intuitive insight through computer simulated and graphically presented results. In the first course students are lectured on topics of room acoustics before they are ready to simulate and analyse a given hall of defined acoustical function by this software. Each student is assigned to a different hall with specific acoustical demands due to its function as a project topic. The halls of study can be selected from physically existing buildings as well as buildings at the design stage. Examples of such projects undertaken in the last two years are also presented in the paper with relevant discussion. Students taking the follow up course are equipped with information on noise criteria, sound transmission and noise control as well as design tools for airborne and structure-borne sound isolation. A sample student project on reverberation control, realized through computer simulation is presented in the paper to support the relevancy of the course material in regard to practice of noise control. From student reaction to these two courses, it is believed such courses could form perfect examples for the way acoustics are introduced to students of architecture. Experience on acoustics education in architecture accumulated at METU through last three years of practice is shared in the paper.

Keywords : Acoustics Education, Sustainable Buildings, Acoustical Parameters, Room Acoustics, Noise Control, Computer Simulation.

1. Introduction

From standpoint of room acoustics sustainability involves conformability of acoustical parameters with corresponding established values mostly derived from years of experience. A specific acoustical function in a particular space requires that room acoustical parameters like reverberation time, early decay time, clarity, early lateral fractions and speech transmission index fall into a range of acceptable values for sustainability. In noise control studies sustainability is associated with meeting a specified noise criteria for specific function of use of the space. Such criteria are developed on accumulated data gained through years of experience and testing.

Architects have an opportunity to consult an acoustical counselor when they have encountered a sophisticated problem in profession. Designs of acoustically sensitive spaces require such an integrated attention from experts of different disciplines. However, when the building is rather small or the budget is limited, solution to the problem is relied on the architect with cost effective approaches. Therefore, it is unavoidable for architects to have a sense of acoustical design for sustainability. Recognizing such needs, efforts have been directed to introduce courses on acoustics into curricula at the Department of Architecture at METU since late eighties by the help from Mechanical Engineering Faculty at the same institution.

Presently, seven courses on acoustics with three hours of credit each are taught, five in undergraduate curriculum; Environmental Systems in Buildings 1-2 (Arch381-Arch382) and Acoustical Design of Halls for Musical Performance (Arch479), Acoustics in Architecture (Arch485) and Noise Control in Architecture (Arch486). Additionally, there are two other courses in graduate curriculum under Building Science option, namely, Acoustics in Architecture I (BS575) which focuses on room acoustics and Acoustics in Architecture II (BS576) which covers design for noise control. Out of seven courses, two undergraduate courses Arch 381 and Arch 382 with partial acoustics content are offered as must courses while the rest are designed as technical electives. Laboratory support in most elective courses is provided by the Department of Mechanical Engineering.

Contents of the two graduate courses, 3 credit hours each, under building science option are designed in such a fashion that even students with no previous undergraduate exposure to acoustics could follow the lectures and contribute in the assigned projects in a 14-week semester. Architectural Acoustics by M.D.Egan (Egan, 1998) is assigned as the textbook for these two graduate level courses. The textbook is supplemented by lecture notes prepared by the instructor. This paper presents educational philosophy and case studies in the form of assigned student projects in these two graduate level courses on room acoustics and noise control offered at the Department of Architecture of Middle East Technical University. Sustainability in acoustical sense is also referred, wherever applicable, in material presented.

2. Room Acoustics

Within the context of “Acoustics in Architecture I” course coded BS 575, the emphasis is especially placed on the design of the halls for music and understanding of acoustical parameters as an input for sustainable concerns in architectural design from room acoustics standpoint. The content of the course is arranged in such a way that fundamental concepts in acoustics like acoustic pressure, frequency, wavelength, speed of sound, acoustic power and intensity are first introduced to architectural students. Decibel scales and level concept immediately follow this introductory material in the first chapter. Human hearing system and perception of sound are discussed in the second chapter. Frequency analysis in terms of octave bands is presented to ease understanding of how hearing system operates. Subjective properties like loudness, pitch, and timbre are also studied along with frequency weighting. Chapter 3 starts with the discussion of physical phenomena of specular reflection, diffusion, scattering, reverberation and sound absorption. Reverberation time is defined and techniques for measurement of sound absorption characteristics and reverberation time are reviewed. Sound absorption performance of material is evaluated with respect to several parameters like material thickness, density, frequency, type of mounting and placement within the space. Sabine, Eyring and Millington-Sette formulations are discussed. Other objective parameters like impulse response, clarity, early lateral energy fraction, speech transmission index are explained. Several benchmark examples are studied in terms of these parameters to underline acoustical design principles for music and speech related functions. Computer simulation techniques are discussed in terms of geometrical room acoustics. In Chapter 4 subjective means of evaluation of room acoustics are introduced with an emphasis on their relations with objective or measurable properties. Finally, modal behavior of rooms is tutored to give students an insight on the relationships of room shape and dimensions with resonant frequencies and room modes.

The conceptual material presented in lecture hours is supported by student projects in which each student is assigned with a different topic. Sustainability is one of major issues in selection of topics and in the evaluation of completed work at the end of the semester. Future designers of acoustically sensitive spaces are expected to display intuitive design sense through such project work. Laboratory sessions are organized to train students on the commercial acoustic simulation software.

Acoustical design of halls is influenced from the developments in the science of acoustics, specifically in psychoacoustics and computer technology over the past 50 years. Nowadays, some other parameters as important as the reverberation time which has been a major design parameter for over 100 years can be classified in three main categories:

- “Objective” acoustical parameters provide measurable acoustical description of halls,
- “Subjective” acoustical parameters state the impression of acoustical characteristics of halls on audiences,
- Design (geometric) parameters like form and dimensions which are important to evaluate objective and subjective parameters.

In the Fall semester of 2002, six students took the course. Three students are asked to design three concert halls of differing in form for symphonic music while the rest are assigned to work on existing halls. The capacity audience is fixed to 500 in all three halls. The major objective in this choice is to investigate effects of the form on the resulting acoustical characteristics and thereby to teach students to compare and evaluate their designs in terms of acoustical parameters, indicative of sustainability in acoustical sense.

With the help of commercial software, students can get an intuitive insight by seeing computer simulated and graphically presented results. Though there exists individual acoustical studies at research level to develop acoustical software mainly for the simulation of room acoustics at METU, the professional software ODEON has been chosen for the purpose of design due to the ease and flexibility it offers.

Three assigned halls which are the subjects of the study have the following forms:

- Shoebox form hall designed by Ms Zuhre Su
- Fan shape hall designed by Ms Berrin Cakmakli
- Combined form designed by Ms Semra Arslan

In many acoustical simulation programs the combination of image source and ray tracing methods are used for simulating early reflections. Diffusion models are utilized to study late reflections. Computer simulations with the extent of perfection reached have more opportunities and flexibilities with respect to physical scale models in today's world of architectural acoustics. Preparing the models, implementing materials and designating sound absorption coefficient to these materials are more easy and speedy than analyzing with scale models. Furthermore, computer simulations can analyze far more parameters than the other.

Geometrical models of specified halls are developed, as required by the software, with 3D faces in AutoCAD dxf format and all the materials are prepared as layers. Same materials are used on internal surfaces for finishing and acoustical purposes in all three halls. The stage floor is covered by wood parquet. Side walls and ceiling of the stage are specified as gypsum plaster. Audience is assumed to sit in medium upholstered chairs. The floor is clad with PVC. Ceiling is glazed plaster whereas the walls are painted plaster. Double glazed are specified for glass surfaces and gypsum board is designated on reflective surfaces (Christensen, 2004). The sizes of stages and height of ceiling differ from each other according to students own design criteria. The resulting values are shown in Table 1.

Table 1. Geometric Characteristics of Halls

Form	Dimensions (m)	Volume(m ³)	Stage size(m ²)
Rectangular	18/36 m	6648 m ³	132 m ²
Fan	22/30 m	5794 m ³	100 m ²
Combined	25/40 m	5905 m ³	120 m ²

Importing the 3D models into the software, a sound source on the stage and receivers at the critical locations in the hall are implemented. After assigning the materials to all surfaces, early reverberation times

are gathered. According to these results necessary modifications on the geometry and materials are performed. The results are optimized according to recommended ranges for acoustical parameters shown in Table 2. The recommended ranges for the specified parameters are indeed requirements of sustainability in terms of the desired acoustical function of the space.

Table 2. Acoustical parameters and recommended ranges for concert halls (Caliskan,2002)

Parameter	Recommended range for concert halls	Just noticeable difference
T30	1.5 to 2.2 s	5% (i.e. about 0.1 s)
EDT	1.8 to 2.2 s	5% (i.e. about 0.1 s)
G	-2 to +10 dB	1 dB
C80	-2 to +4 dB	1 dB
LF	Upper 0,3	0.05

2.1 Reverberation time (T30)

Reverberation Time is the global objective quantitative criterion of the sound field in the room. Room reverberation gives fullness and singing tone to the music. The reverberation time must be in the proper range depending on the room size and the style of music. But the acoustic quality of a room for musical performance cannot be evaluated by reverberation time alone. Two rooms with equal reverberation time may sound completely different. RT is the time it takes for sound pressure level to decay by 60 dB after its source is cut off. It is normally evaluated over the -5 to -35 dB (RT30) ,mostly for practical reasons, decay of sound and multiplied by the factor of 2 for conformity with RT60. These factors are necessary to make the measurements comparable with each other and with the more historical measurement of RT60, which is evaluated over a full 60 dB sound decay.

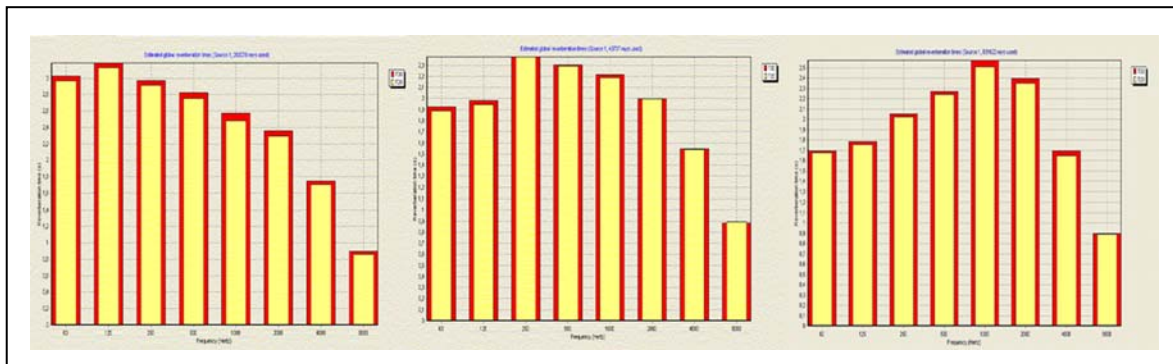


Fig 1. Estimated Global Reverberation Times

2.2 Early decay time (EDT)

The EDT is the special form of reverberation time derived from the initial 10 dB of decay. It is the length of time that it takes for the sound to decay 60 dB if it had maintained the same decay rate of initial 10 dB drop after the sound source is turned off. EDT more closely corresponds to subjective evaluation of the

reverberation time then RT. It affects principally the hall's support to the voice and adds definition to the higher tones of music.

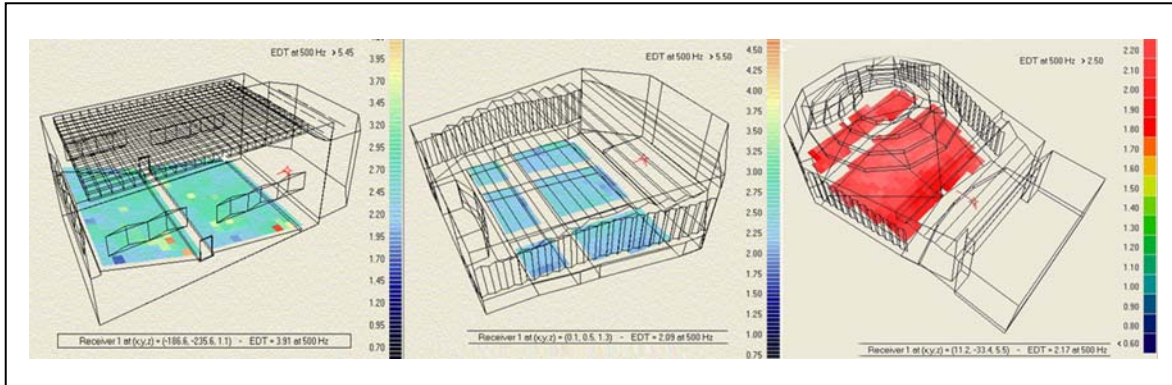


Fig 2. EDT distributions of the ODEON model with indication of one source position at 500Hz.

2.3 Clarity ($C80$)

Clarity is defined as the ratio of the energy in the early sound compared to that in the reverberant sound, expressed in dB. Early sound is what is heard in the first 80 ms ($C50 - 50$ ms) after the arrival of the direct sound. It is a measure of the degree to which the individual sounds stand apart from one another. If the clarity is too low, the fast parts of the music are not "readable" anymore. $C80$ is a function of both the architectural and the stage set design. If there is no reverberation in a dead room, the music will be very clear and $C80$ will have a large positive value. If the reverberation is long, the music will be unclear and $C80$ will have a relatively high negative value. $C80$ becomes 0 dB, if the early and the reverberant sound are equal. Often the values for 500Hz, 1000Hz and 2000Hz are averaged.

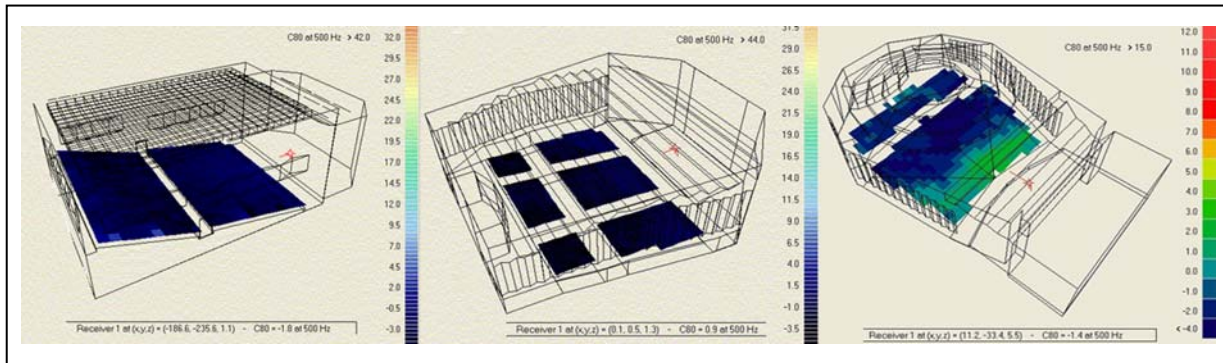


Fig 3. $C80$ distributions of the ODEON model with indication of one source position at 500Hz.

2.4 Lateral energy fraction (LF)

Relative levels of early lateral reflections in the total sound at any receiver location are important from room impression point of view. For concert halls the fraction of such reflections to the total sound in the first 80 ms after the direct sound has arrived is preferred to exceed 30 % for good envelopment of sound. The poor correlation or dissimilarity of sounds reaching to the listener from two sides laterally improves source localization and the feeling of intimacy.

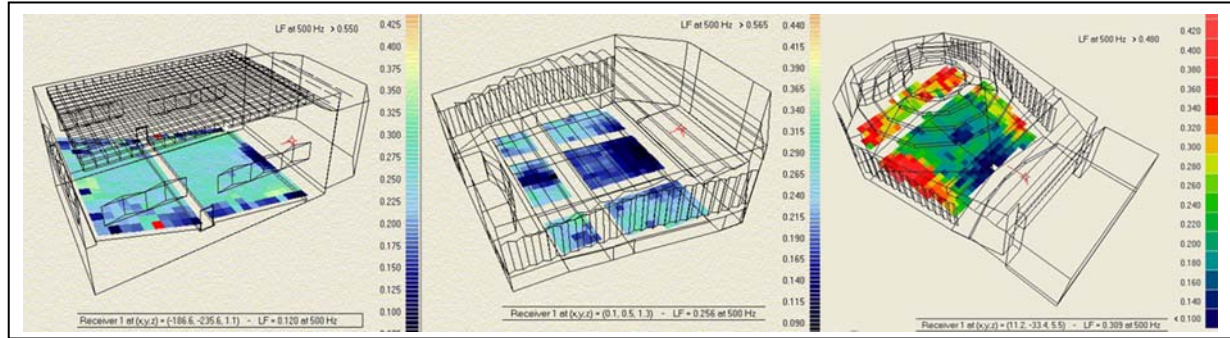


Fig 4. Lateral energy fraction at 500 Hz

Table 3. Comparisons between the results of simulated halls and recommended acoustical parameter ranges

Model	T30	EDT	C80	LF
	1.5s -2.2s	1.8s-2.2 s	-2 dB +4dB	> 0,3
Rectangular	2.46s	3.91s	-1.8dB	0.12
Fan	2.21s	2.09s	-0.9dB	0.25
Combined	2.02s	2.17s	-1.4dB	0.32

3. Noise Control

Concerns about acoustically sustainable buildings from noise control standpoint are intended to overcome by a follow-up graduate course, "Acoustics in Architecture II" coded BS 576. The course aims to introduce means to control noise in dwellings with emphasis on reverberation control for the purpose of comfort, health and safety. The course starts with the same first two chapters as in the former course. In chapter three definitions associated with noise terminology are introduced with emphasis on classification of noise with respect to time and frequency characteristics. The concept of noise energy equivalence in derivation of equivalent continuous sound levels and sound exposure levels is also presented. Noise measurements are exercised on sound level meters to underline such concepts. Means of rating noise in terms of Speech Interference Level, Noise Criteria and Noise Rating Curves as well as standards and domestic and international noise legislation measures are studied in fourth chapter. Students are also exposed to reverberation control, i.e., noise control by changes in room absorption. The next chapter is devoted to sound transmission through room boundaries. Airborne noise transmission index for building materials is discussed with emphasis on measurement and rating techniques. In the final chapter control of structure borne noise and impact noise is studied with practical applications.

Each student taking the course is assigned with a project which involves acoustical correction of an existing building by means of reverberation control. In this paper a sample project by Ms Semra Arslan carried out in that particular course is presented. The building selected for the purpose is METU Alumni Building in Ankara to serve cultural and social needs of METU graduates. The spatial functions of the building can be grouped as multi purpose halls, recreation areas and restaurants. In the restaurant section there are complaints from users about intelligibility of speech and perception of music because of the geometry of space. The building poses acoustical problems due to its circular plan, high ceiling and concave surfaces. Architectural modifications on the form of the building are not permitted. Only reverberation control techniques which involve assignment of more absorptive materials at certain locations are allowed.

Therefore, it is unavoidable to make an acoustical analysis via computer simulation to propose economic, affordable and sustainable solutions.

In the remaining paper the results obtained from computer simulations of the building are presented. An optimization study is undertaken to reach the most economical, practical and sustainable solution. ODEON software is exploited for computer simulations. The results of the study are outlined in graphical outputs shown below:



Fig.5. Views from METU Alumni Building in Ankara

3.1 Acoustical simulation of existing situation

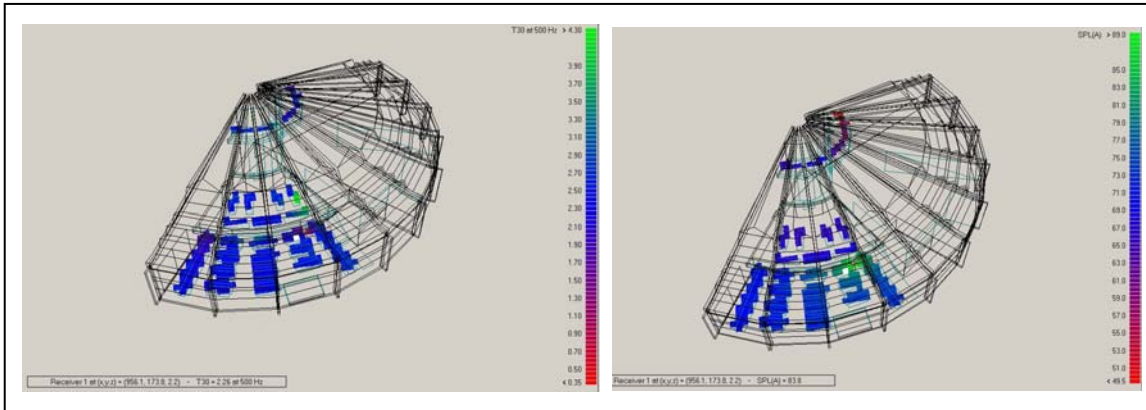


Fig.6. Reverberation Times (T30) at 500 Hz and A-weighted Sound Pressure Level for Existing Situation

Table 4. Generally Accepted Parameter Ranges for STI

	Bad	Average	Good	Excellent
STI	0.2-0.4	0.4-0.6	0.6-0.8	0.8-1.0

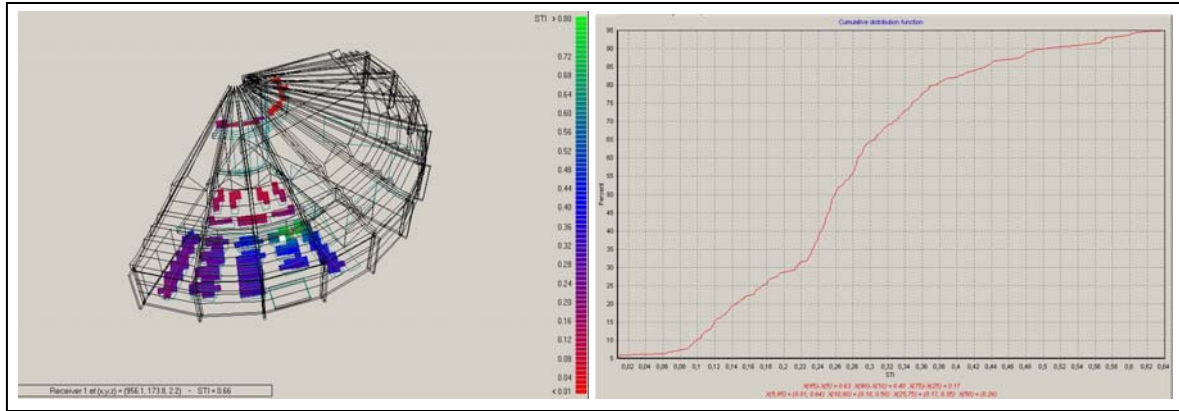


Fig 7. Speech Transmission Index and Distribution Graph for Existing Situation

3.2 Acoustical simulation of proposal

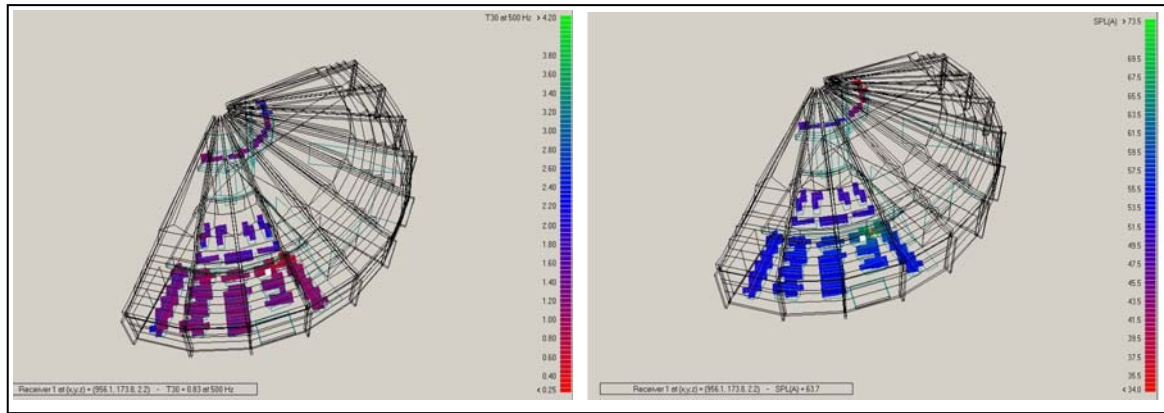


Fig.8 Reverberation Times (T30) at 500 Hz and A-weighted Sound Levels for Proposed case

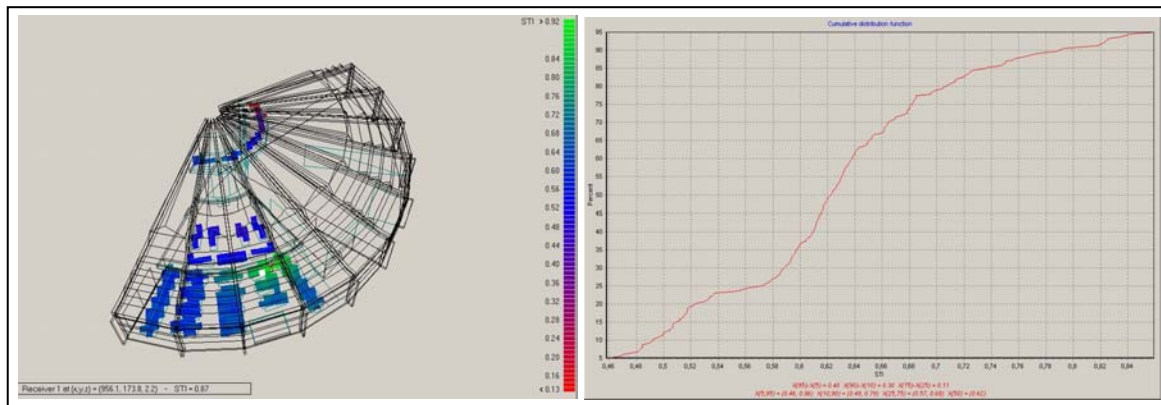


Fig.9 Speech Transmission Index and Distribution Graph for Proposed Case

Table 5. Evaluation of results

	RT (1000Hz)	STI	SPL(A)
Existing Situation	2.42 s	0.2-0.4	67-83 dBA
Proposed Modifications	1.20 s	0.6-0.84	51-63 dBA

Table 5 outlines the vast improvements recorded in three parameters of reverberation time, speech transmission index and A-weighted sound level distribution by the proposed material replacements at locations chosen. Pulling these acoustical parameters within the corresponding limits surely improves sustainability in acoustical sense.

4. Conclusions

Graduate courses on acoustics education in architecture are presented with reference to sustainability in acoustical sense. Conformability of acoustical design parameters with recommended ranges are illustrated in case studies derived from student projects assigned in the course. Such ranges are based on standards, common acoustical practices and data accumulated through years of experience in fields of room acoustics and noise control. Experience gathered at METU is intended to share with academic and professional community.

Acknowledgements

Ms Berrin Cakmakli and Ms Zuhre Su are gratefully acknowledged for their permission on publication of the projects in this paper. Erbug Architectural Corp of Ankara is also acknowledged for the support provided in the acquisition of the software.

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AWARENESS, EDUCATION AND TRAINING TOWARDS SUSTAINABLE ENERGY AND DEVELOPMENT IN MALAYSIA

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Abstract

The depletion of fossil fuels, security of the resources, environmental and global warming issues are forcing private and public institution to be more careful in using energy and electricity. Some important steps are by promoting the implementation of Energy Conservation, Renewable Energy (RE) and Energy Efficiency (EE). This paper describes initiatives and programs on Renewable Energy and Energy Efficiency in Malaysia. The establishment of CETREE in year 2000 focusing on the Promotion and Education on RE& EE is elaborated. CETREE program on RE & EE promotion is targeted to all level in the society. CETREE develop modules and materials suitable for schoolchildren, teachers, university, professionals and the general public. Apart from education and training, the outreach program via exhibition and hands-on activities are developed. The impact from the programs and projects is significant and further support from public and private institutions signify the sustainability of the program.

Keywords : Education, Training, Awareness, Sustainable energy, Energy efficiency, Renewable energy

1.0 Introduction

Malaysia is serious in promoting sustainable development and energy conservation program. The important step is by improving energy efficiency (EE) in all sectors and implementing renewable energy (RE) in all possible means. Renewable energy and energy efficiency (RE & EE) activities are now becoming very important in Malaysia. Moreover, the country enjoys, for a few decades already, a rapid economic growth and entrepreneurs are naturally more interested in increasing their production rather than reducing their energy costs.

The Government of Malaysia has developed appropriate policies on RE & EE. This is followed by the establishment of the key important institution and adopting multi-approach activities and projects on RE & EE. As the country grows towards industrialized nation targeted in the year 2020, the demand of energy increases consistently due to the rapid economic, physical and infrastructural development, thus the issues on energy is crucial and the sustainable energy solution is introduced. Fifth fuel policy which was gazetted in 1995 is one of the important milestone in the country's Renewable Energy program.

2.0 Malaysia Energy Situation & Energy Policy

In Malaysia, demand for energy is growing much faster than the GDP and it keeps on increasing. The situation is changing as the country within a foreseeable future will become an oil importer and the Malaysian government is increasingly involved in international environment initiatives. Malaysia's ratification of the Framework Convention for Climate Change and thus the obligation to prepare National Communications to the Conference of Parties, combined with its push for industrialisation and recognition as being part member of the group of developed countries partly the Asian centre for promoting EE and RE

may also provide the drive towards attaching greater weight on a more sustainable supply and use of energy.

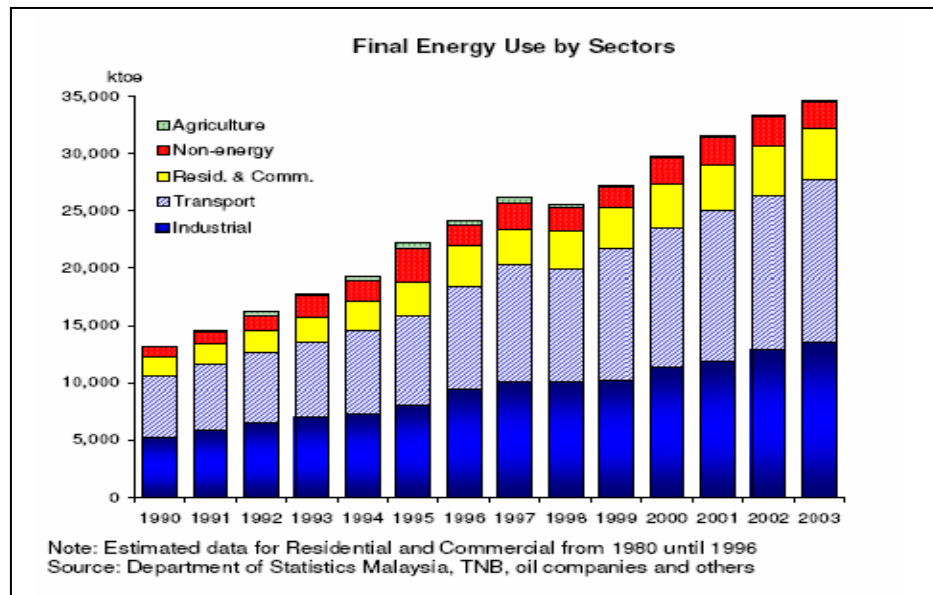


Fig.1 Final Energy Use by Sector, Malaysia.

In this context there is a need for rapid development in renewable energy and energy efficiency. While in the past, the Government of Malaysia (GoM) has maintained the supply/demand balance with supply side instruments; greater attention has recently shifted to include demand side management issues. Fig.1 shows the final energy consumption of the various sectors in Malaysia.

Over the last decade the Government of Malaysia (GoM) has taken decisive steps towards a more sustainable energy sector. At national strategic level, some of the important steps are:-

- Explicit priority given to EE in the energy policy laid out in the 7th Malaysian Plan (1996-2000)
- Under the 8th Malaysian Plan (2001-2005), efforts are being intensified to ensure adequacy, quality, security and cost-effectiveness of energy supply, to encourage greater use of EE & RE.

3.0 RE & EE Initiatives and Promotion

To achieve Malaysia's energy objectives, several initiatives are implemented. A Three-Pronged Approach is implemented covering the introduction of fiscal incentives, promotion program and projects and legislative approach to ensure the effectiveness of the identified program (Fig.2).

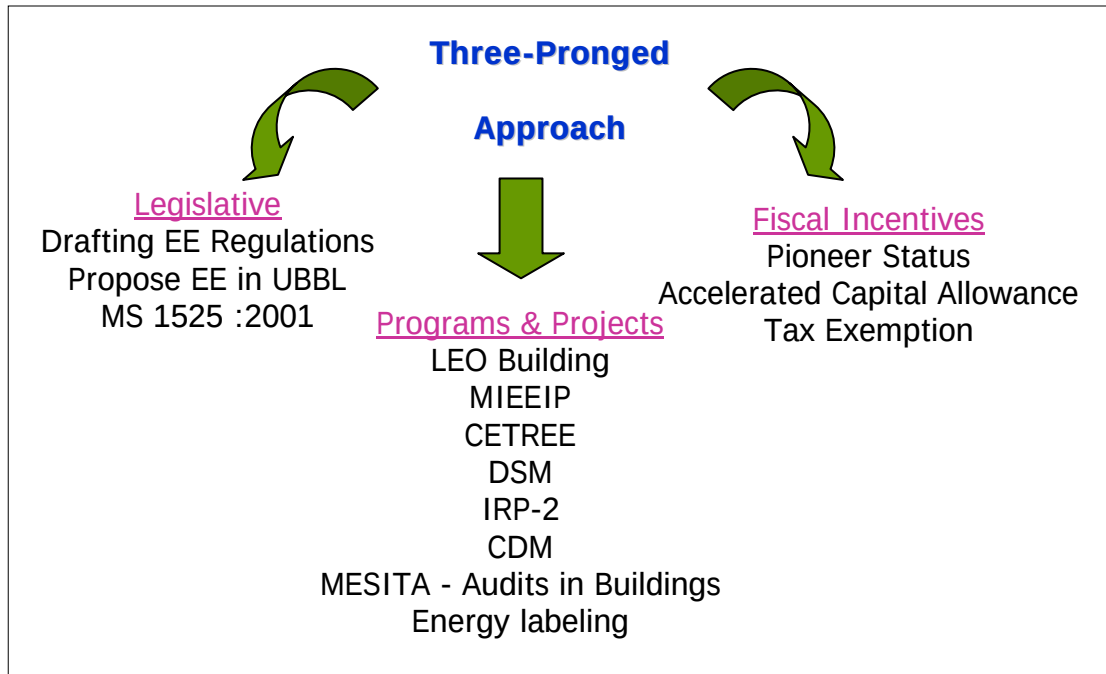


Fig.2 RE & EE Initiatives, Malaysia.

4.0 CETREE: The National Centre Dedicated to the Promotion of RE & EE

The GoM commitment on RE & EE is further proven when in the Eighth Malaysia Plan (2001 – 2005) the GoM announce the establishment of the Centre for Education and Training in Renewable Energy and Energy Efficiency (CETREE) to increase public awareness of the positive attributes of RE & EE measures.

CETREE program has two general objectives (i) “Support to the Development of a Strategy for Renewable Energy as Fifth Fuel”, and (ii) “Support to the Development of Energy Efficiency Strategy” in energy sector.

This program reflects a comprehensive approach to address the present obstacles for a wider implementation of energy efficiency and renewable energy in Malaysia. The strategic approach is to promote awareness and to implement education and training on RE & EE at school levels, Universities, among professionals and information dissemination to the specific target group as well as to general public (Fig.3). CETREE conducted training and dissemination activities, which included the designing of RE & EE modules for teaching in schools and universities.

Education and training is a key factor to increase awareness among public and to break any barrier in the implementation of RE & EE in the commercial and industrial sector.

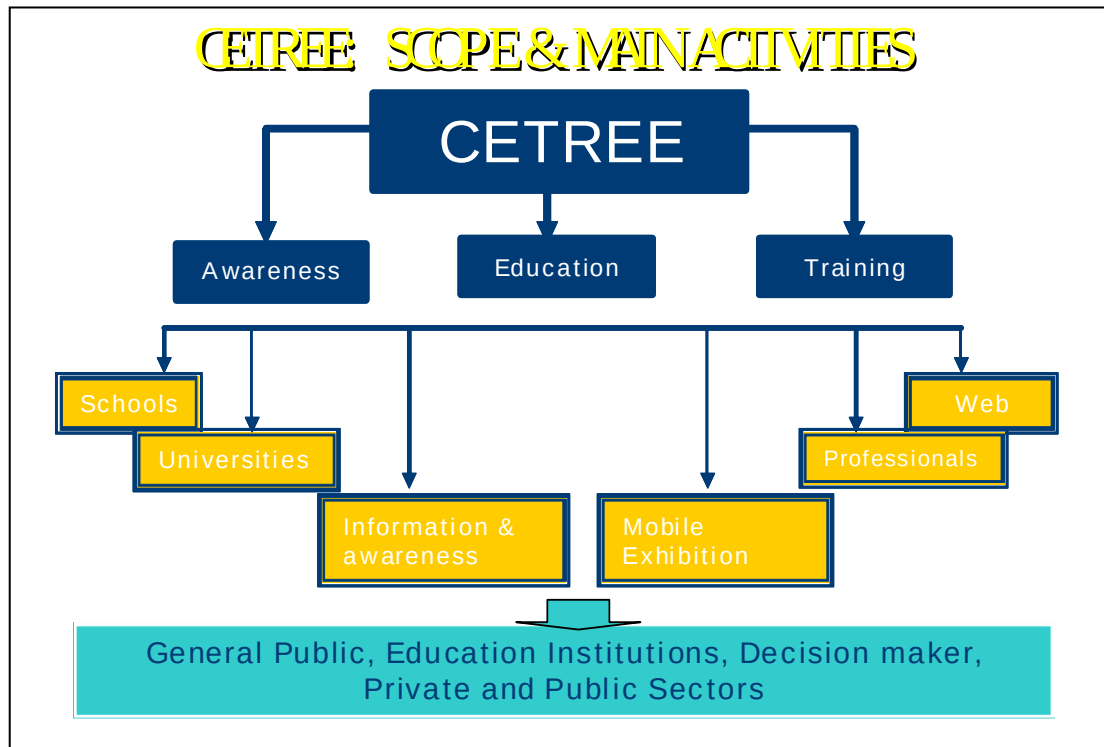


Fig.3 CETREE scope

5.0 Education from the Early Stage

With the full support and cooperation from the Curriculum Development Centre (CDC) in the Ministry of Education of Malaysia (MoE), RE & EE concept is incorporated in the curriculum in Malaysian schools. CETREE has been one of the main vehicles for the practical implementation of this program. The main emphasis being, however, that Knowledge, Attitude and Practice must be integrated in order for the program to be successful.

A number of strategies are implemented:

- Development and publication of teaching materials.
- Training for trainers on RE & EE.
- Training for RE & EE expert teachers from each secondary school in Malaysia.
- Continuous RE & EE program nationwide.

5.1 Development and Publication of Teaching Materials.

CETREE has identified that teaching materials on RE and EE in Malaysia is indeed lacking. The revised Curriculum for Science has included the topics on RE and EE thus requiring teachers to do additional readings and be equipped with teaching guides and activity kits. Together with the Curriculum Development Centre Ministry of Education (CDC - MoE), CETREE decided to develop the necessary resource handbook, teachers guide, activity kits and compendium of co-curriculum activities.

Four books were carefully planned by CETREE and these sources are beneficial to the students in understanding the basic concepts of renewable energy and energy efficiency in the school curriculum. The title of the books is:-

- Resource Book on Renewable Energy and Energy Efficiency

- b. Teachers' Guide on Renewable Energy and Energy Efficiency
- c. Activity Book on Renewable Energy and Energy Efficiency
- d. Compendium of Co-Curriculum Activities on Renewable Energy and Energy Efficiency

5.1.1 Resource Book on Renewable Energy and Energy Efficiency This is a necessary reading book for the teachers in order to understand RE & EE better. It was presented in a teacher friendly format and exciting to read. There were seven Chapters relating to energy, RE & EE topics. Overview of Energy, RE, EE, Fossil Fuels, Nuclear, Solar Thermal, Photovoltaic, Biomass and Others (Hydro, Geothermal, Waves, and Wind & Biogas) has been made.

5.1.2 Teachers' Guide on Renewable Energy and Energy Efficiency The teacher's guide provide a useful resource for teachers to teach Renewable Energy (RE) and Energy Efficiency (EE) for the upper secondary science disciplines, namely Biology, Chemistry, and Physics, the Core Science, and the Additional Science. The guide was written based on the revised curriculum. Thus, the guide was divided into 5 sections as follows: Core Science, Additional Science, Biology, Chemistry, and Physics. Furthermore a distinction was made between the forms. Thus a total of eight chapters were written for the subjects Physics, Chemistry, Biology, Core Science and Additional Science. The teacher's guide then provided detailed guideline to enable teachers to teach RE and EE effectively.

5.1.3 Activity Book on Renewable Energy and Energy Efficiency This book demonstrates the practical experiment of RE&EE activities. Its start with the designing, developing and testing an activities on RE&EE. Four (4) experimental kits have been developed representing the four main topics i.e., Solar Thermal, Photovoltaic, Biomass and Energy Efficiency. The Personnel involved in the production of the demo kits include editorial team, one Expert, one teaching professional and one builder for each experimental kit. The experts start with the research and developing ideas and design appropriate to the size and scope and requirement of the experimental kits. The builders prepared all the materials, components and built at the recommended size and house them in a suitably sized box.

After all necessary adjustment and verification being made, the writing of the activity book is made for publication and distributed later to all school together with the experimental kits.

5.1.4 Compendium of Co-Curriculum Activities on Renewable Energy and Energy Efficiency The Compendium comprised of projects under the chapters of Solar Thermal, Photovoltaic, Biomass and Energy Efficiency. All the activities in this compendium were designed to include essay competition, project competition and exhibition, talks and forums, camps, etc. Moreover, each chapter consists of at least five projects. The personnel involved in developing the co-curricular projects compendium include the editorial team, one expert and one teaching professional for each chapter. Thus a total of 13 people were involved in preparing the chapters and they were co-ordinated by the editorial team, which also includes 2 officers/teachers from the Co-curricular Section of the Schools Division MoE.

5.2 Training the Trainers on RE&EE.

The "Training the trainer's workshop" was organised as a first training program for the implementation of RE & EE teaching in school. The main objective of this workshop was to train the master teacher from each state in Malaysia and to prepare these master teachers in the training of secondary science teachers. There were 104 participants consisting of 17 experts in RE and EE, 15 State Education Department officers, 6 lecturers from the teachers' training colleges in selected states and 53 teachers from schools all over Malaysia. The workshop's secretariats were officers from CETREE and officers from the CDC – MoE and a representative from the Ministry of Education.

The RE and EE experts from CETREE provided the introduction as well as exposure to RE and EE to the master teachers based on the four modules (Teacher resource modules, teachers' guide modules, activity modules and the collection of co-curriculum projects module). An officer from the Curriculum Development Centre presented and shared his report of the pilot RE and EE study in schools.

The discussion was made to motivate participants to implement RE and EE in their various schools. Small group discussions were formed based on the specified themes: photovoltaic, solar thermal, biomass, energy efficiency and contextual teaching. The teachers had to present a summary of their discussion and this served as an initial guide for the training of secondary school teachers.

The teachers too were given the opportunity to actually carry out experiments based on these specified themes. The teachers were also exposed on a one-day study tour to familiar RE installations project in the nearby plants. The tour included the biomass plant in Malaysia Palm Oil Berhad, Bangi, Selangor and the photovoltaic generation system in Port Dickson.

The workshop ended with the certification of the teachers who had participated in this workshop and commended as State Master Trainers on RE & EE.

5.3 Training for RE & EE Resource Teachers from Each Secondary School in Malaysia.

Training for RE & EE resource teachers is a second stage of training for secondary school RE & EE and targeted to all 1,850 secondary school all over Malaysia. A total of 20 workshops with 2051 participants were carried out from February 2003 to May 2003 in 14 states throughout Malaysia. The workshops were organized by CETREE with the cooperation of the State Education Department of all the 14 states in Malaysia.

The masters teachers trained in the previous "Training for Trainers" workshop were involved in these training. The participant in this workshop is appointed as a Resource Teacher on RE & EE in their respective school.

5.4 Follow-Up and Continuous RE & EE Program Nationwide.

Apart from the implementation of education and training program on RE&EE to all schools, CETREE continue to give special attention for continues update on RE & EE information and materials to all secondary schools throughout Malaysia. CETREE was getting involved in several activities organised at school, state and national level.

The Essay Writing competition was organised for the secondary school level nationwide. Financial assistance from Malaysia Electricity Supply Industry Trust Fund (MESITA) was obtained to run the competition. The objectives of the essay competition for the schools were to increase awareness and knowledge on RE and EE among students in schools, to disseminate message on RE and EE to students, their parents and public at large and to educate students to use energy efficiently

The interests for the competition were overwhelming. More than 7000 essay was received before the deadline. The selected winner's essays were compiled and published for distribution to all schools throughout Malaysia as a reference and reading materials.

One year later CETREE is organising secondary school RE & EE project competition. The main theme for the competition is "RE and EE - Easy and Fun". The competition was open to all secondary schools in Malaysia. The participant submitted two projects, i.e. Energy audit project in school and RE and EE technology innovation project. CETREE received more than 100 applications from schools all over Malaysia. The purpose of the competition was to inculcate students' awareness about RE and EE and to encourage students practice their creativity and innovative capabilities in the filed of RE & EE.

6.0 Mobile Exhibition

The Mobile Exhibition Unit (MEU), a traveling ambassador for RE & EE, was specially designed by CETREE and officially launched on July 29th 2002 by the Minister of Energy Water and Communication. This MEU is the first in the country to showcase RE and EE (Fig.4).

Since then, it has met and will continue to meet its overall objectives in increasing awareness and providing most needed practical hands-on RE and EE experiences and knowledge to its primary, secondary and tertiary target groups.



Fig.4 CETREE Mobile Exhibition Unit.

A van was procured and fitted with an alternative fuel system, integrated stand-alone power supply, and basic AV equipment as shown below. Key ingredients are the bio-diesel engine, the rooftop solar PV panels and the energy efficient equipment.

The van and trailer was designed according to the regulations set by the Road Transport Department (RTD). The van has built-in compartments with proper safety measures for electrical appliances, preventing any damage during transit. The trailer carries an alternative power supply 5 KV oil palm generator and other solar hands-on equipment and parasols.

The 2-litre diesel engine Toyota Hi Ace was modified to enable it to run on palm oil. A few of its components were changed and an oil filter, heater and glow plug was added. Its fuel consumption is 8 km palm oil per litre. Inspection by DOE shows that it emits 0.5% carbon monoxide (CO) and 14 ppm hydrocarbon. This value is below DOE limit (4.5% CO max and 800 ppm hydrocarbon).

Eight photovoltaic panels were installed, two panels on the van rooftop and six panels on the trailer. The total output power is about 960 Watts at 1000 watts/cm² solar radiation. At typical condition the output power is 700 Watts. The rooftop PV panels can be tilted 45°. The trailer PV panels are fully extensible at rest. The entire PV panels are connected in parallel to keep the charging voltage at 18 V. The charging current is stored in 2 parallel batteries and controlled by a solar charge controller.

This van uses both AC and DC current. The DC current drawn from the distribution box powered small electrical appliances such as 12 V DC (30 W) refrigerator, 12 V DC (240 W) coffee maker, 12 V DC (216 W) oven, 20 min to toast a bread, 12 V DC (1.8 W) CFL lamp. An inverter is used to convert the DC current to AC current. Total power output from the inverter is 600 W, 240 V AC (80 W) laptop, 240 V AC (80W) LCD screen, AC Fan (45 W) and AC radio (10 W).

The MEU consists of an Energy Van and six (6) RE & EE knowledge kiosks. The kiosks include posters, brochures, e-café and solar educational activities (Fig.5). This non-polluting and self-sufficient exemplary Energy van runs on renewable palm oil and powers its electrical appliances by rooftop solar panels. The robust and agile van, untiring dedicated staffs, client-friendly RE and EE program and continued enthusiastic supportive beneficiaries have contributed synergistically to the successful operation of the MEU in pursuit of CETREE's developmental and overall objectives.

In line with other CETREE activities targeting the educational sector, to be applied as an instrument in the overall training and educational strategy, mainly as a co-curriculum activity, targeting teachers and students in secondary schools

The strategy has all along been to secure strong coordination between the MEU activity and other CETREE activities are Curriculum Activities, Information Materials and Awareness Campaigns

For this purpose, CETREE designed, equipped, and maintains the MEU, and, in post-production efforts, trains and supervises specially trained guides in using the MEU as a campaigning instrument.



Fig.5 School children enjoying the e-cafe and using the hands on kits

Apart from the 5 pamphlets related to the kiosk, there are also two other pamphlets i.e. MEU pamphlet which introduces the MEU and all its salient features and CETREE pamphlet which introduces CETREE and its activities

The Student's handbook is a 35 page publication given to the student participants in the MEU solar educational activities. Two Student Activity Books have also been produced (Fig.6). These books provide guided activity on each of the solar topics i.e. solar power, solar thermal energy, biomass, and energy efficiency. Each book begins with a fun poster hunt, followed by each of the 4 guided solar activities and ends up with a short quiz



Fig.6 The handbook and one of the two activity books

Since July 2002, about 34 000 Malaysian and international visitors have benefited from the MEU RE and EE awareness and hands-on educational program. About 50,000 secondary school students from all over West Malaysia have participated in this MEU solar educational program. General public open sessions have attracted more than 40,000 visitors from all walks of life. CETREE have taken this opportunity to distribute RE and EE pamphlets and books, apart from increasing their awareness about RE & EE and showcasing RE and EE kits and equipments.

A total of 940 Malaysian science teachers (as part of their RE and EE Curriculum and co-curriculum workshop), 60 Achene's science teachers (as part of their RE resource workshop) and 125 Danish scouts have benefited from the MEU solar exhibits.

7.0 RE & EE Publication and Public Campaign

CETREE found that materials on RE & EE is still lacking. At the beginning of CETREE projects, CETREE starts with the baseline survey on public awareness and practice and followed by the publication of several awareness material and newspaper campaign. The comprehensive overview and detailed examination of the existing information and awareness material to the general public within RE and EE confirmed the need for updated information material on EE and new developed information material on RE.

7.1 Publicity Material for General Awareness on EE and RE

CETREE has prepared and published “Energy efficiency at home” guidebook for general awareness in both Malay and English versions on 29th July 2002 (Fig.7).

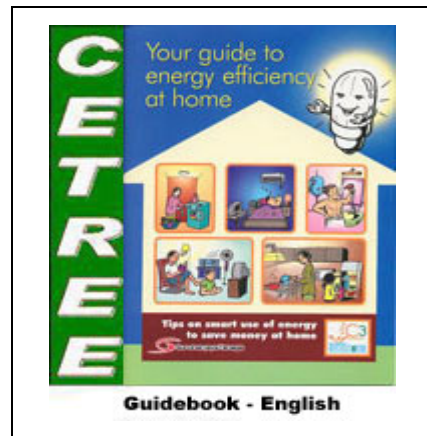


Fig.7 The front page of the guidebook

CETREE has printed approximately 50,000 copies of the “Your Guide to Energy Efficiency at Home” booklet. The Energy Commission (ST) and CETREE covered the costs jointly. More than 90% of the copies have so far been distributed to the general public. The Energy Commission subsequently asked CETREE to print a further 120,000 copies of the guidebook in English and another 120,000 copies in Bahasa version.

7.2 Energy Efficiency Awareness Campaign in the Newspaper

As part of the awareness and information task to promote CETREE and its activities almost all of its task management groups have generated publicity in the media. Since year 2000, articles and press clippings, such as interviews with CETREE Task Managers/Manageress were held in line with the CETREE activities, RE&EE competition and EE Awareness Campaign. This is to generate a greater public knowledge, understanding and awareness on Energy Efficiency and at the same time promoting CETREE and its activities. Some of the titles in press coverage and articles are ; “Using Energy efficiently”, “Trailer Lessons on Energy”, “Solar Architects”, “Educate on efficient energy usage”, “Standard syllabus on energy saving”, “Energy Efficiency testing for fridges”, “Survey: Many not aware of EE appliances”, “Activities on efficient energy usage for students”, “CETREE set to be national centre in 2006”, “Drive for wise usage of energy”, “Housewife role vital in saving money” and other titles in local language.

8.0 University and Professional

Professionals in building and industrial sectors play a significant and important role in RE & EE programs. Malaysia aims to increase EE & RE implementation in both building and industrial sectors. CETREE develop modules for university students and professionals aimed to create awareness, knowledge and practices.

There are two types of professional courses. (a). Energy Management Course and (b). Integrated Energy Building Design Course.

8.1 Energy Management Course

The modules have been agreed with the Energy Commission (ST) to be used as a standard syllabus for the implementation of the Energy Management and Energy Managers training nationwide for government, private as well as industrial sectors. The standard schemes proposed in brief the structure of energy management training scheme and corresponding training activities to be performed in order to implement and operate the scheme. The structure defines the role of CETREE in a broader context and reveals the interfaces between the bodies involved in the proposed training scheme.

Based on the framework developed in the Malaysian Energy Management Programme (MEMP) as a part of the Malaysian Energy Efficiency Strategy (MEES) the activities of the Efficiency Officers (EO) and Efficiency Managers (EM's) are to be administered and supported by the Energy Efficiency Secretariat, which is to be established in the Malaysia Energy Centre (PTM). The scope of this secretariat is servicing the managers and consultants in implementation and maintenance of Energy Management Systems and to monitor that the Energy Efficiency Regulation is applied and observed. Hence the Energy Efficiency Secretariat will be the operational body of implementation of the Energy Efficiency Regulation.

8.2 Integrated Energy Building Design (IEBD) Modules.

IEBD modules are an awareness program through education and training targeting among designers (architects, engineers and quantity surveyors).

The modules express the need for considering EE approach and the potential of using RE such as Heating system, PV system and BIPV in proposed new building and development.

9.0 Conclusions

Malaysia has taken seriously in the implementation of RE & EE. Cooperation, coordination and involvement of public and private sectors have tremendously improved. As the country develops physically, economically and socially, the implementation of RE & EE is a big task. However the focus given by the GoM to human resource development, particularly in RE & EE via education and training are believed to be a strategic and appropriate approach. As a new national centre focusing on RE & EE awareness campaign CETREE have identified target groups across the society from school children to university level and from general public to professional level. CETREE believes that awareness and understanding on RE & EE will induce action and implementation. Thus education and training must be intensified with appropriate approach and innovative programs. Incentives and regulation in RE & EE will further enhance the commitment of every sector involved especially building and industrial sectors.

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SUSTAINABLE CONSTRUCTION IN HONG KONG DEMONSTRATION PROJECT IN FU TEI

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Abstract

This paper presents a recent sustainable development demonstration project in Hong Kong which achieved system level solutions by evolving the nature of architecture system technology and innovating engineering solutions. The project is a thirty-three storey residential tower that was constructed using extensive structural precast components. It is the first of its kind in Hong Kong, and uses fully precast shear wall and columns, balconies, planking, kitchen modules and cladding, and volumetric structural precast bathrooms.

This is one of the pioneering project in the use of "joint construction" of precast wall connections in a high-rise building in the region. This type of connection differs from monolithic cast-in-place concrete construction and exhibits an ability to deform inelastically.

There were several objectives to the project: (i) promote wider use of prefabrication; (ii) minimize generated waste and on site wet trade work; (iii) achieve a better quality product for the end-user; and (iv) provide a safer construction environment. The project employed a partnering approach that brought together construction stakeholders in multi-disciplinary collaboration and thus attained excellent environmental and cost effectiveness results. The promotion of a whole-system strategy that managed the building system i.e. structure, building envelope, partitions, building services and equipment, resulted in new architecture configuration technology that was devised to harvest a spectrum of spatial variations inside the building mass. The successful completion of the project proved the achievement of the objectives are possible and that it is within current reach to erect projects using an efficient amount of site labour, fast construction, safer on site working environments, less waste, and better quality.

Keywords : Sustainable development, Structural precast components, Joint construction, Partnering approach.

1. Introduction

In the mid 80's, the Hong Kong Housing Authority (HKHA) recognized a need to enhance the ease of constructing buildings. In so doing, the HKHA adopted prefabrication as an approach and since, prefabrication technology has become associated as a hallmark method in achieving cost effectiveness, improved durability, and enhanced build ability. On the contrary, the majority of current construction work

in the private sector continues to engage antiquated techniques that date back thirty years. This traditional construction approach demands a high level of craftsmanship and labour intensity, and involves extensive wet trades work on site. Ensuring wet work results are of quality further necessitates excellent on site logistics management and supervision, which typically drives up costs significantly.

Indeed due to the priorities of cost minimization, fast construction time, early revenue generation, and maximum profit, the important concepts of sustainable construction and precautionary principals are often sidelined. Like most industrial processes, traditional construction practices are linear in the exploit of energy and natural resources while discharging relatively large amounts of waste. As Hong Kong continues to run out of both reclamation sites and landfill space for the disposal of construction and demolition waste, it is a matter of time before these issues will result in an impact on areas beyond construction sites and the overall environment.

As alluded to earlier, on site wet trade work is lessened through the adoption of a manufacturing approach that uses metal formwork, prefabrication, and standardised modular components. This impacts positively on the cleanliness of construction zones and contributes to better site safety and less waste generation.

However, there are only a few cases where track records of consequent and significant successes have been achieved. This is particularly true in the private sector and the reasons for this are as follows:

1. Private developers continue to maintain the perception that precast construction cannot provide an agile design.
2. The design of the building is market driven and the developers look for distinctive styles on each project, creating difficulty in standardizing designs.
3. Most buildings in Hong Kong are high-rises that must endure significant wind loads, posing difficulty in using precast construction.
4. Many liability-conscious designers and contractors are reluctant to try innovative construction methods.
5. Developers and contractors need to see clear business benefits before deciding to adopt sustainable construction.

The Hong Kong economic downturn of 1998 marked an impact in the local construction industry. With the local property market in a slump and a decline in demand for domestic property, private sector developers became more cost-conscious. In 1999, the Hong Kong Government completed a 40 million dollars study titled 'Sustainable Development for the 21st Century' (SUSDEV21) that independently researched and identified that continuing economic growth and a commitment to sustainability was vital to Hong Kong. The Hong Kong SAR Government then announced a "Greener Construction" campaign with the objectives of creating a better quality of life through sustainable development. In January 2001, the Government published a Construction Industry Review Committee Report relating to the overall improvement of the construction industry. With a change in the market environment and the Government's desire to move forward, the industry began to take note of methods and good practices that improved efficiency, cost-effectiveness, quality, and delivery timeliness. These factors are the main drivers for in-depth studies of existing housing construction methods, with particular emphasis on reducing the generation of construction waste and the improvement of overall efficiency while meeting specific requirements on time, cost and quality.

This demonstration project sets an example of holistic changes in the design and construction process for the purpose of sustainable construction and showcases a way towards local industry improvement.

The sustainability goal of this project was to unite segments of the building industry that typically work independent of one another. Bringing these segments together in a team of architects, engineers, and builder manufacturers was an innovation to the engineering process that ultimately yielded resource efficient, environmentally sensitive, affordable, and adaptable residences on a single project scale.

2. The Project

The demonstration project is a thirty-three storey residential building in Fu Tei, Tuen Mun, which is the current tallest precast building in Hong Kong that involved extensive use of concrete prefabrication technology. The project was a collaborative effort between developers New World Development Group and main contractors Hip Hing Construction Company (a subsidiary of New World Development Group). Architects were brought onboard from P.K. Ng and Associates with Ove Arup & Partners providing structural and geotechnical engineering consultancy services. The site layout plan and elevation for the development is shown in Fig.1.

Being the subsidiary of New World Group, Hip Hing teamed up with PK Ng and Arup to find innovative solutions and radical improvements in construction quality and efficiency. An increased use of fabricating building components off-site and the partnering of the construction stakeholders played a major role in achieving success, particularly in light of the fluid and fragmented nature of the construction industry.



Fig.1 Site layout plan and elevation for the development

Conventionally, there is often little collaboration between architects, engineers, and contractors in the design and construction process. Normally architects prepare designs based on client requirements and issue instructions to other consultants for action. The typical design-bid-build procurement process sees designers prepare plans and specification for contractor bidding, who in turn submit low bids to maximize their chance of securing contracts. This tends to have a negative effect on build quality and the approach is inflexible to the dynamic changes in materials and methods of fabrication. At times, the contractor may also be forced into a solution that is inefficient. In other words, a typical procurement process is hardly conducive to achieving innovation in design and construction.

The adoption of a partnering approach (So D.K.L.,2003) alleviates many of these issues by having the contractor, precaster, and subcontractors form part of the design team early on. In so doing, the knowledge and expertise of each group is factored in from the onset, allowing parties to share equally in decision making responsibility. Further, parties can also then have their operational constraints and concerns represented at the design development stage, which is simply the best time for such concerns to be considered.

3. Design

3.1 Architectural Design

The project was devised through several key design and construction strategies that were sustainable and friendly to environmental integration. By adopting an Integrated Design Process, multiple benefits were achieved for the developer, builder, occupants, and environment.

Identifiable elements of the process are:

- Whole-systems thinking
- End-user considerations
- Front-loaded design
- Teamwork

As buildings are site-related and technology is normally factory-related, three families of building systems were employed in the whole-systems thinking process:

- Site intensive kit of parts;
- Factory-made 3D modules and 2D panels;
- Hybrid solutions, limiting transportation and minimizing site operations.

A whole-system thinking strategy in a sustainability context organizes architectural functional systems based on flexible modular structures and mechanic components. These are basic functional skeletons from which it is possible to create a rich variety of livable designs where the logic of production resolves any discord between man intervention and the environment.

Considering the needs of end-users is another important element for achieving sustainability. The considerations included:

- Site issues and planning
- Resource efficiency
- Indoor air quality
- Construction materials and methods

The resulting minimized development footprint further reduced the urban heating effect and the incorporation of a cross-ventilation lobby takes to heart occupant comfort and health needs. Through respecting the natural environment during the selection of building placement, the net benefits of good views, natural light, and excellent ventilation were further realized. This was possible only because the project's building system allowed for such thinking in design and construction. Waste is again reduced since the effective planning process coordinates dimensions and positions properly, instead of improvising on site changes to the size later on.

Construction and material use was also a careful consideration in devising the project. The issues considered were:

- Intensified usage of spaces
- Simple walling schemes
- Minimized the number of components
- Standardized services and circulation
- Uniform openings with regulated positions
- Structured clarity and efficiency
- Suitability for adoption in hoisting and erection
- Ease of manufacturing, storing and transportation
- Speed and ease of creation
- Simple on-site jointing system
- Working within the constraints of module size to simplify production and keep cost down
- Capturing potential savings associated with economies of scale and adoption of standardized module from manufacturers

3.2. Standardization and Modularization

Standardization of components (i.e. standardisation of the dimensions of components such as doors and windows for certain common materials such as steel and concrete, etc.) brought many benefits. These include:

- Reducing manufacturing costs
- Having fewer interface and tolerance problems
- Achieving better end product quality
- Enjoying greater certainty over outcomes
- More efficient research and development of components
- Reducing maintenance cost for end-users
- Reducing waste and offering more scope for recycling.

To maximise these benefits, the design team factored in the use of standardised components early in the design stage to ensure compatibility between design and the manufacturing process. As covered earlier, industry professionals will need to act together in order to achieve the necessary economy of scale.

Resulting from the intention of standardisation and modular design, the layout of the typical floor consisted of three standard types of units that met the client's marketing strategy. Provided in a standard form were bay windows, balcony, and kitchen designs (Fig.2). This approach minimised the number of casting forms required.

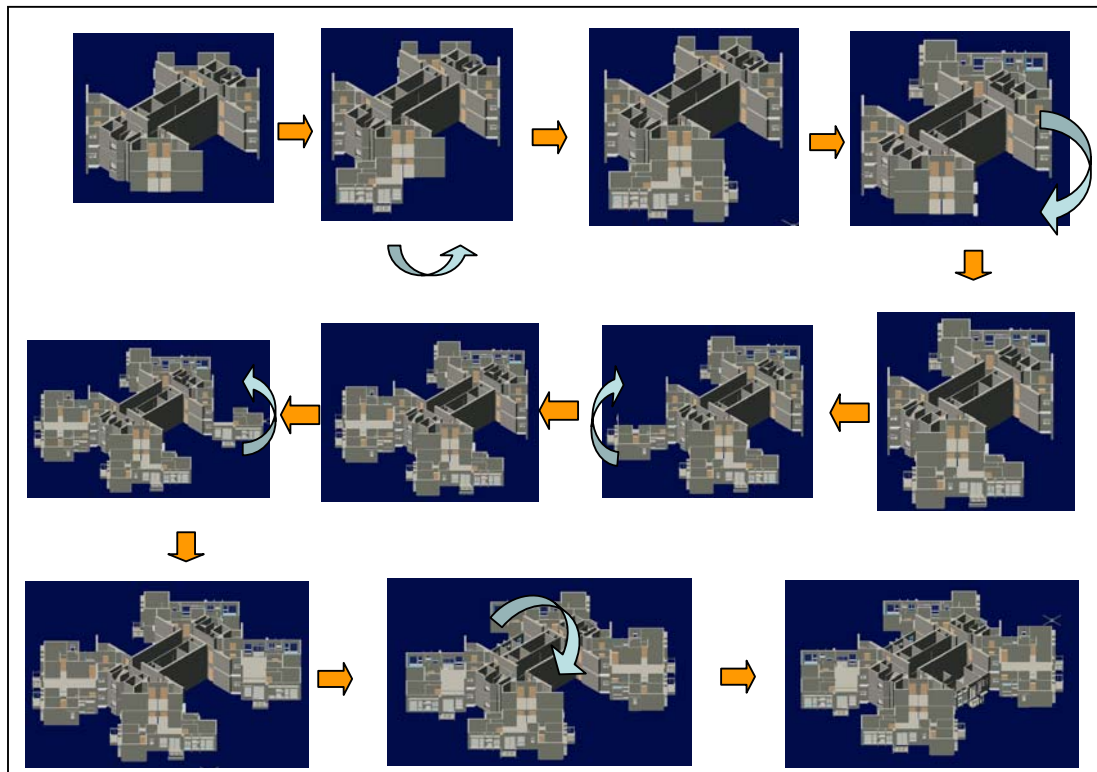


Fig.2 – Standardization and modularization of precast components

3.3 Structural Design

The high wind load typical of Hong Kong buildings posed a significant challenge to the engineering and design. Current building codes in Hong Kong do not cover the design of precast high-rise buildings. A literature review was required of existing guidelines and codes of practices on precast buildings. Issues of concrete, current construction practice, unique experiences, and latest technologies were researched in foreign countries prior to the commencement of the structural design. Eventually British Standard BS8110 was used as the design standard for the project with references also made to standards from Singapore, USA, New Zealand, and the Netherlands. The structure was designed for wind loading in accordance with the Code of Practice on Wind Effects Hong Kong-1983.

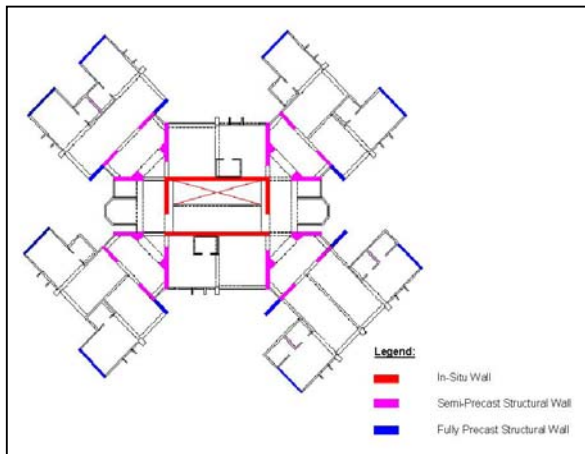


Fig.3 Building lateral system

From a marketing perspective, the team advised no changes to the layout of the residential unit given the design had already been widely accepted in the market for some time. The building was thus designed as a central core wall and shear wall structure which provided lateral stability to resist wind load (Fig.3). The flooring structure is a beam-slab system and the central core was constructed by a cast-in-place method to avoid complicated connection of precast elements. The building envelope adopted precast construction.

3.3.1 Precast Shear Wall Hong Kong rarely sees the use of precast walls for lateral load resisting elements in high-rise buildings (Freedman,1999). In order to adopt precast construction of the external building envelop, engineers decided on the use of “joint-connected” precast shear wall for the external shear wall. This allows the precast shear wall to deform inelastically. Unlike traditional design methods commonly used in other countries, the precast systems are designed to have load resisting characteristics that are equal or superior to those of equivalent cast-in-place concrete systems (Cleland,1997). This “cast-in-place emulation” has the tendency to undermine the cost-effectiveness of the precast concrete systems. Instead the joint-connected shear wall approach adopted in this project allowed the precast wall to have its stiffness “tuned” by detailing and connection definition of load path. The “joint-connected” shear wall and the in-situ central core wall provided lateral load resistance to the building. ETABS was used to model the building and the analysis was reiterated by adjusting the stiffness of the precast walls to simulate the actual behavior of the lateral system.

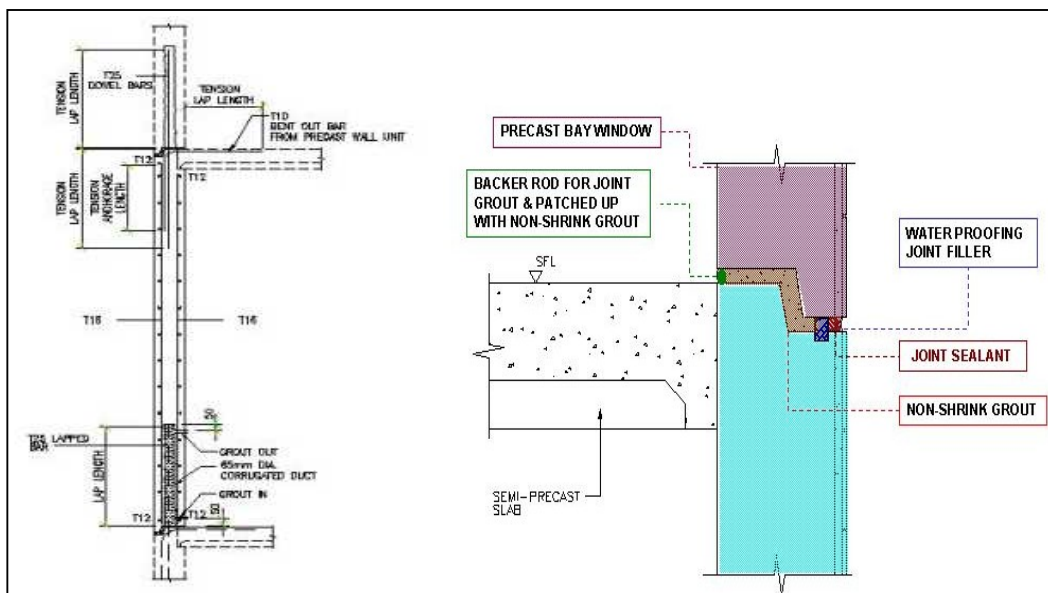


Fig.4 Typical horizontal joint detail for precast structural wall

The horizontal joints of the precast wall were the weakest link in the overall performance of the building. Joint design and treatment are critical to the performance of the finished structure. It was therefore important that the performance and durability of the joint precast wall construction are adequately provided to prevent water leakages and air penetration. The design team spent considerable effort designing and detailing the joint of the precast structural wall to ensure optimum performance (Fig.4). The three-line defense against water and air penetration that was devised include the joint sealant between the tiles, the inorganic compression seal which also serves as the grout seal during grouting of the horizontal joint, and finally the joggled joint of the wall panel.

3.3.2 Semi-precast Planking Semi-precast slab was used to minimise the use of false work and formwork. The overall thickness of the slab is 150mm which consisted of precast slab planking 50mm thick with lattice trusses and 100mm thick in-situ topping. The lattice trusses give strength and stiffness for handling and transport and also allow panels to support construction loads with a minimum of temporary propping. The precast plank is of variable width (up to 2.5m) and length due to transportation constraints. Part of the slab next to the precast balcony was in-situ construction in order to provide better tieback to the cantilever precast balcony.

3.3.3 Precast Balcony The project marked the first its kind in terms of fully precast balcony use in Hong Kong that also fully complies with Government regulations on cantilever structures. Part of the edge beam (100mm width) was designed to attach to the precast balcony making the construction joint within the internal environment (Fig.5). The floor drain was concealed in the precast balcony so that the contractor needed only to install the vertical storm drainpipe on site under very safe conditions.

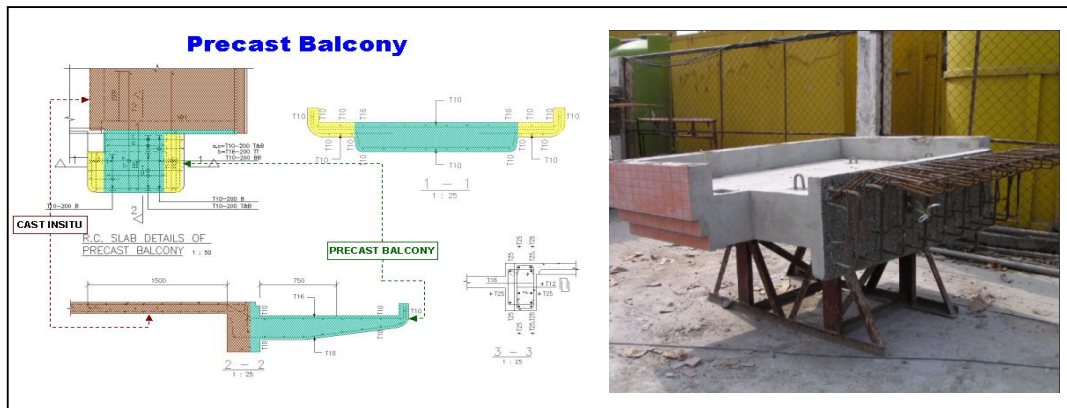


Fig.5 Precast balcony

3.3.4 Precast Bay Window/Column The precast bay window was integrated with the precast column on one side (Fig.6). The bay window is designed as a spandrel beam spanning between the precast column and the precast structural wall. The precast columns are connected by using mechanical splice sleeves to transfer the axial loads. This is the first project to use mechanical splice sleeves in a precast building project in Hong Kong.

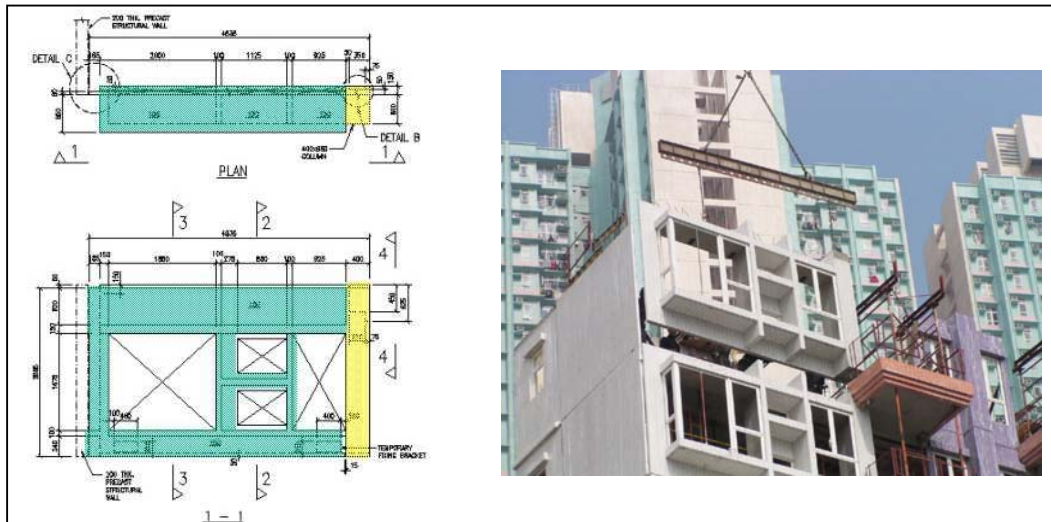


Fig.6 Precast bay window / column

3.3.5 Volumetric Precast Components Volumetric precast bathroom, kitchen and stair core modules were also employed in this project (Fig.7). The benefit producing in factories entire rooms such as kitchens and bathrooms (which are particularly service-intensive building elements) is clearly evident here, since on site wet tray work and building services are greatly reduced. With the use of structural precast wall in this project, the design team decided to integrate the precast modules and precast structural wall into one module taking into account the transportation restriction and lifting capacity of the tower crane. The service inside the bathroom module and the connection detail with the external services was carefully planned during the design development phase together with the M&E subcontractor. All the concealed drainpipes and waterproofing work was done in the factory with

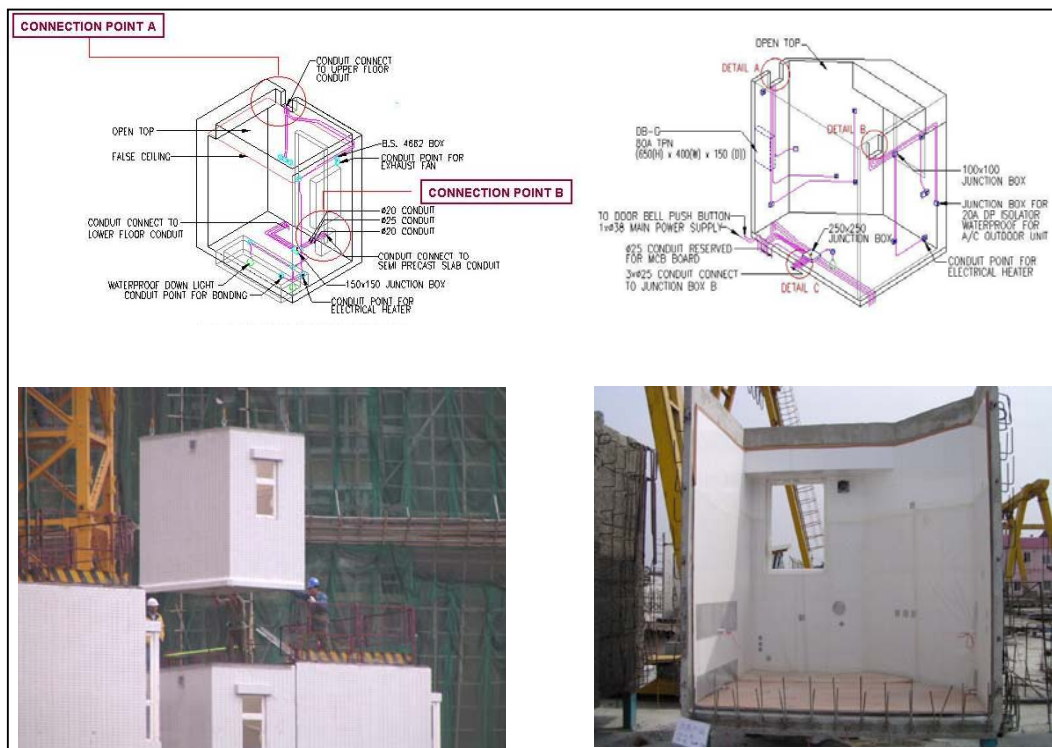


Fig.7 Volumetric precast components

4. Cyclic Load Test and Full Scale Mock-up

Full scale testing for the precast shear wall was performed in order to understand the behavior of the horizontal joint between precast wall panels (Fig.8). The aim of the study was to determine the performance and durability of the horizontal joint of the structural precast wall panel when subject to lateral wind load. The test specimen is selected to simulate the horizontal connection near the 28/F of the typical external wall of the building where maximum inter-storey drift is estimated to occur. The result of the test demonstrated that the horizontal joint of the precast wall performed satisfactorily in terms of load carrying capacity and long-term durability.

After the completion of the design, a full scale mock-up for the precast components (Fig.9) were fabricated and erected in the precaster's yard in Shunde China to examine the connection detail and the build ability of the precast system. With the extensive use of structural precast components in this project, the connections for the precast elements were an essential part of the overall structural support system. In general, grouted connection was used for the horizontal and vertical joint of the precast wall panel. As a basic requirement, the grouted connection had to meet all strength, stiffness, and other performance criteria for serviceability and ultimate limits states. Mock-up trial grouting for the horizontal and vertical joint was carried out in Shunde to confirm the configuration, constructability, grouting performance and grouting procedure for the joint. After finalizing the precasting and connection details for components, a two storey mock-up flat was then erected to check the adequacy of the erection procedure and other connection details.



Fig.8 Cyclic load test for precast wall panel



Fig.9 Full scale mock up

During this process, the main contractor and the precaster advised the size and weight of the precast components within the limitation of transportation, handling and erection capacity of the proposed lifting crane. A detailed method statement for handling, transportation and erection was also prepared for engineering considerations. Based on the proposed installation sequence of precast components and site limitations, the contractor had established a detailed logistics plan of precast component production and delivery schedule to fulfill requirements in the master construction program.

5. Construction Highlights

The entire construction comprised a twenty-two month schedule. The foundations of the building started on February 2003 with the installation of structural steel H-piles. The sub-structure work was completed in August 2003. A comprehensive site planning study at the design stage was carried out to fully appreciate the tower crane's location, storage area for precast elements, and lifting capacity at various reaches (Fig.10).

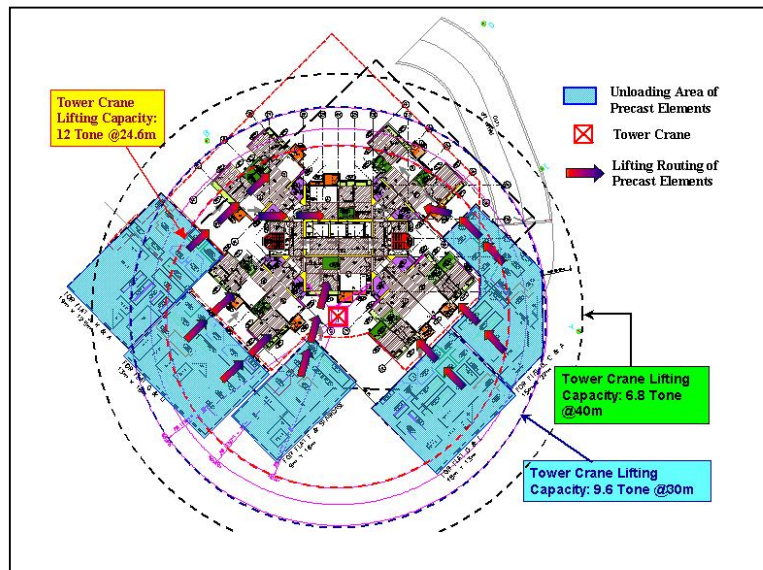


Fig.10 Site planning logistics

Production of the precast components, including the fabrication of steel moulds in Shunde, began two months before the completion of the foundation work. The precast components were shipped by barge to Tuen Mun jetty. This jetty is located close to the site and allowed for further transportation of components by truck trailer. Storage of precast components was done on site. Superstructure work began immediately after the completion of the foundation and pile cap work. Fig.11 shown the precast elements layout on typical floor.

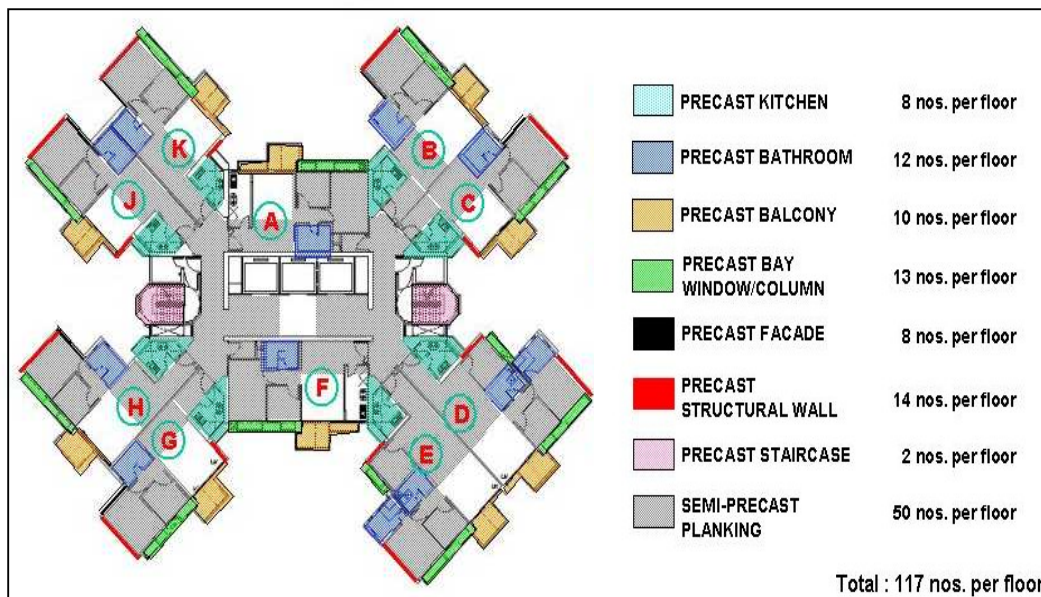


Fig.11 Precast elements layout on typical floor

From the pile cap to the first floor, cast-in-place construction was used. This was necessary because of the non-repetitive elements involved for the first floor. Above the first floor, precast construction was used. Setting the precast members onto the first floor was complicated by the surface profile of the first floor. Considerable time was spent adjusting the level of the surface to ensure all pieces aligned properly between the cast-in-place first floor and the precast members.

Initially, erection of the precast components was slower, but as work progressed an average rate of two and a half floors completion per month was attained. Fig.12 shows various erection phases of the

building. Fig.13 is a completed view of the building amidst other residential high-rises in Fu Tei. The sequence of erection followed the original sequence prepared in the planning stage. A major time benefit was the rapid enclosure of each floor with significant wet trade work being completed in the factory.



Fig.12 Progress photos of building



Fig.13 Completed building elevation

The floor construction cycle took 5 days to complete and started with the placement of the precast concrete up to the sixth floor. The floor was divided into two portions and detailed work breakdown of the typical construction cycle is shown as below. The contractor spent a good deal of effort in engineering the design of a temporary bracing system for the precast members.

Day 1

- Installation of upper stair flights for the floor below
- Installation of precast bay windows with column
- Installation of precast facades
- Installation of 200 and 300 thick precast walls
- Installation of staircase cells & lower stair flights

Day 2

- Final adjustment of installed precast elements
- Grouting of horizontal joints
- Filling of vertical joints with grade 45/10 concrete
- Fixing of wall reinforcement and service conduits

Day 3

- Installation of aluminum formworks for in-situ walls
- Erection of falsework for precast balcony and semi-precast slab
- Installation of precast balcony
- Installation of semi-precast slabs

Day 4

- Installation of precast bathroom units
- Installation of precast kitchens
- Fixing of topping slab reinforcements and service conduits

Day 5

- Placing concrete of topping slabs and in-situ walls.

The 300 ton-meter tower crane (a common type for Hong Kong) was used to erect the precast members and placement of steel mould. Despite being the first structural precast project, the contractor reported that the erection and assembly process was smooth and that noise and pollution were minimal. The construction of the structure frame was completed within nine months and the project finished by December 2004.

6. Conclusions

The demonstration project is evidence of several promising achievements:

- i. As a result of better control over materials and workmanship, precast elements generally have better durability compared to cast in-place structures. Defects, such as tile fall and water leakage in windows and bathrooms, are reduced significantly.
- ii. Wastage of tile, reinforcement, and concrete are found to be 40%, 75% and 65% respectively less as compared with a traditional construction method.
- iii. On site skilled labour requirements were reduced by 30%.
- iv. There was a two-thirds reduction in on site construction waste.
- v. Cost for miscellaneous work such as make good work, rectification work, and site clearance was reduced by 90%.

This innovative project paves the way for a wider use of sustainable construction practices in the local housing industry. The essential factors for this project's success include enthusiasm by the project team, a willingness to share with and learn from others, and careful planning. From a design perspective, the performance and assembly advantage associated with the development of precast concrete system is clear and promising. This project is evidence of the benefits of a true partnering approach in finding innovations that meet client, architect, engineer and contractor requirements, despite also improved construction from the view of costs, productivity, quality, safety and sustainability.

Acknowledgements

The authors gratefully acknowledge New World Development Group for their support to this project. The authors would also like to thank Mr. T C Chu of Hip Hing Construction Company for his visionary contribution in promoting the use of innovative construction technology for this project.

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SUPER-PODIUM: HONG KONG'S NEW MULTI-FUNCTIONAL HOUSING BASE

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Abstract

This paper presents the work of the University of Florida 2004 Hong Kong-China Program, where three faculty along with senior and graduate students conducted on-site analysis of the phenomenon of the *podium* - a big-box, multi-level housing base that incorporates a complex program of amenities. The type is a creative response to the housing market, bringing every amenity from food markets to cinemas to shopping malls to the doorstep of high-rise tower dwellers. Left unchecked, however, podium developments produce a type of high-rise sprawl that abandons the ground plane and threatens the quality of life at street level. As the studio documented the tension between over-inflated podium forms and the intimate scale of the street, it attempted to reclaim the forgotten middle-ground of the city where people ultimately make their place and conduct their daily lives. Through hypothetical podium designs, the work presented here seeks to invert, unfold and unravel the hermetic black hole of the super-podium, and offer guidelines for urban design principles and open-building strategies for this ubiquitous Hong Kong building type.

Keywords : Urban design, Sustainable neighbourhoods, Hong Kong housing, High-rise housing, Open building, Innovative teaching methods.

1. Introduction

During the University of Florida School of Architecture 2004 Hong Kong-China Program, three faculty and 21 senior and graduate students conducted on-site analysis of the urban phenomenon of the *podium* - a big-box, multi-level housing base that incorporates a complex program of urban amenities, now influencing housing developments throughout densely populated cities in Asia. The podium-type, evolving from economies of maximizing large sites for profit, remains an unfinished project of urbanism and place making. Spanning the space of several blocks, the podiums of Hong Kong's New Territories are monumental, overbearing, and unapologetic to existing urban fabric. In clusters of up to 12 towers rising more than 50 stories each and with eight units on a floor, a single block such as *Park Central* in Tseung Kwan-O houses 12,000 or more inhabitants. High-rise podium housing is a highly marketable strategy for developers. It is also arguably a creative response to programming, bringing every amenity from fresh food markets to cinemas to shopping malls right to the doorstep of high-rise tower dwellers. Left unchecked, however, these developments produce a type of high-rise sprawl that abandons the ground plane and threatens the quality of life at street level. As we documented the disparity between over-inflated podium forms and the intimate scale of traditional urban fabric, we found ourselves interested in that which might reside between the small and the large scale, as it is within this forgotten middle-ground that people make their place and conduct their daily lives. (Fig.1) While aiming to amplify the promise of the podium as a dynamic and functional response to changing lifestyles, our research aims to bridge the disparities between a life conducted indoors in one developer's hyper-mall and a life conducted in the organic and free space of street and square.



Fig.1 Intimate scale streets in the old fabric of Sai Kung village (left) vs. pedestrian un-friendly super-scale housing infrastructure of New Territories podium-cities (right).

1.1 Background of the Podium Type.

The housing context in Hong Kong over the last decade, defined predominantly by high-rise towers set on multi-story, multi-functional podia, has evolved out of a successful combination of speculation on the podium economic model; proliferation of the podium as a typological model due to codes of practice; and advertising propaganda relating to the podium-city lifestyle. The phenomenon of Hong Kong's super-speculation stems from policies of land development, but is also tied to specifics of the tower-type itself: the extruded modified cruciform. The modification of the cruciform tower over time has been a drive toward increasing the peripheral surface area within as compact a plan as possible. This increases the quantity and the compaction of units and increases open views, which are highly marketable. Large revenues and returns to both government (through large land-parcel auctions) and private developers are generated, and in an economic and environmental sense, the type has been a very successful construct. Extruded fifty or more stories into the air, podium blocks instantly concretize into built form a planning logic of minimized building cost and maximized real estate potential and house a growing population with extensive natural land area preserved. The proliferation phenomena stems from the super-podium's ability as a type to satisfy demands of growth at great speed and efficiency. Tower construction is typical of southern China's rapidly developing cities: poured-in-place reinforced concrete construction with exposed beams and the typical proliferation of extruded bay windows – a developer response to maximizing code allowances. Thick transfer slabs within the podium allow an appropriate structural grid for parking and transportation levels, but pose a challenge in the design of the podium elevation and limit the potential to open it up sectionally to sky and roof.

In a span of only a few decades, the tower blocks have provided improvements over cramped living conditions still fresh in the memories of two generations of people. In 1954 Hong Kong established a resettlement department to replace thousands of squatter communities, populated by post-war Chinese immigrants, with base-minimal housing. The Housing Authority was also formed, and tens of thousands of people were accommodated in the 6-story gallery slab typology, an extreme application of minimum existence housing. As described by Roger Sherwood in his *Housing Prototypes*, the slab consisted of single room dwelling units for extended families without private kitchens or baths. Only a single door and one window opened onto the breezeway. The cruciform tower block of today represents measurable improvement over these quite recent prototypes. Today's monolithic super-podia and their clusters of modified cruciform towers, are representative of high standards of living and achievement. In the densely populated region of Hong Kong, they also offer real solutions to environmental land use issues and economies. Although criticized from beyond as homogenous vertical sprawl, they are also simply called *home* by millions of people and offer them amenities, conveniences and access to light, fresh air and open (although vertiginous and random) views. (Fig.2) Low income public housing estates and high-end developments alike increasingly share the podium block model, (although the latter often distinguish themselves with classical decoration and more lavish amenities).

Although the region's on-going economic slowdown, together with changing ideals in housing, brings the possibility for new and more varied typologies, including adaptive re-use of existing non-residential buildings, the podium block is a persistently expanding phenomenon. Architects and planners have few

precedents to follow in establishing good urban neighborhoods with the rapidly expanding type. Developers turn to advertising agencies to create the *illusion* of design innovation, while architects merely decorate an ever expanding and impenetrable box. (Fig.3)



Fig.2 From 6-story 1-room 'gallery slabs' to 50-story mock palaces: 1960's housing: horizontal and urbanistically ordered (left- photo from Roger Sherwood *Housing Prototypes*) and today's modified cruciform towers: housing of the sky: vertiginous and urbanistically random (right).

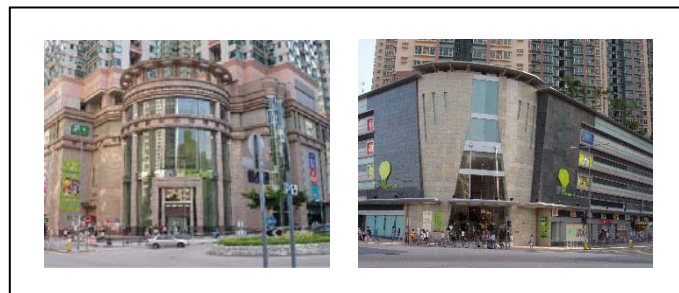


Fig.3 Hong Kong's podium as a decorated template: classical left and contemporary right.

However, as discussed in the article by Sharon and Kevin Coullinane (2003), a culture of huge negative equity now anchors the current generation of home owners, like never before, to their property, and forces an opportunity to construct a sense of social belonging not seen in the super speculation era that created the super-podium and the universal repetition of the cruciform tower block. The economic slowdown provides an opportunity to begin to ask the same questions of Hong Kong's *vertical* sprawl as planning experts do of repetitive suburban sprawl in other parts of the world. In questioning sprawl in his book *Parallax* (2002), visionary architect Steven Holl asks, "is sprawl a spontaneous spreading of democracy or the political accumulation of unprecedented ignorance?" To begin to approach the question of sprawl and develop guidelines for sustainable and humanistic neighborhoods associated with the podium block model, six urban problems and five urban potentials of the type were identified through the studio research:

2. Urban Problems of Podium Typology

1. Massive solidity and impenetrability of the block: The massive structural scale required of the base of 50 story towers leads to a poor street scale, an abandoned ground plane, and a lack of walkability on the podium block perimeter. In accommodating parking garages, taxi stands, and bus stations to serve the tens of thousands living above, the design of the ground plane poses challenges for negotiation of traffic and pedestrians. The perimeter of the podium, a veritable pedestrian wasteland, tends to be a decorated garage and offers nothing to the urban streetscape. (Fig.4) Massive transfer slabs, several meters thick, also pose problems of scale on the elevations of the podium and limit possibilities to puncture the roof plane and create light wells and volumetric connections between podium roofscape and internal spaces.

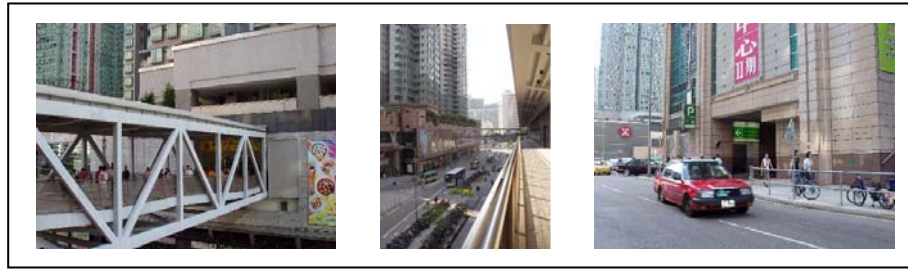


Fig.4 Abandoned pedestrian ground plane

2. Incongruous juxtaposition with existing fabric: Swallowing large tracts of fabric or land and disrupting existing urban form or traditional patterns of settlement, super-podia create an acute urban discontinuity. The super-podium will also cause ongoing problems associated with large-scale redevelopment.

3. Interiority and gatedness: Flat owners seek an understandable degree of security in accessing their residences. This creates conflicting circulation needs for residents and the general non-resident public within the podium. Typically, large areas within the podium are devoted to public and commercial space while some areas are cordoned-off as highly marketable private facilities for residents. These abrupt thresholds of separation pose difficulties in designing the podium block as an organic urban continuum. Robert MacLeod discusses the problem in his essay (2003) on public space in Hong Kong : “this is a simulated public realm, akin to the cultural condition Jean Baudrillard describes in the ‘Ecstasy of Communication’, a contemporary electronic world – and, in [Hong Kong’s] case, a subsequent synthetic public realm...having no place for authentic publicness or privateness.”

4. Lack of natural light and ventilation: Much like in a megamall, the deep interior space of the super-podium is not penetrated by natural light and air, except at the roof-scape. Again, the massive transfer slab between towers and base, makes it even more difficult to incorporate atria, skylights or open-air apertures.

5. Random orientations: As podia become larger and larger, they tend to become designed from an internal point of view. Also, as they span large blocks - and even consume multiple blocks - it becomes more difficult to acknowledge adjacent relationships or create urban clarity and order. Thus super-podia become random in their orientations to context.

6. Uniformity of towers: Besides creating a monotony of repetition and a loss of individual identity, the uniformity of towers, all set permanently upon a structural podium base, creates long-term difficulties where re-development might be needed. In his article on Podium redevelopment problems, Joseph Francis Wong (2003) explains that since towers are typically not varied in their relationship to ground and podium within a block, partial redevelopment and transformation over time is difficult, if not impossible.

3. Urban Potentials of Podium Typology

1. Infrastructure/transport interface and commuter convenience: The podium has the potential to be understood as essentially infrastructural and urbanistic. Some 55% of residents in the New Territories commute to work on Hong Kong Island or Kowloon (Hong Kong Census and Statistics Dept., 2002). In order to mature as an urban form, architects must find ways to construct a sense of belonging and of “address” within the podium without blanketing an entire development in superficial aesthetic styles. Rather, a sense of place should be imparted through programmed, experiential space that mediates between residential territory of towers and infrastructural realms of podium and surrounding context.

2. Marketplace programs, convenience, and “walkability” within the podium: Ultimately, the podium (in its scale and its intense hybridity with an emphasis on shopping and leisure) is typologically connected to the historic precedent of the marketplace, and has the potential as such to become a meaningful urban construct, helping to define the public dimension of contemporary life in greater Hong Kong.

3. Dynamic interface of public and private realms: The interface of public and private in the podium block is complex and challenging. However, the potential exists for a symbiosis between the two: residents, who view the podium block as their immediate neighborhood maintain a strong sense of concern and connection to the development; while the non-resident user, who relies on a cluster of several blocks as they conduct their lives in and out of the podium-city, extends a vital connectedness to the larger surrounding context.

4. High Density: The high density of populations housed in podium-cities preserves the largest possible amount of natural land for universal use. However the preservation of smaller-scale development patterns remains critical, and the podium scale should not automatically trump lower-density conditions. The podium should not be an “eraser” of existing fabric and villages, nor should it turn it’s back on them.

5. Light, air, and view: Openness to air, light, and views on the podium roof-scape (and from within generously spaced towers) is an understandable need in a noisy, dense urban context. The podium block will continue to proliferate because of its satisfaction of this need. The potential for architectural mastery of light, view, and natural breezes within the spatial and material design of the podium is great. (Fig.5)



Fig.5 View from a podium exhibits a sense of openness and light, a much sought-after release from dense urbanism.

4. Podium-city Investigations

Podium buildings throughout the new territories, and emerging within established urban areas, follow well-known developers’ formulas, originating largely through proven, but unimaginative, speculative real estate strategies and antiquated building development codes. It is our challenge to reconsider the concept of podium and podia not just as a type, but also as an urban condition. Designers and planners must allow the possibilities of this ambitious ‘super-vernacular’ design type to be infused with critical urban theory as well as imagination. How might a super-podium make a fluid connection to humanly scaled streets and plazas rather than turning its back to existing building fabric? How might its form be designed with a mind to open-building strategies to enable it to adapt to changing lifestyles, population growth, and the maturing of a neighborhood? The work of this studio aims to address the above urban design and sustainability issues through hypothetical drawings and diagrams that invert, unfold, unravel, and loosen the hermetic black hole of the super-podium, and offer guidelines for applying more humanistic and more site-specific design strategies to this urban phenomenon.

Although broad-based in its implications, the work does not specifically study issues of podium structural systems, materials and methods of construction, or mechanical systems, which are outside the scope of our investigations. The focus is on sectional models and drawings and studies of building “skins” and “scapes,” where the podium is investigated both as a physical and a theoretical urban condition. Plexi-glass is used as a primary material in the models to induce a sense of light and transparency to the hermetic box of the podium. Being outside the objectives of the research to design a podium in exhaustive detail, investigations focus on podium edges and public open space at grade, as well as roof-scapes, internal circulation, and open space design within the block (Fig.6).

Architect Greg Lynn (2004) states that, “tall buildings are turning into urban fabrics as architects are thinking about how to pull the qualities of the street into the building.” Our stage one drawings and photographs similarly attempt to conscientiously construct joints, pockets, and portals to patterns of street-

life, intertwining street and podium to invest the latter with the humanizing qualities of the former (Fig.7). While speculating on an alternate existence to the urban realm of podium form, the stage one studies aim to amplify the promise of the podium as a dynamic and functional response to changing lifestyles while retaining the organic and free space of street and square.



Fig.6 J.U. Lee presents stage one urban analysis drawings in the Hong Kong studio facilities (left); S. Shirah develops stage two model - high-rise housing (center); Professor Robert MacLeod reviews students' stage two designs (right).



Fig.7 Stage one analytical digital constructions where students draw podium design cues from Hong Kong's streetscapes. C. Anderson (left), R. Gelles (right).

5. Podium Experimental Design Inquiry

In stage two of the work, students selected one of two typical site conditions for a hypothetical podium development that would best demonstrate their urban theories: In the typical *open field site*, located in the New Territories high-rise suburban context, the podium is an object bounded on four sides by roads. To the north (and rear of the site) there are mountains, and to the south a distant harbor-view. In this site the MTR intersection point is located 1 block away, requiring a link, either above, below or at grade. Major bus and taxi hubs are incorporated within. In the typical *congested site*, located near older fabric of Hong Kong or Kowloon, the podium is embedded in a dense, low to mid-rise context. To the south there is a major road, to the north a secondary road. The east and west edges of the site are bounded by older, architecturally insignificant seven to twelve-story buildings separated from the podium block with narrow streets. The MTR intersection is linked to the block directly. Bus and taxi stops are incorporated. (Fig.8)

Specificity of individual designs was driven by investigations into innovative programming. As a program-intensive type, the super-podium intermingles the banal with the bizarre, the everyday with the celebratory. Eight programs of everyday life, typically integrated into traditional urban fabric in Hong Kong but dispersed in the new towns, were selected as core functions for the designs: housing _ worship _ open space _ shop _ park(ing) _ play _ learn _ work. These 8 conditions make up the common program-base of each project, while qualities of light, material, and atmosphere of the traditional street - studied in stage 1 - inform the phenomenological, tactile, and sensual quality of space, and serve as a reminder of the importance of detail, everyday routines, and humanly scaled elements. The programs are not limited to the eight core functions. Rather each design expands independently on them as the specific neighborhood context calls for. The designs aim to induce a broad urban complexity and a layered synthesis of conditions, and arrived collectively at a set of urban design guidelines to improve and enhance quality of life in *podium-cities*.

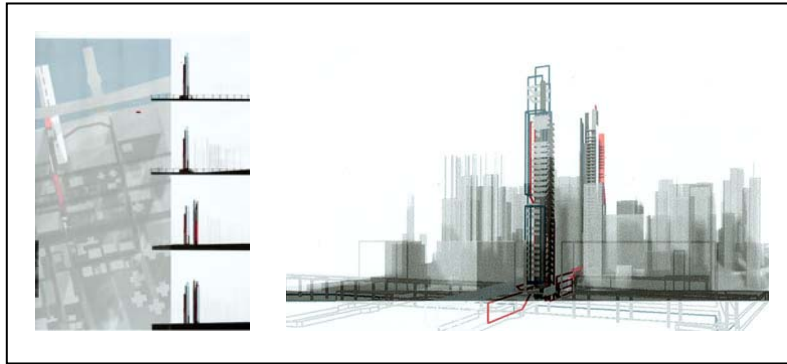


Fig.8 Podium stage two designs by S. Shirah located in North Point, Hong Kong

6. Urban Design Guidelines

1. Localize the podium: Encourage variety and depth of concept and theme beyond commercial considerations to create specificity of place; acknowledgement of neighborhood history and culture; connections and views to significant natural features, villages, or monuments. (Fig.9)

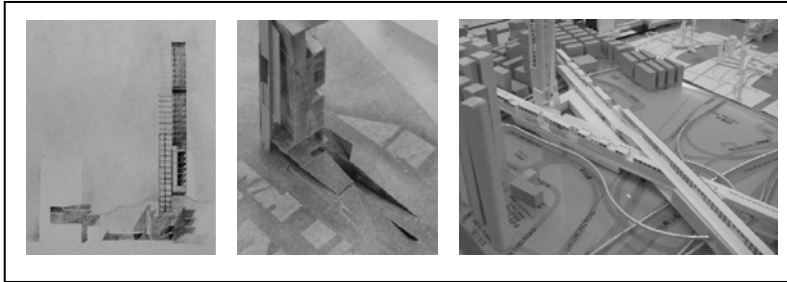


Fig.9 Site-specific design for a mountainous New Territories context (C. Anderson); Marking the ground with a memory of historic fabric in Kowloon (S. Yip); site-specific urban gesture for a super podium in west Kowloon (D. Crabtree).

2. Infrastructuralize and apply open-building strategies: Vary tower footprints and bases where they interface with the podium to alleviate longer-term problems associated with redevelopment and to create spatial variations suitable for dynamic open-space programming within the block. Allow some towers to penetrate the podium and land on open void space while others remain elevated on the transfer slab to accommodate parking and transport at grade and podium levels. (Fig.10)

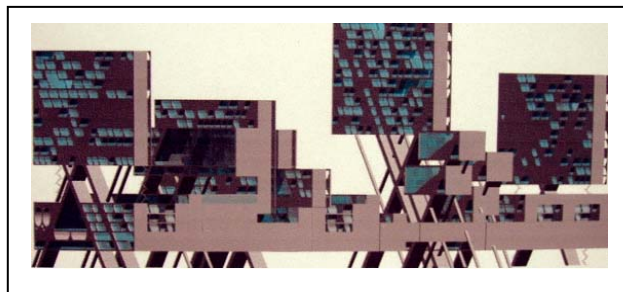


Fig.10 Tower variations with different relationships to ground and podium. (R. Gelles).

3. Incorporate sky gardens at intervals within towers: alleviates tower uniformity and imparts a sense of identity; creates semi-public or resident-only leisure and recreation realms that free portions of the podium roofscape for volumetric light wells and other public linkages to the inner podium. (Fig.11)

4. *Landscape the edges of the podium* (not just the top): Extend landscaping considerations from the podium roof along edges and down to street level to make the perimeter streetscape more dynamic and more hospitable to walking, waiting for buses and taxis, etc.

5. *Incorporate flexible, adaptable commercial space* at the sidewalk and ground plane in a manner consistent with existing urban street life, and as an extension of the internal pedestrian/shopping experience of the podium. (Fig.12)

6. *Carve out open-air plazas on the podium perimeter*, at the ground plane and above, that create multiple entries (locations based on surrounding conditions) to the podium interior and offer pedestrian recesses from busy traffic streets. Incorporate plaza-scaping, water features, and public art –continuous with the interior public spaces of the podium - to create public places that mediate between inside and outside.

7. *Design podium elevations in direct response to internal programs*: That is, allow shops, parking, health clubs, etc. to be visible from the street rather than cladding the podium in decorative, formal elevations with no relationship to the program within.

8. *Expand and increase the plurality of programs* within the podium to include more free public amenities including atria and multifunction spaces for performance and gathering; pocket-gardens of naturally lit, planted and ventilated spaces; sports and recreational spaces; small libraries; post offices, etc.

9. *Program the linkages*: Activate linkages between podia by programming walking bridges and subways with kiosks, public art, resting places, natural light and carefully designed signs and symbols. (Fig.13)

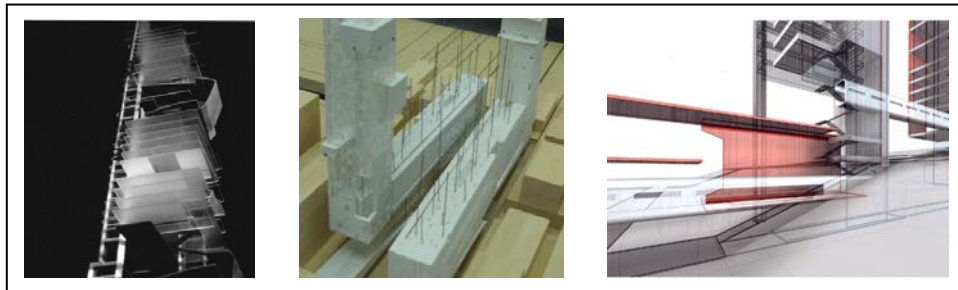


Fig.11 Sky gardens (S.Yip); Fig. 12 shopping street folds into the podium (A. Casey); Fig. 13 Programmed infrastructural linkages (S. Shirah)

7. Discussions

In Hong Kong's New Towns, mostly in the New Territories region, placelessness is acutely felt. Almost instantly metamorphosed from very rural to very urban, the area exhibits the difficult characteristics of the vertical sprawl city (discussed in previous work by the author, 2003). The lack of continuity in Hong Kong's new town urbanism also attracts criticism for lacking the kind of beauty of denser parts of old Hong Kong and Kowloon. Density there is understood in itself as being diverse, complex, intricate, and immediate. Tall density, the dominant characteristic of podium cities, is not as obviously so. Abutments, connections, and layers of activities that render meaningful human associations are lacking. Millions of people live together yet apart in a perceptually *sparse-density*. It has a paradoxical dense-emptiness that is yet to be tapped.

The podium, a multi-story, city-in-a-box beneath the towers, is the programmatic life-support of the residential development, but the enemy of the streetscape around it. Anchoring public space solely to the podium (itself adrift from the urban fabric) or solely to the ground plane (primarily leftover space), will not suffice. It is essentially in the relationship *between* the podium and the ground plane that public space must originate. This is clearly a joint responsibility requiring greater design communication between government and private developers. It is hoped that this work will contribute, and add direction, to the ongoing dialogue surrounding the urban considerations of Hong Kong's unique podium building typology and ultimately

encourage a richer, more experiential, and less alienating urbanism in the greater Hong Kong/New Territories continuum.

8. Conclusions

The implications of working within such an immeasurably large and common building type under constant evolution, but not widely understood, in order to enhance quality of life and connection to place in Hong Kong, are broad-based and significant. We have approached the podium more as *a template* than as a building, in order to uncover a new kind of urban space and propose design guidelines for “opening up” the podium box and preventing it from swallowing the block and erasing a sense of neighborhood. It is hoped that the underpinnings of the project will be understood as having applications at multiple scales and will lead to further investigations on the transformation of housing infrastructure in Hong Kong.

Acknowledgements

Associate Professor Robert M. MacLeod and Associate Professor Dr. Diana Bitz, The University of Florida School of Architecture; Essy Baniassad, Chair, The Chinese University of Hong Kong for providing studio space and resources for students and faculty. All photos by author and Robert M. MacLeod except where specified.

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THE PTM ZEO BUILDING

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Abstract

The new headquarter for Pusat Tenaga Malaysia is designed to be a Zero Emission Office Building, or a ZEO Building. A full range of passive and active energy efficiency measures are implemented such that the building will need no more electricity than what can be produced via its own Building Integrated photo-voltaic (PV) system. The overall objective of the project is to achieve zero energy consumption at lowest possible initial investments. Advanced computer design tools have been used throughout the design process.

The paper highlights the implementation of the integrated design concepts in ZEO Building where active and passive energy systems are interwoven into the building itself, and where several building elements serve as energy systems. This integration helps to bring the extra costs of the building down, and hence the economic feasibility of the ZEO building concept is improved. A detailed description of the passive design features, energy efficiency measures and photo voltaic system is presented.

Keywords : Energy Efficiency, Photo-voltaic (PV), Zero Energy, Floor Slab Cooling, Radiant roof.

1. Introduction

The New PTM Zero Energy Office Building (ZEO Building) is presently being designed. Construction of the main building will start in June 2005, and completion is expected in August 2006. This 4000 m² building in Banghi will be the new building for PTM, and in line with the scope for PTM, the new building will in itself be a research and demonstration building for new energy technologies in buildings in Malaysia. The new PTM building aims to demonstrate that an office building need not consume any electricity from fossil fuels. All electricity needed by the building will be produced by the buildings own Photo-Voltaic System (PV System).

The development of the PTM ZEO building is a logical continuation of the work behind the MEWC Low Energy Office Building(LEO Building) in Putrajaya. The LEO Building is designed to have an Energy Index of approximately 100 kWh/m²year. The LEO building is aimed at demonstrating state of the art energy technologies that can be applied in new non-domestic buildings now, technologies that are both technically and economically feasible.

The computer modeling of the LEO building indicated that it was in fact technically possible to reduce the Energy Index of an office building to approximately 50 kWh/m²year. The measures that would bring down the EI from 100 to 50 are not economically feasible in today's context, with relatively low electricity rates and with technologies that are still relatively expensive due to little market share and small volume productions. However, all these technologies, such as super energy efficient double glazing and super low energy office equipment are in the future likely to become economically feasible.

In Malaysia, Solar PV elements will produce approximately 150 kWh per m² roof per year. Therefore, if a three storey building with an Energy Index of 50 kWh/m²year has a roof covered with Solar PV elements, the PV system will be able to produce all the electricity needed by the building. This is the simple logic of how to get to a Zero Energy Office Building, or ZEO Building.

The building will be powered only by the sun falling onto the roof and by the daylight entering the windows.

The climate in Malaysia is very appropriate for exploitation of renewable energies for climatisation and running of buildings. The largest renewable energy sources in Malaysia are daylight and solar energy. The PTM building shall utilize these renewable energy sources to the maximum.

The PTM ZEO Building will be the first building of its kind in SE Asia, and it will be a landmark building in the strive towards developing fully sustainable building that does not require fossil fuels at all. The PTM building will be a test bed for innovative energy technologies, for the benefit of Malaysian building industry and academia.

2. How Zero Energy Consumption is Achieved

In the Design Brief of the ZEO building, the overall energy design objective for the building is formulated as “achieving zero energy consumption at least construction costs”. Since PV electricity is still quite expensive, this means that investments in energy saving technologies can be stretched much further than under normal economical conditions. Energy saving technologies that are relatively expensive can be applied. At present, where the building is under development, it seems that an Energy Index of approximately 40 kWh/m²year and a resulting PV area of 85 kW_{peak} is close to the optimum. The area of this PV system is approximately 700 m², depending on the PV technology applied.

3. The key energy saving strategies

Reducing the energy consumption to approximately 40 kWh/m²year is achieved by applying a host of energy saving strategies in building design, design of the mechanical and electric system and in choice of energy efficient office equipment. However, the following areas are the main contributors to the low energy consumption :

- An energy efficient building envelope with super energy efficient glazing and well insulated walls and roofs.
- Use of daylight as the only source of lighting during daytime.
- Use of energy efficient office equipment

The diagram above shows the influence of some of the design parameters of the building. To the left is the Energy Index of the present building design, a design that will be improved during the detailed design phase of the coming months. Each of the bars shows the influence of changing one parameter from the present building design.

The actual design has double glazing with low emissive coating and spectrally selective coating. This glazing has a shading coefficient of 25% only, that is only 25% of the solar radiation is transmitted through the glazing. The daylight transmission coefficient is 50%, and this favorable difference in transmission coefficient of sun and daylight creates the spectrally selective glazing, glazing that lets in more daylight than sunlight.

If the glazing would not have been spectrally selective, and had let in 50% radiation, the energy consumption increases by 8%. If the glazing would only be single glazing, the energy consumption would increase by 22% compared to case 1. It is also seen that if there was no exterior shading in the form of an

exterior overhang over the windows, then the energy consumption would increase by 3%, similar to if the building had windows to the east and west instead of to the north and south.

It should be noted, that the influence of orientation and shading would have been much more profound if the base case was not a building with super efficient glazing but a building with single glazing. The high performance glazing reduces the penalty of having a non-ideal orientation or having no exterior shading.

It is noted that if the building did not use 100% daylight during daytime, but had to rely on electric lighting (energy efficient), then the energy index would increase by 35% !! If traditional office equipment were used instead of energy efficient office equipment, then the energy index would increase by 30%.

These results of the computer modeling clearly demonstrates the importance of having high performance glazing, using daylight instead of electric lighting and using energy efficient office equipment. Without these key energy saving measures, it would be impossible to reduce the energy consumption of the building to around 41 kWh/m²year, and thus it would be impossible to cover that energy consumption with a PV system integrated in the roof. The necessary PV area would simply be exorbitantly large and very expensive.

4. Overall design

4.1 Building Integrated PV

The building will have a Solar PV system integrated in the roof of the building, a Building Integrated PV System (BIPV System). The BIPV system is designed to cover all the electricity load of the building. The BIPV system of the new PTM ZEO building will become one of the National Demonstration projects for BIPV under the coming program for the promotion of grid connected BIPV in Malaysia. This program is funded by the United Nations Development Program, the Global Environmental Facility, the Government of Malaysia and PV companies in cooperation. This 5 year program starts in 2005 and runs until 2009.

The production of electricity from PV elements is fully sustainable and based on the abundant amount of solar energy available as a renewable energy source. Furthermore, the production of electricity from PV in Malaysia fits very well with the demand curve for electricity, which is shown in the diagram below.

It is seen that the maximum electricity demand occurs between 10.00 in the morning and 05.00 in the afternoon. This is also the period where the performance of the PV system will be largest. The PV system of the PTM building will be inclined 15 degrees to the west. Therefore, production will be slightly larger in the afternoon.

PV power is therefore ideal as a peak shaving measure, input of PV occurs when it is mostly needed. This is the main strategy in the coming UNDP/GEF program on BIPV in Malaysia.

However, in the PTM building, the positive effect of using PV is double. Firstly, the building will need very little electricity during daytime because the necessary load is covered by the buildings own PV system. Secondly, most of the PV power produced by the PV system is fed into the electricity grid during daytime. This is possible because the chiller of the building will operate only during night time. During daytime, chilled water for cooling of the building is sourced from a system of chilled water storage, as explained later. The electricity used by the chillers during nighttime is drawn from the grid, and the amount will be equivalent to the electricity exported to the grid during daytime. This makes the building into a Zero Energy building, which in addition shown how PV can be coupled to the electric grid to provide further advantages to the utilities.

4.2 High Performance Glazing

Electric lighting is a major source of electricity consumption in office buildings. Furthermore, the heat generated from the electric lighting also increases the electricity consumption for cooling.

The diagram shown the energy content of daylight/sunlight for varying wavelength. Visible light occurs between 750 and 400 nm, and visible light accounts for approximately 50% of the energy in daylight. The rest of the radiation, ultraviolet and infrared radiation is invisible, and in energy terms it is “heat only”. It is preferable to let only the visible light into the building, and not to let the heat only part in. This is possible with a new generation of advanced glazing, so-called Spectrally Selective Glazing.

Spectrally selective glazing is sealed double glazing, where one of the surfaces towards the cavity has a thin invisible coating which reflects the major part of IR and UV light back to the ambient. The PTM building will use this new advanced glazing type, and this glazing is key to use natural daylight and at the same time to avoid unnecessary radiation into the building.

4.3 100% Day Lit During Daytime

Electricity for lighting in an office building may consume 30 – 40 kWh/m²year. In Malaysia, daylight can potentially cover most of that lighting load, as daylight is abundantly available outside the building throughout normal office hours 08.00 – 18.00. However there are a number of constraints that means that this potential for free daylight is not used in buildings today.

Daylight is easily available near the windows, whereas it is more difficult to provide daylight deep in a building. Furthermore, admission of daylight into a room often causes glare and discomfort due to the high radiation level in Malaysia.

However, the energy saving potential using daylight is as shown very large, and the occurrence of advanced spectrally selective glazing that transmits only “cool daylight” has led to that use of daylight has been defined as one of the key energy saving technologies to be implemented in the PTM ZEO building.

In order to develop the right design that will transmit daylight deep into the building, and in order to achieve a design that does not cause glare, a full scale test cell for testing daylight will be constructed. In this 6x6 meter test room various window and shading systems will be installed and tested, in order to arrive at the optimal system to be installed in the ZEO building.

4.4 Concrete Floor Slabs with Thermal Storage and Radiant Cooling

The chiller of the building will run only during nighttime in order not to use electricity for cooling during daytime where the pressure for electricity consumption is largest. Here the concrete floor slabs will play a key role in storing cooling from nighttime to daytime.

The concrete floor slabs will have embedded tubes that allow the floor slabs to be cooled down at night. The cooling will be released from the floor slabs to the rooms above and below during daytime. Due to the thermal capacity of the concrete, there is a delay between active input of cooling and passive release of cooling.

The concrete floor slabs will provide part of the cooling load to the rooms during daytime. This cooling will be supplemented by cooling provided by a conventional air cooling system. The performance of the air cooling system will be regulated so that the sum of cooling released from the floor slabs and from the air system is adequate to cover the cooling load needed for the actual room or zone of the building. In some rooms, such as on the top floor, a hydro radiant ceiling cooling system will be installed, and there will be no concrete floor slab above the top floor.

The floor slabs provide part of the storage needed for cooling, and they transmit part of the cooling load to the rooms. The advantages are that storage is provided without using storage tanks with chilled water. Furthermore, providing cooling using water as heat transfer medium instead of air is much more effective. Pumping water requires only a fraction of the electricity compared to pumping air.

The air handling system is still needed, but it can be reduced in size. The air handling system will provide dehumidification of the air, and it will balance the passive output of cooling from the floor slabs with active cooling input, so that the required room temperature is achieved.

The part of the cooling which is provided by the air handling units during daytime will come from storage tanks using chilled water as storage medium. So storage of cooling from night to day is provided partially by the floor slabs and partially by the water storage tanks.

4.5 Trickling Night Cooling Roof

The release of heat from the chillers will normally be via cooling towers. However, for the PTM building, another system is being considered. The chillers will run only during night time, and the heat may be released from the PV roof by trickling water over the slope of the roof. Water will be added at the ridge of the roof, and will be collected at gutter. Heat will be released from the wet roof through radiation to the night sky, through convection and through evaporation.

Initial calculations suggest that such a trickling roof system is interesting, as enough heat can be released at relatively low water temperatures (25 – 35 °C). It has to be noted that as the cooling load of the ZEO building is very low compared to a traditional building, so is the amount of heat that has to be released. For a conventional building with a much higher cooling load, it would normally not be possible to use the roof as the “cooling tower”. Also, during daytime a wet roof is not useful as a “cooling tower”, as solar energy will heat up the water.

As part of the design of the trickling roof, a small mock up of a roof will be built, and the performance of a trickling roof during night time will be tested.

4.6 Fresh Air and Dehumidification.

Dehumidification of the air is as important in this building as in any building, in order to provide comfort for the users. Furthermore, effective dehumidification is necessary to avoid condensation on cold surfaces, such as the cool concrete floor slabs.

Dehumidification of the air in the building is expensive in electricity consumption. Therefore several measures will be implemented to reduce the load caused by dehumidification. It will be considered to use a so-called desiccant heat wheel, that is a heat wheel that will cool and dehumidify the incoming hot and humid fresh air by exchanging to the relatively cool and dry exhaust air. Furthermore, the amount of fresh air will be controlled according to the CO₂ level of the air in the building. This allows the amount of fresh air to be controlled according to the number of occupants in the building. The more occupants, the more CO₂ emission and the more fresh air will be provided. Finally, it is important to build and to keep the building very airtight, so that hot and humid air does not enter the building through cracks and openings.

4.7 Energy Efficient Office Equipment

The use of energy efficient office equipment has proven to be crucial to achieve the very low electricity load of the building, in the region of 40 – 50 kWh/m²year. In a modern office where most people have their own computer, the installed capacity for office equipment can easily be corresponding to 10 W/m² office space. This is equivalent to an annual electricity consumption of 25 kWh/m²year. Adding the cooling load caused by the office equipment, the total electricity load caused by office equipment amounts to 30 – 35 kWh/m²year, depending on the efficiency of the chiller installed.

However, using only the most energy efficient office equipment available, the installed load can be reduced to around 2.5 W/m². It has therefore been decided by the management of PTM that purchase of new office equipment from now on will be predominantly buying the most energy efficient equipment. This means that when PTM will migrate the new building in less than two years time, most office equipment will be super energy efficient, suitable to the scope for the new building.

A feasibility study was performed, comparing the use of the more energy efficient laptop computers to traditional desktop computers, with the energy efficient flat screens. The extra costs of a laptop PC compared to a desktop of similar performance was found to be ~ RM 1, 100 per unit. However, providing extra PV power to cater for the increased energy consumption of the desktop was found to be more expensive, ~ RM 2,600 per PC. Hence it is more feasible to opt for the more costly and more energy efficient laptop PCs.

It should be noted that this result is obviously triggered by the relatively expensive PV power. However, with the reduction in costs for energy efficient flat screens and energy efficient laptops, the trend will be that flat screen computers or laptops are to be preferred in any case.

4.8 Integrated Design Development of the Building and Its Energy Systems.

The development of the PTM ZEO building is done using the approach of integrated design development, using advanced computer design tools in the process.

By using computer modeling from day 1 in the design process, strategic design decisions can be made early in the design, where this is possible. One example is that the benefits of using high performance windows can be predicted early on, benefits of reduced cooling load and also benefits of reduced size of the chiller and reduced size of the cooling system. The computer design tools are thus used to optimise the architectural design of the building in harmony with the optimal design of the mechanical and electrical systems, in order to achieve the goal of zero energy consumption at the least investment cost.

4.9 Other Measures to Improve Energy Efficiency.

Beyond the various innovative energy solutions mentioned above, a host of good practice and good housekeeping measures are implemented in the design to reduce energy consumption. However, compared to a traditional well designed building, such as the MEWC LEO building, in this case these good practice measures are being evaluated very carefully, and their performance typically be chosen to be the best possible on the market. This is because the PV electricity is expensive, and more investments in better performance can be justified.

These good practice solutions include on the architectural side use of external window shading, and use of well insulated walls and roofs. Within the regime of M&E systems, pumps and fans will have very high efficiencies, and pipes and ducts will be designed for very low resistances.

The chillers will be designed to take advantage of a high off coil temperature and a low condenser temperature, in order to improve the efficiency of the chiller and reduce electricity consumption. The air cooling system will be of the Variable Air Volume type, and all pumps and fans will have Variable Speed Drives, measures that are now finding its way also in more conventional buildings.

The electric lighting system will not be on to the same level as in a conventional office building. However, the most energy efficient equipment will be used in order to reduce the electricity bill for lighting even further, beyond what is achieved by the use of daylight as the prime light source. In order to optimise the performance of the electric lighting system, lighting will be controlled according to demand in all zones of the building. Occupancy sensors and daylight sensors will see to that electric lighting is only on when daylight is insufficient and only in those rooms that are occupied.

5. Conclusions

The energy design of the PTM Zero Energy Office Building (ZEO Building) rely on comprehensive use of renewable energies and on building integrated design technologies. The ZEO building is “designed as an energy system, thereby reducing the need for active energy systems in the building”. The key energy

efficiency strategies include use of high performance glazing, N/S orientation of the building and use of high efficiency lighting and office equipment. Daylight provides nearly all lighting needed during daytime.

The innovative floor slab cooling system means that floors and ceilings are cool, thereby allowing the air temperature to be higher, up to 25 – 27 °C, without compromising user comfort. The sensible heat load can be removed using off coil temperatures of 18 – 22 °C, which improves chiller efficiency drastically compared to the normal off coil temperatures of 6 – 8 °C. Furthermore, the sensible cooling load itself is reduced because of the higher air temperatures in the building.

The building is driven by renewable energy only: daylight falling through the windows and solar radiation falling onto the roof.

The ZEO Building aims to demonstrate that it is indeed possible today to build buildings in the tropics that do not need any fossil fuel, yet buildings that still meet the highest standards on indoor climate. All the technologies that are used to achieve this are off the shelf products that are technically feasible today. The ZEO Building project aims to stimulate further development of building components and systems such that in the near future, buildings that do not consume any fossil fuels are also the right choice in an overall economic context.

ZONE AT SYDNEY OLYMPIC PARK – A CASE STUDY ON THE UNDER-FLOOR VENTILATION IN A SPECULATIVE OFFICE BUILDING

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Abstract

Connell Wagner is the design engineer for the Zone at Sydney Olympic Park project in Australia, a 42,000m², three building campus style development. This project incorporates a wide range of integrated ESD features into a speculative commercial office design which includes an under-floor ventilation system. The development is currently being marketed prior to construction.

The process of developing an under-floor air conditioning system for this project involved research, risk management and extensive modeling as well understanding the needs of a tenant likely to be attracted to this type of building.

This paper describes the process that was developed and key findings from various studies that were undertaken during the modeling phase of the design program.

Keywords : Sustainable buildings, Under-floor ventilation, Air conditioning, CFD modeling.

1. Introduction

“Zone” is a speculative office development comprising 3 six storey office buildings within part of a site previously dedicated to the Sydney Olympic Games held in 2000. The total development consists of a net lease area of 42,000m² and parking for 900 cars.

The agreement to lease from the beneficial owner of the site, the Sydney Olympic Park Authority, required a commitment from the developer to clear and unequivocal ESD principles.

To help secure the rights to this site, the developer commissioned a design that focussed on:

- *Quality of the Indoor Environment* with high ceilings (3100mm), a mixture of direct and indirect lighting, daylighting and improved indoor air quality using underfloor ventilation as shown in Fig.1
- *Energy Efficiency* with double glazing, low “e” glass, twin 600mm deep external sun shades, high efficiency chillers, T5 lighting linked to perimeter PE cells, CO controlled car park ventilation
- *Sustainability Features* with recycled water for flushing, cooling towers and landscaping; no PVC for cables or piping; and roof mounted wind turbines

However the building was speculative and had to be capable of attracting tenants in an open market environment notwithstanding the constraints of the prevailing rentals compared with likely construction costs and the geographical location of the site which is essentially a campus style office park.

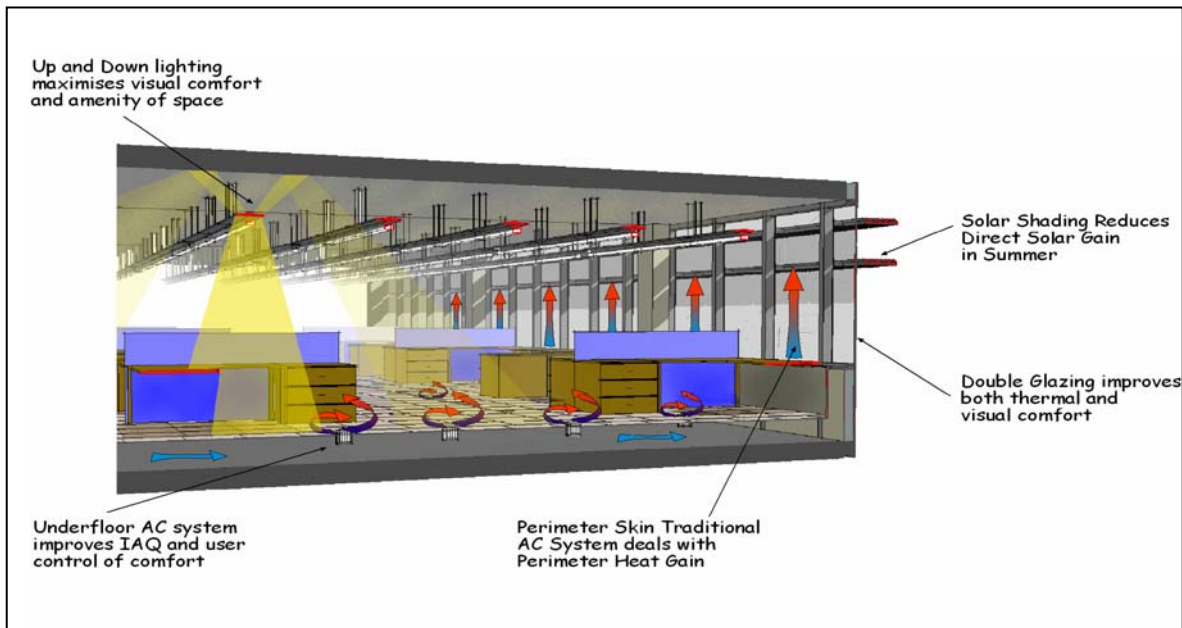


Fig.1 Features of the Indoor Environment

Being speculative, the building had to appeal to, and accommodate a broad range of possible tenants. In terms of mechanical services it had to air conditioned to market expectations, adaptable to suit offices, meeting rooms, service centres and the like, and it had to be comfortable with even temperatures and moderate air movement.

Whilst underfloor ventilation has many appealing features, the fact that it is so fundamentally different to a conventional overhead system means the commitment to such a system has considerable risks associated with each of the features required of an air conditioned building noted above. This is particularly the case when the development is essentially speculative.

Therefore the designers of the underfloor ventilation system adopted a comprehensive process of risk management, modelling, peer review and transparency in deriving a solution to suit the particular requirements of the project.

This paper focuses on the extensive modelling that was undertaken to develop confidence in the concept and to help understand the sensitivities that have to be managed during the ongoing design and construction.

2. General Concept of an Underfloor Ventilation System

Conventional air conditioning systems in buildings typically use an overhead system of ductwork that delivers and mixes low temperature air (12-13°C) throughout the occupied space to provide cooling and to meet the ventilation requirements of the space.

Standard ceiling diffusers and other similar terminal devices have been developed over time to promote mixing without creating drafts. Similarly the system of ductwork and/or in-ceiling equipment such as VAV boxes and fan coil units can provide separate air conditioning zones for different areas within the building to suit its orientation, occupancy or usage.

Under-floor air distribution is promoted as an alternative to a system of overhead ductwork with advantages in the following areas:

- air is distributed using pressurised floor plenums rather than ductwork which saves material and space
- air can be delivered closer to where it is needed by positioning floor outlets as required
- delivering air at floor level and drawing it away from the space at high level means that air quality is improved because internally generated pollutants generally move upwards and away from occupants rather than being re-mixed by an overhead delivery system that forces the air down
- the net upward movement of air promotes temperature stratification in the space which means less cooling needs to be delivered to the occupied zone compared with a conventional system where much of the heat of lights and similar is forced back down by the overhead delivery system

3. Key Features and Challenges of Underfloor Ventilation

Underfloor ventilation systems in an office environment are generally characterised by the following:

- (a) Air distribution is through large plenums created by a raised or false floor that also serves as a means of reticulating power and communications cabling and other services. Separate air conditioning zones can be created by partitioning within the plenum. For construction reasons, these partitioned zones are generally much larger than conventional overhead air conditioning zones.
- (b) Supply air temperatures are 5-6°C higher than a conventional overhead system to improve buoyancy and reduce adverse temperature gradients close to the floor.
- (c) Specially designed floor outlets that promote a high degree of mixing are used. These outlets generally have a lower capacity than a typical overhead or ceiling mounted outlets
- (d) Air is returned at ceiling level to a central air handling plant

Each of these features creates challenges for the designer seeking a cost effective and adaptable solution. These include:

- *Plenum Challenges* : Issues associated with creating a separate perimeter zone, accommodating multiple internal zones to suit varying uses, and supply air temperature pick-up from the slab below and occupied space above must all be addressed
- *Supply Air Challenges* : With higher supply air temperatures, larger air quantities are required to provide the same degree of cooling, and hence there is a greater risk of drafts. Similarly higher air quantities and higher air movement can disrupt the thermal stratification that underfloor ventilation seeks to establish
- *Floor Outlet Challenges* : There is a need to establish the optimum number of floor outlets by balancing the risk of draft and disturbing the stratification layer using a smaller number of outlets operating at their upper band, or creating congestion at floor level and reducing flexibility with more outlets. Also there needs to be confidence that a large expansive plenum will be self balancing in terms of air supply at each outlet. The high air volumes required in perimeter zones is not readily compatible with the use of floor outlets.
- *Return Air Challenges* : Return air at high level can disturb the stratification layer.

The design of an underfloor ventilation system must address each of these issues and a methodical approach to analysis and resolution needs to be adopted if there is to be confidence in the solutions being developed.

4. Risk Management During Design

The initial underfloor ventilation scheme for Zone at Sydney Olympic Park followed standard principles but was soon clear that the requirement for large air quantities at the perimeter, the reasonable assurance of the development of a stratification layer and the distribution of cooling capacity across the internal areas would need particular attention.

Further consideration indicated that a careful, methodical and integrated approach to resolving these issues would be required. The first step was to adopt a risk management approach that involved all members of the design team. The initial planning sessions indicated the possible key areas of risk to be:

- *Knowledge*
 - existing experience and resources useful but never 100% applicable to project requirements
 - published information rarely included "hard data"
 - limited client and contractor experience with underfloor ventilation and appreciation of key challenges
- *Performance of the System*
 - large, crude zoning compared with a conventional system
 - effect of temperature pick-up in the perimeter zone
 - high velocities in the perimeter zone
 - impact of asymmetric radiation from the stratification layer
 - provision of heating because of low occupancy on the perimeter and/or low occupancy in internal zones
- *Confidence in Calculations*
 - distribution of loads into the occupation and stratification zones
 - impact of surface temperatures (particularly plenum surface temperatures)
- *Construction*
 - sealing the plenum and associated workmanship
 - impact of cable ducts and other services in the plenum
 - balancing air quantities in the perimeter zones where large air quantities are required
- *Tenant Fitout*
 - additional zoning to suit tenant requirements
 - tenant misuse (blocking outlets)
 - hazards due to the outlets (high heels)

5. Modeling

The primary approach to addressing these risks was to undertake a wide-ranging sequence of thermodynamic modelling using CFD. However this was not a matter of simply constructing a number of CFD models of the space and seeing what would happen. Key preliminary tasks included:

(a) Predicting Surface Temperatures

CFD models of a realistic size for design tasks such as this rely upon the input of surface temperature data. For modelling the proposed underfloor ventilation system, information was required on temperatures associated with the slab that forms the base of the underfloor plenum, the internal face of the glass forming part of the façade, the ceiling above the stratification layer and similar.

A dynamic thermal simulation modelling program, TAS was used to estimate these values. TAS has some limitations. However it was recognised that an iterative design as was proposed, must start somewhere. The results of the TAS modelling were carefully reviewed and in some cases tested in sensitivity studies to establish the impact they had on the final CFD modelling.

For example, both the TAS and subsequent CFD modelling predicted a supply air temperature rise of 2.0-3.0°C within the plenum. However CFD predicts a different location of maximum temperature rise compared with the TAS model. The variation of up to 1.0°C in supply air temperature in some parts of the plenum was not considered significant in terms of developing confidence in the overall system design.

(b) Outlet Performance

The performance of floor outlets (or swirl diffusers due to the nature of air discharge as shown in Fig.2) is the key to low temperature gradients in the occupation zone whilst maintaining stratified air at high level. Therefore, as a preliminary task, considerable effort was put into representing the performance of a single diffuser using CFD and comparing it with the manufacturer's published data in terms of generated velocities and temperature profile.

Without knowing the exact conditions of the manufacturer's tests and having to rely upon various assumptions, a reasonable comparison was obtained, particularly at lower levels where a high degree of mixing and a reduction in thermal gradients is a key requirement.



Fig.2 Typical Swirl Diffuser

Other preliminary tasks included:

- Developing an outlet at the sill of the façade (to offset skin loads) which had to have a comparable pressure drop to adjacent swirl diffusers because of the common supply air plenum
- Checking the degree of blockage caused by plenum cable management and the like
- Confirming modeling assumptions against likely fitout configurations (workstation heat loads)

The main modeling was undertaken to provide confidence in the general design approach being adopted. It was used to inform both the designers and the client. It is also an important tool to be used during the detailed design and shop drawing phases. This will be a time when many key features and sensitivities can be lost because of the reality of evolving spatial constraints, constructability issues and the like notwithstanding the attention given in the early stages of the project.

With programming and resourcing constraints, it is tempting but impossible to extend modelling indefinitely. Hence somewhat conservative assumptions were made that would tend to predict a marginal reduction in

effectiveness of the underfloor ventilation system. The intention of this approach was to demonstrate that the proposed design solution was robust rather than seeking to replicate or predict with a high degree of accuracy, actual as built performance.

The main model was used to investigate and/or confirm:

- Supply air temperature in the plenum and likely factors affecting this phenomena (considered to be air velocity and “residency” time in the plenum)
- Air movement at the perimeter and its effect on comfort conditions and the stratification layer
- Vertical temperature gradient and stability of the stratification layer across the floor to the return air
- Temperature variations within the occupation zone (up to approximately 2.0m)
- Extent of vertical mixing across the occupation zone and into the stratification layer above (the extent to which pollutants are drawn back from high level into the breathing zone)

6. Results from Modeling

6.1 Temperature Rise in the Plenum

The temperature rise in the plenum was generally 2.0-3.0°C after the air slowed following a jet discharge into the relevant plenum as indicated in Fig.3 below.

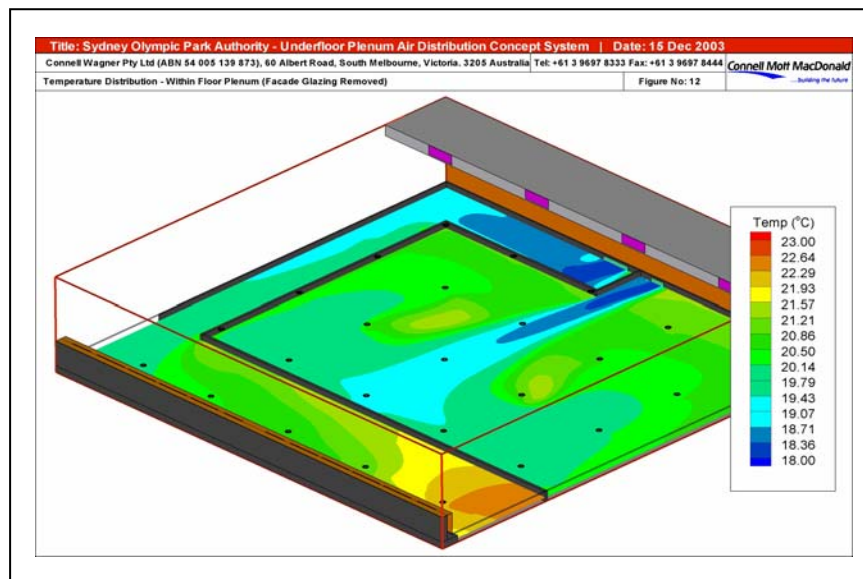


Fig.3 Supply Air Temperature Variations in the Floor Plenum

In the perimeter zone, as expected, the highest temperature rise occurred furthest away from the point of supply. The small area of the perimeter zone plenum that had the highest temperature rise (4.5°C) was beyond the furthest outlet and therefore of little interest.

The interior zone exhibited a high degree of circulation within the plenum and the highest temperature rise appeared to occur within an eddy that developed just beyond the initial jet of supply air.

The temperature of the air discharging from the plenum did not appear to affect the temperature of the space above suggesting that, in general, mixing was good and the system was robust.

6.2 Air Movement at the Perimeter

The perimeter zone required significantly more air than the internal zone. A twin slot (with a lower pressure drop) was used on the façade to deliver most of the air to offset skin loads whilst standard swirl diffusers were used away from the edge of the building. Whilst this arrangement increased air velocities over the glazing and thereby increased thermal conduction this was considered acceptable given the relatively low thermal transfer due to the double glazing. The need to reduce excessive air movement within the general office area and to avoid a large number of floor outlets were also relevant considerations. The modelling indicated that the high volume slot diffuser had some minor affect on the stratification layer above to the extent that local thinning occurred and there was a reasonably high degree of mixing within the occupation zone out to the first row of floor outlets.

6.3 Vertical Temperature Gradient

The modelling indicated a thermal gradient of about 1.0-1.2°C from 0.5m to 2.4m above floor level away from the direct influence of the floor outlets as indicated in Fig.4 below. Given that a well regarded manufacturer of swirl diffusers with an established record was proposed as the supplier, there was less concern with results immediately adjacent to the outlets although they were encouraging in themselves.

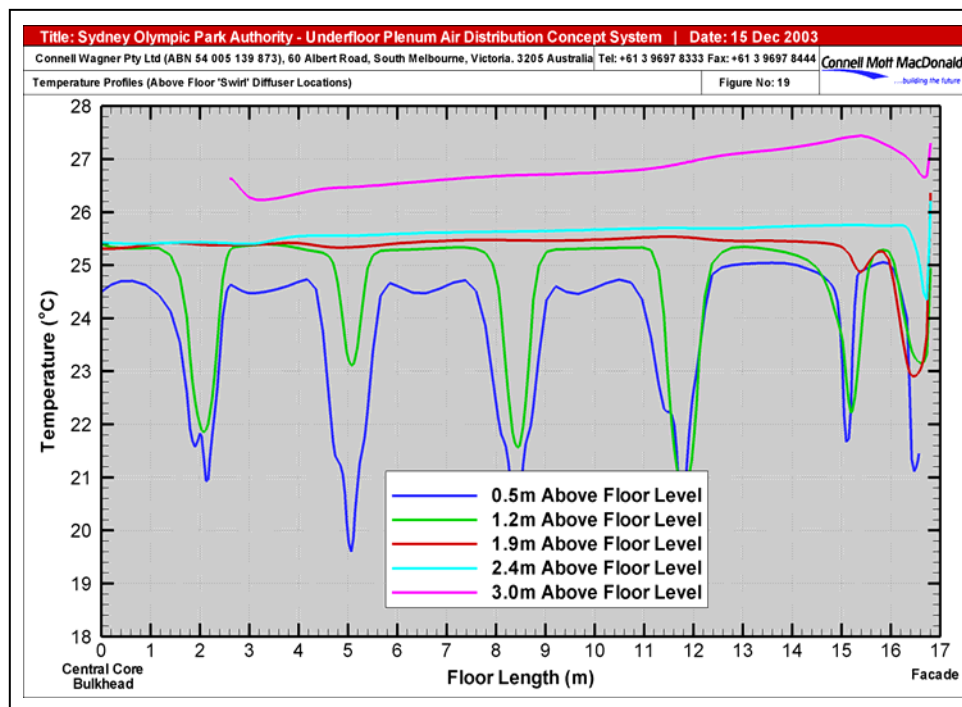


Fig.4 Vertical Profiles Between Swirl Diffusers

A stratification layer at 3.0m above floor level is clearly indicated in the modelling. However there is evidence of thinning (but not destruction) in the perimeter zone where there is a high degree of air movement and in the internal zone near where return air is drawn back to the central plant at high level.

6.4 Temperature Variation Across the Floor

Various temperature profiles indicated a high degree of uniformity across the floor within the occupation zone which was very encouraging. Although it should be noted that an even distribution of cooling load was assumed for the purposes of modeling. However it is appears that the proposed system is not inherently assymetrical in the delivery of cooling and/or the mixing of air. Also, the results indicated a slightly high (but even) temperature across the floor of around 25°C. This is due to a decision to use a

slightly higher supply air temperature (18°C) rather than the originally predicted value of 16-17°C of which the system as designed will be capable.

6.5 Mixing Across the Occupation Zone and into the Stratification Zone

Streamline (air path) profiles were generated (Fig.5) to see if there was any tendency for lower (cleaner) air to mix with higher (more polluted) air and to draw the pollutants back down into the breathing zone of occupants (which is what an underfloor ventilation system is trying to avoid). These outputs were also used to see if there was any tendency for warm, stratified air to be drawn down into the lower (cooler) zone (again something an underfloor ventilation system is trying to avoid).

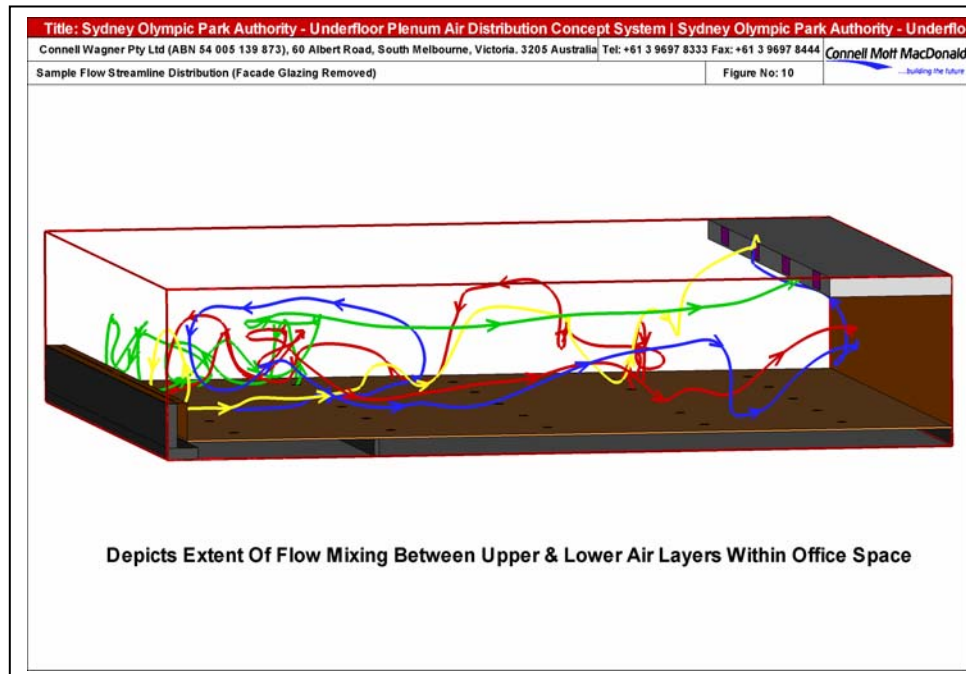


Fig.5 Streamlines Depicting Mixing Between Upper and Lower Layers

The results of the modelling suggested a higher than expected degree of mixing to bring pollutants back down into the breathing zone. It appears that the return air, which is drawing from one side of the building only, exacerbated this tendency as air moved across the floor as well as vertically. Mixing into and out of the stratification layer did occur however this did not appear to be a dominating feature of air movement patterns.

7. Discussions

The CFD modelling undertaken to simulate an underfloor system and to test various assumptions about system performance gave encouraging results. However a number of features of the building contributed to the success of the modelling, namely:

- (a) High performance façade which controlled perimeter cooling loads and reduced the amount of supply air needed to be delivered to this area thereby increasing the probability of controlled mixing and the maintenance of a stable stratification layer.
- (b) The ability to use a slot on the inside of the façade to deliver most of the perimeter supply air, again to limit high levels of air movement to a relatively small area.
- (c) High ceilings (3.1m) to give the vertical height to allow a stable stratification layer to develop

- (d) Distributed return air at high level (albeit only across one side of the building) to control air velocities in the stratification layer and to control undue mixing with the occupation zone below
- (e) use of a floor outlet that has been designed and manufactured for this type of application.

However whilst the modelling was extensive, there were many other issues that needed to be addressed in parallel which were effectively of equal importance to the issue of testing the concept. These included:

- provision of supplementary chilled and condenser water for additional cooling in high heat load tenant areas and/or to provide more refined zoning
- Provision of supplementary outside air for high occupancy areas to suit a particular tenancy fitout
- Provision of heating to suit particular occupancy requirements that may arise following tenancy fitout (this was seen as a drawback of the large zoning that underfloor ventilation entails but was judged to be an acceptable, and only occasionally required, compromise)
- Development of guidelines and briefing papers for tenants so they understand the differences between an underfloor ventilation system and more conventional air conditioning.

8. Conclusions

Underfloor ventilation in the context of a speculative office design process is challenging. But a robust solution can be developed provided it is being integrated with appropriate building features; the key ones being:

- High ceilings
- High performance façade
- Distributed return air
- Properly selected air outlets

An underfloor ventilation system can not be incorporated into any building arrangement to the same degree that a conventional air conditioning system can be. If poorly integrated, there is likely to be significant performance compromises that would put the entire rationale for selecting such a concept into question (why have an under-floor ventilation system unless it is going to work properly).

Similarly, it must always be recognised that underfloor ventilation is fundamentally different to conventional overhead air conditioning. Therefore the design team (architects, engineers, interior designers), owners/developers and tenants must all be appraised of key features and sensitivities if the final outcome is to be a long term success.

ECO LIFT: DEMONSTRATION AND APPLICATION OF SUSTAINABLE TECHNOLOGIES FOR OPERATING OF GENERAL PURPOSE ELEVATORS

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Abstract

This paper aims to present and demonstrate the technical feasibility of the application to elevators of innovative and sustainable technologies and techniques, including LED lighting sources, photovoltaic systems and fuel cell power devices, to increase building net/gross efficiency, reduce the environmental impact of building in its complete life cycle, and improve the integration of elevators inside the building. There are different estimates for the percentage energy dissipation of lifts as a percentage of the energy consumption of the whole building (5 - 15% of the total costs, depending on what other services are running in the building). KONE estimates it at 5 - 10%, whereas Schroeder estimates 15% of the building's total electric energy consumption. For this reason this paper intends to present some possible solutions for reducing the (indirect) environmental impact of elevator systems due to their electric energy consumption. Such reduction can be achieved by increasing the efficiency of electric energy production and using clean energy sources. To this aim, for the first time, small sized systems for local energy production, to be coupled with elevators, have been considered, mainly based on fuel cells and photovoltaic technologies. These modular systems will be suitable for the development of a decentralized generation system with high electrical efficiency and very favourable environmental impact, enabling the achievement of important results in energy savings and in the reduction of greenhouse gas emissions.

Keywords : Sustainable buildings, Lift energy consumption, Renewable energy technologies, Energy efficiency.

1. Introduction

Besides automotive cars, elevators are one of the most used means of transportation in the world. After 151 years of existence, the total number of elevators installed in the world is six million, about 1 elevator every 1,000 persons, slightly over half of which are in Europe, 20% in the Asia-Pacific area, and 10% in North America.

As shown in the work by Al-Sharif et.al. (2004), the energy consumption of an elevator installation is a significant proportion of the total building electrical load. There are different estimates for the percentage energy dissipation of lifts as a percentage of the energy consumption of the whole building (5-15% of the total costs, depending on what other services are running in the building). KONE estimates it at 5- 10%, whereas Schroeder estimates 15% of the building's total electric energy consumption (assuming no air conditioning or oil heating). Moreover, Schroeder also estimates it at 1% of the total rental cost of the office space. Understanding energy usage and costs is becoming increasingly important to clients of the elevator industry. Thus it is necessary to be able to predict, with reasonable accuracy, the energy usage of a new elevator installation and of an existing installation post modernization.

KONE has achieved significant improvements in the environmental performance of its products and services through continuous research and product development. The success in reducing energy consumption during use has meant substantial progress in the environmentally most important areas. KONE products feature low energy consumption, space savings in buildings and reduced or eliminated oil use.

It is interesting to evaluate the energy and environmental impact of a standard rope elevator, model KONE MonoSpace™, installed in a 5 floors residential building, with an hoisting capacity of 630 kg and a nominal

speed of 1.0 m/s. Calculations are based on a frequency of starts of 150,000 per year (about 411 starts per day and 17 per hour) and an average traveling height of 9m, i.e. 3 floors. The machine-room-less design enable space savings in buildings and the reduced use of construction material. The KONE EcoDisc® elevator hoisting machine contains no oil. This eliminates waste oil handling, an important environmental hazard.

The choice of drive system and rated speed affect the energy consumption. Gearless, permanent magnet motor, KONE EcoDisc®, and variable frequency drive feature have enabled significant improvements in energy efficiency during use. This elevator has lower energy consumption than equipment with geared hoisting unit or drive without frequency converter. Also typical hydraulic elevators consume significantly higher amount of energy during use. This naturally leads to higher environmental impacts.

Following the conventional method to assess the energy consumed in elevators based on calculations using formulae and tables derived from experience and simple rules of thumb (Al-Sharif, 2004), as reported in Table 1, energy is consumed in moving the passengers and goods, illumination and control of the equipment.

Table 1. Typical annual energy consumption for KONE MonoSpace™

Elevator Function	Electricity consumption (kWh/year)
Hoisting	640
Brake	140
Cabin light	600
Control system	620
Total	2,000

KONE has carried out a Life Cycle Assessment (LCA) for the standard elevator described above, considering an estimated lifetime of 25 years. This analysis covers all environmental aspects for material production, component manufacturing, delivery, installation, use, maintenance, modernisation and end-of-life treatment. These inputs and outputs may include the use of resources and releases into air, water and land associated with the system. National mix of energy has been used for calculating emissions during manufacturing and an OECD mix of energy has been used for calculating emissions due to energy consumption during use and end-of-life treatment.

The life cycle interpretation shows that most of the environmental impacts of this standard elevator occur during its period of use. The environmental impacts of the period of use are from the electricity production. Furthermore, these emissions, generated by traditional power generation sources, are responsible for social (mainly sanitary) and environmental costs due to main damages to people and the environment. The amount of carbon dioxide emission during the lifetime of an elevator is almost 35 tons. Roughly 80% of CO₂ emissions are generated during the use stage, as are about 71% of nitrogen oxide emissions and around 82% of sulphur oxide emissions. By comparison, during material production CO₂ emissions are 15% and during component manufacturing 3% of the total. According to the results of LCA, the period of use, in practice the energy consumed by elevator, is the most significant source for environmental impacts. Therefore it is necessary to minimize the energy consumption and the pollutant emissions during its period of use.

This paper aims to present and demonstrate the technical feasibility of the application to elevators of innovative and sustainable technologies and techniques, including LED lighting sources, photovoltaic

systems and fuel cell power devices, to increase building net/gross efficiency, reduce the environmental impact of building in its complete life cycle, and improve the integration of elevators inside the building.

In a strongly competitive market it is believed that environmental compatibility may represent a good a-tout. For this reason KONE evaluated some possible solutions, presented in this paper, for reducing the (indirect) environmental impact of the elevator systems due to their electric energy consumption. Such a reduction can be achieved increasing the efficiency of electric energy production and, eventually, using green energy. To this aim, for the first time, small systems for local energy production, to be coupled with elevators, have been considered, mainly based on fuel cells and photovoltaic technologies. These modular systems will be suitable for the development of a delocalised generation system with high electrical efficiency and very favourable environmental impact.

The technologies chosen should provide effective solutions in the 1 – 5 kW range, corresponding to a very wide potential market (general purpose elevators). These innovative systems enable the achievement of important results in the reduction of greenhouse gases and energy savings. In addition these technologies should provide effective solutions in emergency situations, as in case of black out of the grid. Finally the local power supply system can provide energy not only to the elevator but also to the apartments in the building.

The energy absorption of the elevator is not continuous, thus any supply system cannot operate in optimal conditions. For this reason, this paper assumes that the local power supply system can provide energy not only to the elevator, but also to the apartments in the building. In this way the load curve is flattened and the supply system may perform with better results. It is possible to meet the energy requirements of the overall system (elevator and building) by the local generation system (fuel cell or photovoltaic modules), but the main supply line remains necessary for the integration either when the generation system doesn't operate or when peak load overcomes the system capacity. Since both energy storage in large quantities and non-continuous production are not efficient processes, the system must be in grid parallel.

The energy to run an elevator can be supplied by a local generation system or by the national grid. If a local generation system is installed, the national power system can reduce its production by the amount of energy locally produced (plus the relevant losses). Therefore, from an environmental and energy point of view, the most preferable solution is the one that allows the lowest global emissions and the highest ratio between the energy required by the elevator and the primary fuel energy.

The paper is structured in three main modules:

- a) Application of LED technology for elevator cabin lighting
- b) Application of photovoltaic technology for elevator operating
- c) Application of fuel cells technology for elevator operating

These modules are mutually integrating, different but with the same project matrix finalised to produce elevators with minimized environmental impact and high energy saving. These modules can produce flexible and compatible modular systems, also for non-KONE elevators.

In the following pages the three modules are presented and described.

2. Application of LED Technology for Elevator Cabin Lighting

Usually the lighting fixtures in elevator cabins can be chosen between fluorescent lamps and halogen spotlights. Fluorescent lamps are more energy efficient but contain mercury. As reported above, about a third of electricity consumption of a standard elevator is due to cabin lighting. The objective of this module is to present a new lighting system for the elevator cabin based on Light Emitting Diode (LED) technology in order to achieve cost saving in product life cycle (long lifetime and high reliability), energy saving, a lower environmental impact (no mercury, no UV and thermal radiation emission, reduced quantity of waste

produced), increased light features and flexibility, and maximum level of safety (low tension power supply and a light source that is safe to touch).

LEDs are semiconductor devices. Like transistors, and other diodes, LEDs are made out of silicon. What makes an LED give off light are the small amounts of chemical impurities that are added to the silicon, such as gallium, arsenide, indium, and nitride. When current passes through the LED, it emits photons as a by-product. Normal light bulbs produce light by heating a metal filament until it is white hot. Because LEDs produce photons directly and not via heat, they are far more efficient than incandescent bulbs. Not long ago LEDs were only bright enough to be used as indicators on dashboards or electronic equipment. But recent advances have made LEDs bright enough to rival traditional lighting technologies. Modern LEDs can replace incandescent bulbs in almost any application. At present the efficiency of white LED range from 20 to 24 lumens/Watt. As shown in the work by Narendran (2004), lighting systems using LEDs can be thought of as having a light source (typically, the individual LED sources), a ballast (for LEDs, often called a driver), and a luminaire, the surrounding materials for optical control of the emitted light and thermal control of the overall system.



Fig.1 The new LED spotlight

The new type of elevator ceiling proposed by KONE is composed by a new LED spotlight (Fig.1). The new light bulb is based on the newest 1 Watt LED generation, with high brightness and lifetime not comparable with standard light sources. It uses 3x1Watt white LEDs, an optic with an angle of 25° and electronics that drive the LEDs at a constant current in order to achieve the best performances. The LEDs are soldered directly on a customized heat sink where the PCB is an LTS (Low Temperature Sintering Circuit) to achieve the best performances in terms of thermal resistance. It is mechanically similar to a conventional halogen bulb with 50mm diameter and a power of 20 W. Electronically driven, it is fully compatible with an existing electromechanical transformer with an operating voltage of 12 Vac. In conclusion, by using LED spotlight instead of halogen spotlight, an energy saving of 80% in cabin light is achieved.

3. Application of Photovoltaic Technology for Elevator Operating

Photovoltaic power plants, commonly referred to as PV plants, directly convert solar energy into electricity. PV power plants do not have any moving parts. They are reliable, require little maintenance and generate no noise or pollutants. PV systems are modular, because they are composed by blocks (PV modules). The PV effect, direct conversion of the sun's rays into electricity, takes place in elementary PV cells sited in the PV modules. In a photovoltaic plant, PV modules are connected together in series and parallel to produce the levels of voltage and current required by the load (Castaner et.al., 2003). Other PV plant components,

such as cabling, batteries, battery charge controllers, inverters, etc. are commonly known as "Balance of System" components (BOS). These provide the necessary interface with the grid or specific application.

Photovoltaic power plants are already in widespread use, largely for small-scale stand-alone applications such as isolated houses, water pumping, telecommunications and navigation aids. However, in the near future, the most important application of PV is expected to be the Grid-Connected PV system - A PV system in which the PV arrays act like central "generating plants" supplying power to the grid. Either the PV system is operated by the utility (in what is known as a grid-interactive system) or the individual houses and other buildings in the grid are equipped with PV systems, fully integrated into the building structure (e.g. the PV panels forming an integral part of the building's roof), that feed into the grid when they generate excess power. These systems will draw from the grid at night and in periods of low sunshine.

The integration of photovoltaic power systems into local electricity supply networks is currently in the early stages of development. The current high cost of PV systems means that to date relatively few requests have been received by electricity companies for the connection of such systems. However, the increasing international activity related to cost-reduction of PV systems, especially in the area of building integration, means that significant reductions in basic system costs will continue to be made. If the current trend in cost reduction continues it will not be long before grid-connected PV systems are a true commercial proposition. PV dissemination programmes such as the government programmes are also helping to stimulate demand for grid-connected PV systems. Whilst there are no fundamental principles that prevent the connection of PV systems into local electricity supply networks, electricity companies are subject to various statutory and legal requirements which could be compromised by certain characteristics of grid-connected PV systems. Consequentially, any increased use of PV systems is likely to have a significant impact on the future design, operation and management of electricity supply networks.

Prices for entire PV systems vary widely and depend on a variety of factors including system size, location, customer type, grid connection, technical specification and, of course, the extent to which end-user prices reflect the real costs of all the components. PV modules comprise a significant proportion of system prices (on average, about 60% for grid-connected systems in 2002) and, compared to the widely-varying non-technical and other costs, presents a useful indicator for tracking the changes in PV technology costs over time. The average price of modules in 2002 in the IEA countries was 4 USD per watt. A typical price of installed grid-connected systems in 2002 was about 7 USD per watt. Even photovoltaic cells, which do not use fuel, have production costs that are much higher (almost 10 times) than tariffs for electricity supply. However, some additional considerations can be proposed. It is not expected that in a near future photovoltaic cells will reduce their cost and their production will probably always be 5 to 10 times more expensive than energy market value. However, because of their almost absent environmental impact, they are considered as a green source of energy, therefore their installation is and will possibly be supported by national and regional legislation. In this way, global production costs may become almost competitive with the energy supply from the grid.

This module aims to demonstrate the technical feasibility of a grid connected PV plant, located in Milan (Italy), to be coupled with a standard elevator. The sizing of the photovoltaic system considered a yearly energy production covering the yearly electricity consumption of the standard elevator reported in Table 1. The proposed PV system, shown in Fig.2, is based on a new photovoltaic module, the BP Solar Saturn 7 Series, with high performance and reliability due to revolutionary construction of monocrystalline silicon cells.



Fig.2 The PV installation under development in Italy

PV modules do not require any mechanical installation diagram, besides a structure to hold them correctly oriented and in place, in order to optimise the sunlight radiation on the cells. Electric connection is very easy as well. All modules, connected in series and parallel for obtaining the required voltage and current, are connected to the DC side of the inverter. The three phase output of the inverter is connected in parallel to the load, with all the necessary devices. To allow the measurement of the purchased energy and the surplus injected into the grid separately, two metering devices are to be installed. The main features of PV installation are reported in Table 2.

Table 2. The PV plant features

Feature	Unit	Value
Inclination of modules	degrees	90°
Number of modules (BP Solar 7180)		16
Total surfaces of modules	m ²	20
Plant peak power	kW	2.88
PV plant efficiency	%	11.5
Yearly energy production	KWh/year	2,100

4. Application of Fuel Cells Technology for Elevator Operating

Fuel cells are electrochemical devices that continuously convert the chemical energy of a fuel and an oxidant into electrical energy; the fuel and the oxidant are typically stored outside the cell and transferred into the cell as the reactants are consumed. The principles of the functioning of the cell are quite simple and well understood, but the realisation of a cost effective, reliable power generation system based on a fuel cell is complex and requires the solution of several technological problems. The basic choice is relevant to the electrolyte, i.e. the ion carrier (Iacobazzi et.al., 2002). The optimum ionic conductivity of the electrolyte determines the useful operating temperature range of the fuel cell and therefore all the technological requirements of the whole system. PEM (Proton Exchange Membrane) fuel cells largely dominate the sector for residential applications in a few kW power range, but an increasing number of constructors are developing small units based on high temperature SOFC (Solid Oxide Fuel Cells).

This module aims to demonstrate the technical feasibility of an elevator operated from electricity produced by Fuel Cells (FC) technology, that can supply electricity and eventually thermal energy to building users. The fuel cell system provides a base load, if necessary reduced with respect to the maximum capacity of the system, if this is noticeably higher than the needs, and in the other situations the control system takes the difference between the requested power and the produced power from the main supply line. According to the simulation results, the optimal power of this generation system should be around 2000 We, because with this configuration it is possible to get the highest production of energy with a low average surplus of energy produced by the fuel cell, with respect to the electricity needs of the elevator system. However the size of the system must rely on the commercial availability of fuel cells, technical aspects (working hours in lifetime) and economic aspects. The physical principles which characterise fuel cells have been known for a long time, but the application of such principles started few years ago. For this reason the technology of fuel cells has not been completely developed and reliability and duration may be limited. In particular, degradation reduces efficiency in short times and failure rates are still too high today to allow a wide diffusion in industrial and commercial applications. Moreover, fuel cells are components that can be used to assure a continuous service even in case of black out of the grid.

An economic comparison between alternative solutions has to consider several aspects, such as investment costs, fuel costs, efficiency, other operational costs, availability and reliability. The large scale is a great advantage for the national power supply system, in terms of costs (investments, fuel and other operational costs) and efficiency: scale factors can widely compensate for transmission and distribution losses, as well as for theoretical differences in the performance of the alternative processes. Traditional thermal power plants are based on a cheap and well developed technology and their specific costs are the lowest between plants for energy production. Similarly, electric energy from fuel cells is not expected to become competitive on the market, even if related investment costs should sensibly reduce, as the producers declare. The success of fuel cells will be related to their easy and convenient application for cogeneration, low emissions in the environment (NO_x , SO_2 and dust are practically absent) and reliability. In a cogeneration plant, particularly if based on fuel cells, heat can be exploited without any additional fuel consumption. Therefore, if heat exploitation can avoid alternative heat production costs, the economic balance of a fuel cell application may become almost competitive. Moreover, it is to be considered that, for encouraging rational and clean use of energy, fuel gas for cogeneration plants is charged by a favourable tax regime, even if the heat production capacity is integrated with a traditional boiler.

The main fuel that can be used in FC is natural gas, still available in building sites for heating and/or household purposes. A NGFC (Natural Gas Fuel Cell) system is composed of three primary subsystems: a fuel processor or reformer, a fuel cell stack, and a DC-to-AC power converter. The fuel processor combines natural gas with steam (recovered from the power section) to reform the fuel into a hydrogen-rich mixture for use by the fuel cell stack in the power section. In the power section, the fuel mixture, rich in hydrogen, is combined with oxygen from the air to produce DC electricity. The process generates heat and produces carbon dioxide and water as exhaust gases. The DC-to-AC power converter takes the DC electricity from the fuel stack and converts it to usable AC power. A secondary subsystem for thermal management (a cooling module) is required if recoverable thermal energy is not fully utilized in some form of cogeneration

application. NGFC systems can also provide thermal energy through heat recovery from the process of conversion from natural gas to electricity.

Referring to the case of a building and an elevator as described in the paper introduction, the proposed size of the fuel cell is around 2500 We, so that about 2000 We can be available to the final user. In particular, a Vaillant Fuel Cell Heating Appliance provides both heat and electricity to the customer and it can be taken as reference case. The performance of such system is summarised in Table 3.

Table 3. Main features of fuel cell system

Output type	Combined Heat & Power
Scope	Engineered for European use
Certification	CE certified
Electrical output	2.5 – 4.5 kWe (230 V, 50 Hz)
Electrical interface	Grid parallel only
Fuel	Natural gas feed
Location	Indoor placement

The reformer and the fuel cell are integrated and seen as a single black box. Mechanical connections include a natural gas feeding pipe, an air intake, a water inlet for increasing air humidity, an exhaust gas discharge duct. Water for increasing air humidity is better demineralised, therefore a water tank is the best solution. Being connected to the public grid, the output of the inverter is connected in parallel with the electric load and the grid connection. Since purchased energy and the surplus of energy sent back to the grid must be measured separately, two metering devices must be installed for the two fluxes (input and output). Moreover, if the produced energy is to be shared also with the residents in the building, then such customers must be connected downstream the two common metering devices. Eventually, further metering devices for internal purposes of energy costs subdivisions can be installed. For what concerns the heat recovery, a centralised hot water circuit must be available, and the fuel cell can be connected in parallel to the existing boiler, to feed the same hot boiler tank. A circulation pump controlled by a temperature measurement in the fuel cell assures the fuel cell cooling. In case hot water is not used and water temperature raises beyond a given threshold, an emergency circulation of cold water must be temporarily activated to cool the system.

In order to realize the great possibilities of fuel cells, many different issues must be addressed. First of all, many layers of innovations and improvements in technology are needed. The polymer membrane and catalyst used in the heart of the fuel cell, called the cell stack, needs to be improved and its output density and durability greatly increased. There are also problems with the reformer. Also, technology and containers for the efficient storage of hydrogen are necessary. Secondly, the economic feasibility of fuel cells must be greatly improved. At present, the cost question represents a major hurdle. The third factor needed for development of fuel cells is development of a fuel supply infrastructure. A hydrogen fuel supply network equivalent to the network of gas stations will be needed. With a wide range of fuel options available to the consumer, the building of a fuel supply system that is consumer-friendly and economical will be a huge undertaking. Fourthly, the development of invisible, “soft” infrastructure is also vital. For example, a completely new technology requires new safety standards. The old regulations and systems need to be reviewed. International standards and norms will also have to be established. Finally, the citizens, for which hydrogen use will become a normal part of life, will need to be educated about fuel cells and their use.

5. Conclusions

To implement these modules for improving the integration of elevator installations inside the building, an accurate analysis of building energy requirements and a strong and close cooperation between building manager, designers (engineers and architects), elevator supplier, and final users during the design and the construction of the building is necessary.

This paper has presented and demonstrated the technical feasibility of the application to elevators of innovative and sustainable technologies and techniques, including LED lighting sources, photovoltaic systems and fuel cell power devices, to increase building net/gross efficiency, reduce the environmental impact of building in its complete life cycle, and improve the integration of elevators inside the building.

The energy consumption of an elevator installation is a significant proportion of the total building electrical load. Estimates range from 5% to 15% depending on the other services installed in the building. Architects, engineers and buildings managers can improve the energy and resource efficiency of commercial, industrial and multi-unit residential buildings through the use of the technologies and practices described in this paper. The following design and construction issues are covered: sustainable buildings, lift energy consumption, renewable energy technologies, energy efficiency.

In conclusion, by using LED spotlight instead of halogen spotlight, an energy saving of 80% in cabin light is achieved. Photovoltaic cells have the lowest environmental impact, since they do not release any kind of emissions into atmosphere, either in normal operation or in case of abnormal operation or fault. Therefore environmental benefit would be great and without appreciable disadvantages. However, such benefits are balanced by high costs that are not expected to appreciably decrease in a future. Moreover, differently from the very compact fuel cells, large space for panel installation may become an issue in some cases. Also environmental impact of fuel cells in a cogenerative application is very low, especially concerning conventional pollutants. But such a solution also presents the perspective that its costs may soon become competitive in the energy market.

Acknowledgements

It is proper to thank all those who collaborated in this work for their valuable help. First Mr. Luca Galbiati for co-ordination work and supporting activity. Heartfelt thanks to Mr. Giuseppe Bilardello, for providing technical review of this paper, and to Ms Joanne Lambert Barnes for providing language review of this publication. Finally a great thank to Mr. Harri Hakala and Mr. Kim Barlund for the useful recommendations and technical contributions.

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A SOLAR ENERGY STORAGE SYSTEM FOR LIGHT TIMBER FRAMED HOUSES

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Abstract

A solar energy storage system is proposed for light timber frame buildings. Its main purpose is to improve the thermal mass of timber framed buildings, but it also provides a source of low grade heating and cooling for other purposes. The solar energy may be supplemented with a heat pump which provides both additional heating and cooling. A simple rig was built to prove the thermo-siphon principles involved, and measurements were made on the heat gains and losses. The experimental results demonstrated that the thermo siphoning principle works in this heating and cooling situation. The experimentally measured heat and coolness gains were small compared with estimates of what can be achieved. This was probably due to the low efficiency of the uncovered pool heater type of panel and the losses due to lack of insulation of pipes and the solar panel itself. However the potential for a useful heating and cooling system is demonstrated for temperate climates with a good proportion of clear skies during the night and the day. The flexibility of a system using water as the heat storage medium should encourage other uses of low-grade heat. The heat from concrete thermal mass is not transported so easily. An additional advantage of using a cold tank in the circuit is that it should automatically provide panel frost protection that may otherwise use water from the hot tank. Suggested design parameters for a domestic system are given based on known performance parameters.

Keywords : Solar heating and cooling, Thermal mass, Timber framed buildings, Heat storage

1. Introduction

Timber framed housing comprises 95% of new housing starts in New Zealand. The timber frames are largely constructed from radiata pine sustainably grown in plantations. This building system has relatively low energy inputs compared with heavy masonry construction, so potentially rates well in terms of overall sustainability (National Timber Development Council, 2001).

Before the late 1970's timber framed construction did not always perform well from a thermal efficiency and comfort perspective due to poor thermal insulation, air leakage through doors and windows, inadequate heating systems and low thermal mass. Over the last 25 years, insulation of new houses has been mandatory, joinery has become much more air tight, and heating systems have improved in efficiency. However the issue of poor thermal mass has not been addressed, other than through the increased use of concrete floors. This low thermal mass is seen by the concrete industry as a weakness of timber framed construction and has been targeted in advertising campaigns promoting concrete construction. Although brick or masonry blocks are popular exterior cladding materials, the brick or masonry, because it is on the outside of the insulated timber frame, does not contribute to the thermal mass of the buildings.

Funding was available for researching improvements in the performance of timber framed construction. As structural performance meets all needs and acoustic and thermal insulation are already being researched, the project chosen was to improve the thermal mass of timber framed construction with an emphasis on the use of solar energy.

2. Principles of the Proposed Solar Energy Storage System

Thermal mass reduces fluctuations in indoor temperatures, in climates with cool nights and warm days, by absorbing heat during the day (thus cooling the building) and releasing it at night to warm the building. With small diurnal ambient temperature fluctuations, such as in tropical countries, thermal mass is of little or negative benefit in helping to maintain comfortable indoor temperatures.

The proposed energy storage system uses two tanks of water; a hot tank and a cold tank. Heat from a solar panel is stored in the hot tank during the day and coolness from a (preferably) passive cooling system is stored in the cold tank during the night. Radiators deliver heat at night from the hot tank to warm the building and the same radiators cool the building during the day using the cold tank.

If the hot tank is above the solar panel, the thermosiphon principle can be used to heat the hot tank without pumps and control valves. Similarly a cold tank below the panel can be cooled by the panel radiating heat out of the cold tank with the thermosiphon operating in reverse. Diagrammatically the system operates as shown in the left hand side of Fig.1.

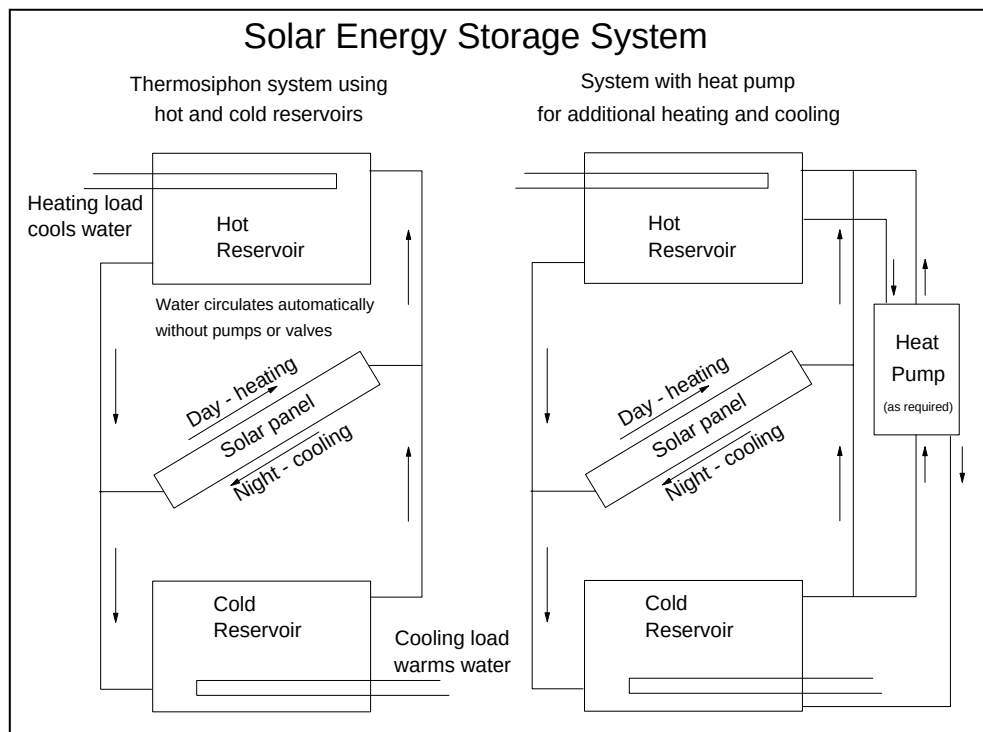


Fig.1 Solar energy store thermosiphon circuit

3. Enhancements to the Solar Energy Storage System

The solar energy store may act as a general low-grade heat energy store for purposes other than simply space heating or cooling and store energy from sources other than a solar panel.

3.1 Use of Heat Pump to Supplement Heat and Coolness

A heat pump operating between the hot and cold tanks can top up heat in the hot tank and coolness in the cold tank, thus doubling the useable heat energy compared with the normal applications of heat pumps which generally use one side of the heat pump only for heating or cooling, not both. Fig. 1 on right hand side, shows this application.

Heat obtained from a wastewater heat recovery unit may also be stored in the hot tank.

3.2 Additional Applications for Stored Heat and Coolness

Low grade heat stored in the hot tank can be used with heat exchangers to preheat a domestic hot water supply, dry clothes, heat towel rails and supply heat for any other low grade heat application.

Similarly coolness stored in the cold tank may also be used for low grade cooling purposes such as cooling an insulated food storage cupboard where the lower temperatures of a refrigerator are not required.

4. Performance Estimates of a Solar Energy Storage System

The performance of the system depends on the performance of the storage tanks, the solar panel and the heat and coolness distribution system.

4.1 Performance of Storage Tanks

Heat storage capacity and heat losses determine the practicality and efficiency of the heat storage medium. A comparison of the thermal capacity of water and concrete is given in Table 1 (Commonwealth of Australia, March 2004).

Table 1. Comparison of thermal capacity of water with other materials

Material	Water	Concrete	Brick	Softwood
Thermal capacity, C, weight basis, J/kg.K	4186.8	1050	840	2090
Thermal conductivity, W/m.K	0.6	0.65	1.18	0.1
Density, D, kg/m ³	1000	1600	1930	500
Specific thermal capacity, J/kg.K as % of water	100%	25%	20%	50%
Ratio of weights of materials to weight of water for equivalent heat storage.	1.00	3.99	4.98	2.00
Specific thermal capacity volume basis, J/m ³ .K = C x D	4,186,800	1,680,000	1,621,200	1,045,000
Specific thermal capacity, J/m ³ .K as % of water	100%	40%	39%	25%
Ratio of volumes of materials to volume of water for equivalent heat storage.	1.00	2.49	2.58	4.01

It can be seen from Table 1 that water is 4 times as efficient as concrete on a weight basis for storing heat and 2 ½ times as efficient on a volume basis.

Using the definition of the calorie as 4.1868 Joules, which is equal to the amount of energy required to raise 1 g of water through 1 K, it can be shown that the energy required to raise 1 tonne of water through 1 K is 1.16 kWh. In practical terms, 2 tonnes of water, cooling through a 45 °C temperature change from 75 °C to 30 °C releases about 105 kWh of energy. This is sufficient to maintain a well-insulated medium sized house at a comfortable temperature over a cold night.

The heat losses from a storage tank are also of interest. Assuming a 2 cubic metre insulated tank with dimensions of 1 m x 1 m x 2 m it is shown in Table 2 and Table 3 that the heat losses in a practical situation are as little as 5% of the heat stored over a 24 hour period.

Table 2. Storage Capacity for Hot Storage Tank

Storage capacity of reservoir		
Volume of heat store. Litres	2000	L
Lower usable temperature, °C	30	°C
Upper usable temperature, °C	75	°C
Thermal capacity, kg water.°C	90000	kg water.°C
Thermal capacity, kWh = kg water.°C x .001167	104.7	kWh

Table 3. Estimated Heat Losses for Hot Storage Tank

Heat losses from a typical insulated tank		
Assume rectangular tank of ratio $h=1 \times w=1 \times l=2$, metres		
Volume = $(l^3)/4$, $l = 4(V^{1/3})$ litres.	2000	litres
Total surface area = $2.5 \times l^2$ and substitute for l		
Total surface area = $2.5 \times (4V)^{2/3}$	10.00	m ²
Conductivity of insulation, k , W/m.C	0.05	W/(m.C)
Thickness of insulation, t	0.1	M
Conductance = k/t	0.5	W/(m ² .°C)
Area conductance = $k/t \times A$	5.00	W/°C
Average internal tank temperature over 24 hour period	52.5	°C
External temperature	5	°C
Temperature difference	47.5	°C
Rate of heat loss, kW	0.238	KW
Total heat loss over 24 hour period, kWh	5.7	KWh
Usable heat left after losses kWh	99.0	KWh
Percentage of heat stored still available after 24 hours	94.6 %	
Percentage of heat lost after 24 hours	5.4 %	

The heat loss calculation above is an approximate estimate based on an average temperature difference between the contents of the tank and the surroundings but gives the order of losses that can be expected. If the storage tank were buried in the ground, depending on the soil properties, it is possible to design an insulation system that takes advantage of the thermal mass of the ground. This would allow a smaller tank to be used with a consequent costs saving.

4.2 Performance of Solar Panels

The performance of solar panels with respect to heat gain, is dependent on design and installation of the panel, climate variables such as solar radiation and ambient temperature, and operational variables such as the amount of heat drawn off the storage tank and the time it is drawn off. Nevertheless a rough idea of the amount of heat that can be gained on a clear day can be found from the published Thermal Performance Rating of commercial Certified Solar Collectors (Solar Rating and Certification Corporation 2004). A value of around 7 Megajoules/m²/day can be achieved on a sunny day. In electrical energy terms this is about 7/3.6 or roughly 2 kWh/m²/day. To provide say 25 kWh of energy would require a panel of around $25/2 = 12.5 \text{ m}^2$. This is a substantial area of roof but is achievable.

For heat dispersal from a flat panel radiator, the data are less readily available. Norton (1992) gives a value of approximately 5 W/m² per °C temperature difference between ambient and the night sky. A temperature difference of around 10°C is achievable on a clear night in summer. Hence dissipation can be around 50 W/m² for a panel exposed to the clear night sky if the panel is at ambient temperature. If it is higher, more

heat can be dissipated. For a summer night of say 6 hours of darkness, and a 12.5 m^2 panel this is approximately 3.75 kWh of cooling capacity. This cooling energy is much less than the heating energy derived from the same panel but is about the same as that delivered by the typical domestic refrigerator or freezer, so is useful energy nevertheless. It is however relatively small compared with the usage of energy in air-conditioning systems.

5. Experimental Work

A simple solar water heating and cooling rig was set up to confirm that a system using thermosiphoning alone would work without control valves or pumps and that both heating and cooling would result. Although a low efficiency uncovered panel was used, measurements of the heating and cooling power were made.

5.1 Description of Experimental Rig

The rig comprised a pool heater uncovered flat plate collector panel, 4.3 m^2 in area, connected to an insulated tank above the panel and an insulated tank below the panel. Thermocouples were placed in the circuit and drain taps allowed a load to be put on both hot and cold tanks by drawing off up to 60 litres of water at a time. This drawn off water was made up by water supplied at ambient temperatures from a header tank, Fig.2.

This figure shows the hand valves incorporated to control the emptying and filling of each reservoir so as to avoid mixing or draw-off from both tanks, V1, V2 etc as well as the positions of the thermocouples for temperature measurement, T1, T2 etc. A data logger was used to record and download the temperature measurements over a period.

5.2 Operation of Rig

In the morning, the temperature of the header tank water was measured, 60 litres of water were drawn off from the cold tank and the temperature of this water recorded. Similarly in the evening 60 litres of hot water were drawn off.

The energy abstracted from the hot and cold water reservoirs was calculated as the product of the volume of water drawn off and the temperature difference between the makeup water at the previous draw-off and the water drawn off. The energy delivered by the system was the product of the volume of water drawn off (60 litres) and the temperature rise or decrease of that water during the previous day or night.

Temperature data were downloaded from the data logger daily and plotted against time.

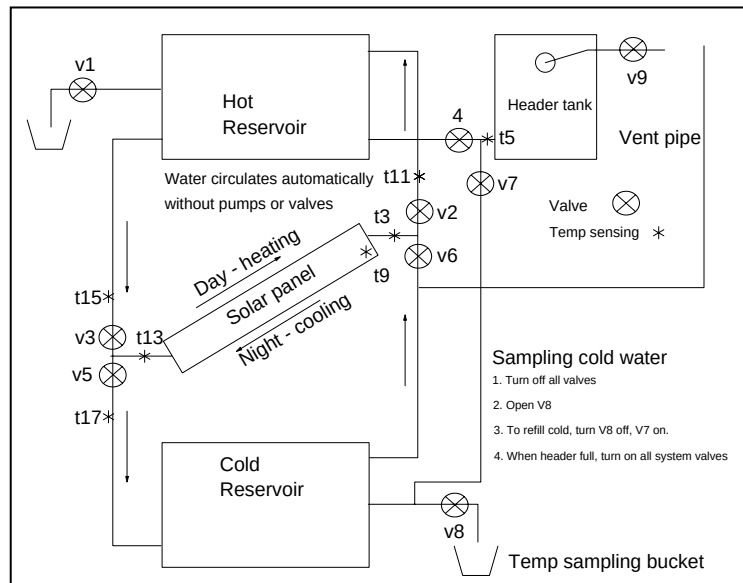


Fig.2 Experimental rig setup

5.3 Results

Calculations were made of net energy gained and lost by the panel. An example of this is given in Table 4. below.

Table 4. Energy gains and losses for hot and cold tanks

Temperature Record for Solar Energy Storage Rig.										
Heat extracted, kWh = kg water x °C x						0.001167				
Date	Time	Temp of Sample			Draw-off Litres		Energy Extracted kWh			Cold /hot Ratio
		Hot	Cold	Header	Hot	Cold	Hot	Cold	Total	
05-Feb-04	7:35 a.m.	25.5		16.8	60		0.32	0.00		
05-Feb-04	2:40 p.m.		16.6	21.1		60	0.00	0.13	0.45	42.2%
09-Feb-04	7:35 a.m.	31.6		12.2	60		1.04	0.00		
09-Feb-04	4:00 p.m.		16.2	22.0		60	0.00	0.34	1.38	33.1%
10-Feb-04	8:00 a.m.	35.6		18.8	60		1.64	0.00		
10-Feb-04	3:40 p.m.		17.3	22.6		60	0.00	0.33	1.97	20.1%
11-Feb-04	7:25 a.m.	32.7		20.7	60		0.97	0.00		
11-Feb-04	3:40 p.m.		19.2	22.2		60	0.00	0.24	1.21	24.5%
12-Feb-04	7:45 a.m.	32.3		20.5	60		0.81	0.00		
12-Feb-04	4:15 p.m.		19.1	20.0		60	0.00	0.22	1.03	26.7%
13-Feb-04	7:45 a.m.	24.0		15.7	60		0.25	0.00		
13-Feb-04	3:00 p.m.		18.1	20.7		60	0.00	0.13	0.38	54.3%
16-Feb-04	10:30 a.m.	33.6		14.2	60		1.25	0.00		
16-Feb-04	3:00 p.m.		13.7	18.5		60	0.00	0.49	1.74	39.1%
17-Feb-04	8:15 a.m.	28.4			60		0.99	0.00		
17-Feb-04	8:15 a.m.		15.0			60	0.00	0.25	1.24	24.6%
Averages for 5 Feb to 17 Feb							0.99	0.29	1.28	28.7%
Max							1.64	0.49	1.97	

It can be seen from Table 4. that for the period recorded, the net heat gain averaged about 1 kWh per day with a maximum gain of 1.6 kWh and heat lost averaged 0.3 kWh with a maximum loss of 0.5 kWh.

The panel area, 4.3 m², gave a heat collection power of 0.37 kWh/m²/day and a heat loss of 0.12 kWh/m²/day. These figures are considerably less than the values of 2 kWh/m²/day heat gain and 0.3 kWh/m²/day heat loss estimated above. These differences arise from panel efficiency, heat losses in the simple rig, and climate variations.

Although the data above relate to summer conditions, the rig was also run during the coldest part of winter with heavy ground frosts. The panel was an uncovered pool heater type and the tanks and pipes were not well insulated. No frost damage occurred as the water circulating from the cold tank prevented freezing.

The thermocouple data show clearly the points at which the thermosiphon reverses its actions. The plots also show the effects of cloudy days and nights compared with clear days and nights. Fig.3 and Fig.4.

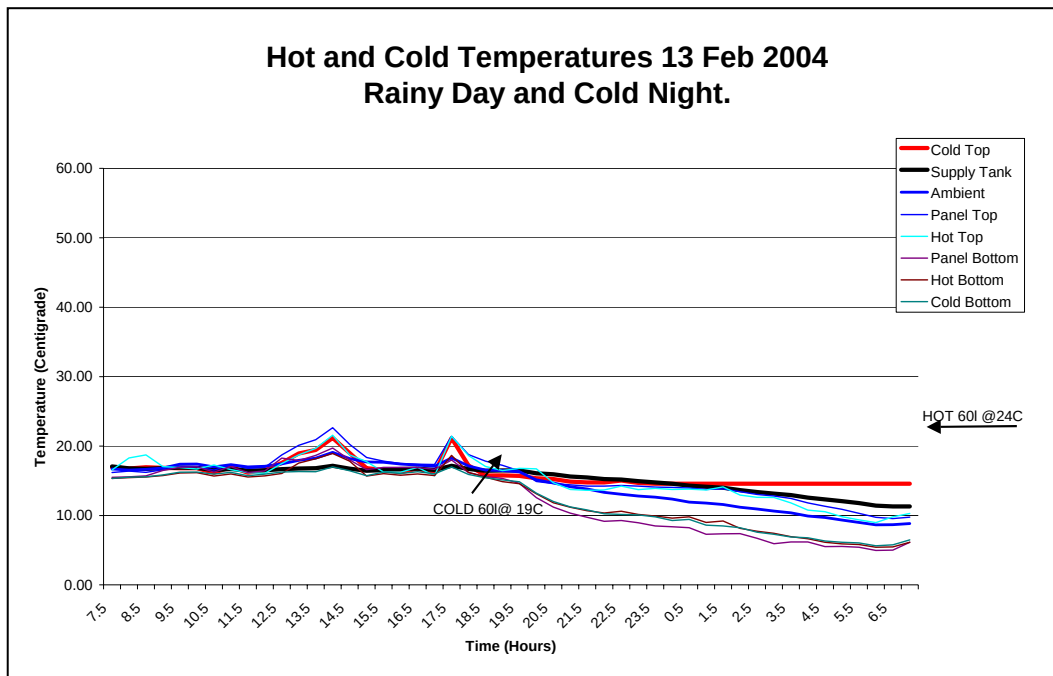


Fig.3 Temperature records for cloudy night and day.

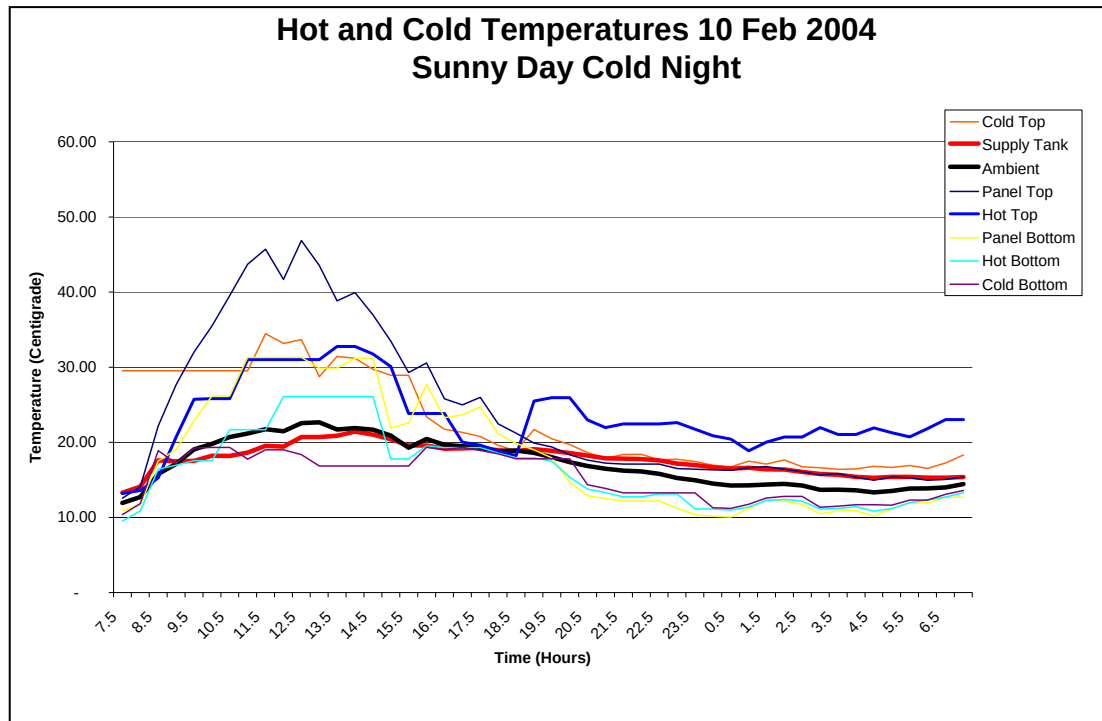


Fig.4 Temperature records for sunny day and clear night.

It can be seen from Fig. 3 that there is little heat gained on a rainy day but considerable heat lost during the cold night. When the skies are clear, as in Fig. 4, there are large heat gains during the day and some loss of heat, below ambient temperatures, during the night.

6. Discussions and conclusions

The experimental results did demonstrate that the thermosiphoning principle will work in this heating and cooling situation. The experimentally measured heat gains and losses were small compared with estimates of what can be achieved. This was probably due to the low efficiency of the uncovered pool heater type of panel and the losses due to lack of insulation of pipes and the solar panel itself. For a thermo-siphon system to work well the pipes have to be larger than for a pumped system, and the panels should be tilted to allow the water to flow evenly through the panels. An additional advantage of using a cold tank in the circuit is that it should provide a degree of frost protection that may otherwise use water from the hot tank.

However the potential for a useful heating and cooling system is clearly demonstrated for temperate climates with a good proportion of clear skies during the night and the day.

The flexibility of a system using water as the heat storage medium should encourage other uses of low-grade heat. The heat from concrete thermal mass is not transported so easily.

It should be noted, that whilst heavy construction, incorporating concrete masonry walls and floors has its advocates because of the thermal mass present, in practice not all of this mass is available for use. Floors are often carpeted reducing the ability of heat to enter or leave the floor. Masonry walls are poor insulators against heat flow. 900 mm of concrete has the same resistance to heat loss as 100 mm of insulated timber framed wall. Hence thin concrete walls often have insulation fixed to the inside. Like the carpeted concrete floor, this internal insulation reduces the ability of the concrete wall to contribute to thermal mass.

Acknowledgement

This research work was funded by the Foundation for Research Science and Technology, Wellington, New Zealand.

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ENERGY EFFICIENT MULTI STOREY RESIDENTIAL DEVELOPMENTS

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Abstract

Worldwide, the current pattern of urban development is unsustainable and metropolitan planning and development strategies deliver poor environmental outcomes in relation to energy production. As a result, an increasing number of governments and private sector development companies are initiating projects that aim to deliver enhanced environmental outcomes rather than a 'business as usual' approach.

This paper will summarise the findings from a study that explored the link between building orientation and energy efficiencies in sub-tropical and tropical climates. The study used a new thermal modelling software tool developed by CSIRO that responds more accurately to residential heating and cooling energy performance in those climate zones. This software tool responds to industry criticisms regarding cold climate modelling systems that do not make sufficient allowance for natural ventilation. The study examined a range of low, medium and high-density dwelling types and investigated the impact of orientation, insulation, ventilation and shading devices on energy efficiencies. This paper will examine the findings from the medium and high-density case study developments as these are relevant to residential developments in many South East Asian countries, such as Singapore, Hong Kong and Malaysia.

Finally, the paper will explore the potential benefits that medium and high-density residential developments have in the development of 'solar cities' and 'solar suburbs'.

Keywords : Sustainable buildings, Energy efficiency, Solar cities.

1. Introduction

Australia's current pattern of residential development is resulting in urban sprawl and highlights the necessity for development to be sustainable to avoid unnecessary demand on natural resources and to prevent environmental degradation and to safeguard the environment for future generations. This becomes more apparent when noting facts such as:

- Australia's metropolitan planning and development strategies deliver poor environmental outcomes in relation to energy production and consumption;
- Australia's per capita consumption of space (floor space, private open space), energy and water rank among the highest in the world and are continuing to increase; Specifically
- There are an increasing percentage of new dwellings undergoing construction with the number of dwelling units approved increased from -6.5% in September 2001-2002 (ABS, 2003) to +26% (September 2002 to 2003). This totals 175,135 new dwelling units (ABS, 2003);
- This growth in housing stock is outstripping the population growth and while the average household size is decreasing, the floor space per person is increasing (AGO, 1999b); and
- In Queensland, the number of dwelling units approved in 2002-03 increased by 10.6% on the previous financial year to 39,347 and much of this growth concentrated in South-East Queensland (SEQ).

This paper will summarise the findings from a study that explored the link between energy efficiencies and building orientation in sub-tropical and tropical climates. The study used a new thermal modelling software tool developed by CSIRO that responds more accurately to residential heating and cooling energy performance in those climate zones. This software tool responds to industry criticisms regarding cold climate modelling systems that do not make sufficient allowance for natural ventilation. The tool was used to explore the link between building orientation, insulation, ventilation and energy efficiencies in a range of low, medium and high-density dwelling types in sub-tropical southeast Queensland. This paper will focus on the findings from the medium and high-density case study developments as this are relevant to residential developments in many South East Asian countries, such as Singapore, Hong Kong and Malaysia.

2. Energy use patterns in Australia

The essence of a solar suburb is one that maximizes the percentage of dwelling allotments having good solar access, which in turn facilitates the design of energy efficient dwellings. The study reported in this paper focused on examining dwelling heating and cooling energy efficiency as it relates to and did not examine the following factors that significantly affect the overall energy efficiency of a dwelling or development:

- The embodied energy of materials used in construction of the dwellings;
- The efficiency of heating and cooling appliances;
- The use of other electrical appliances within the dwelling; and
- Variations in dwelling occupant behaviour.

There are significant variations in energy use throughout Australia. Fig.1 shows the typical breakdown of energy consumption for Australian dwellings. The breakdown of energy use in Queensland is quite different with the amount used for heating and cooling being significantly lower. Fig.2 shows that heating and cooling energy accounts for only 5% of the total, compared with 39% as the Australian average.

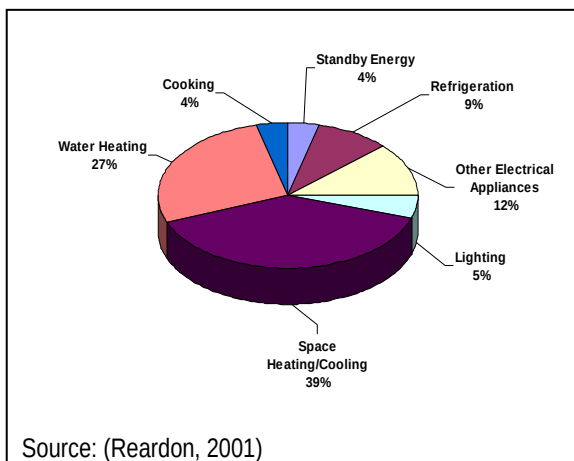


Fig.1 Average Energy use in Australian dwellings

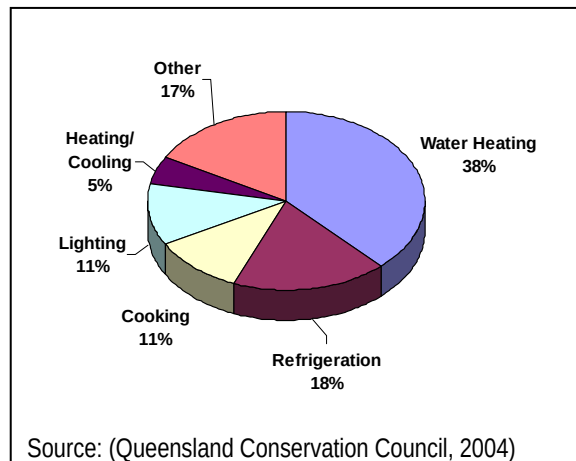


Fig.2 Queensland Household Energy Use

There has been a rapid increase in the number of air-conditioned dwellings in Queensland. Fig.3 shows that in 2001 around 28% of dwellings were air-conditioned, however, this has increased to 36% in 2004 and is expected to rise to 56% by May 2005 (Mickel, 2004).

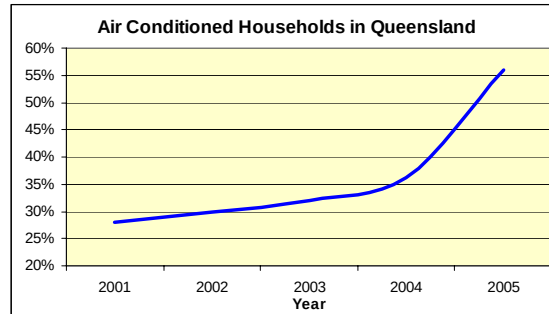


Fig.3 Air-conditioned Households in Queensland

This increase in air conditioning coupled with an increasing population in SEQ will see cooling energy become more dominant and will also place increased stress on the existing power generation and distribution network. It has been estimated that for every new air-conditioner installed it costs the state about \$13,000 to keep it running. This cost takes into consideration the cost of generation as well as distribution upgrades and augmentation (Mickel, 2004). These variations in energy consumption patterns for heating and cooling throughout Australia highlight the danger of sub-tropical and tropical regions, such as SEQ, adopting energy efficiency priorities that respond to different climatic requirements.

The increase in energy consumption and changing usage patterns in SEQ are also occurring throughout SouthEast Asia (SEA). In highly urbanized countries such as Singapore, it has been estimated that buildings consume more than half the electricity generated. Also in Singapore, an Energy Market Authority (EMA) survey found that since 1995, energy consumption has increased for all household type. EMA data shows that apartments with air-conditioning consume approximately 30% more energy than apartments without air-conditioning and that this increase is offset by only a minor decrease in the energy used for fans (EMA, 2003). The EMA survey also highlighted the difficulty of changing consumption habits, noting that people 'use electric blankets because the air-conditioning is too cold' (BCA-NUS 2003). Australia, in particular SEQ, needs to learn from the experience of its SEA neighbours and act to reduce the recent increase in air-conditioning before the trend becomes established.

3. Multi storey residential developments and energy efficiency

For the purposes of both the study and this paper, medium density is defined as two to three storey developments and typically walk up (Fig.4, Fig.5), while high density is defined as being four stories and over and typically serviced by a lift (Fig.6). These are common usage terms and may not correspond with definitions used by local authorities. According to the Australian Greenhouse Office (AGO), in 1998 these forms of attached dwellings accounted for 23% of the total housing stock and this was predicted to increase to 26% by 2010 (AGO, 1999). As urban densities increase, the impact of multi storey residential developments needs to be considered and the aim of this section is to examine a range of current design options in the context of the emerging energy code for medium and high-density dwellings.

Three multi-storey residential developments were selected for examination. All are of brick or block work construction, with suspended slab floors and plasterboard walls and ceilings. The floors were assumed to be carpet throughout with ceramic tiles in the wet areas. Other modelling assumptions include medium coloured surfaces throughout and the Holland blind window coverings. To eliminate variations based on differing climatic conditions, the apartments were modelled as if located in the same inner urban location, which was the Kelvin Grove Urban Village (KGUV). KGUV was launched in 2002 and comprises 16 hectares located 2 kilometres from the Brisbane Central Business District (CBD). The development is expected to deliver approximately 800 low, medium and high-rise residential units over the next six years. Case study 1 was a mid-level medium density one bedroom, one bathroom apartment, with approximately 58m² internal floor space. Case studies 2 to 4 (Fig.4) were three-bedroom, two bathroom apartments with 100 – 110m² internal space.



Fig.4 Case Studies 2 to 4 - Suburban or Inner Urban Medium Density Development

The high-density development (Fig.5) housed case studies 5 to 7 which were two, one bedroom, one-bathroom apartments with 48 – 55 m² internal space and a two bedroom, two-bathroom apartment with 77 m² internal space.

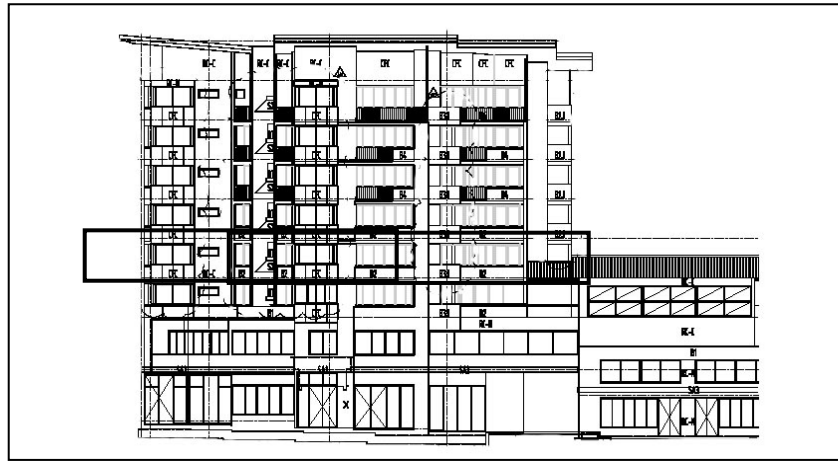


Fig.5 Case Studies 5 to 7 - Inner Urban or CBD High-Density Development

The case study dwellings vary in their degree of exposure to external climatic conditions. The medium density apartments open to covered stairwells, but have variations in the area of external wall and in the nature of adjoining spaces. Two of the apartments are located above another conditioned space and two are located partially over the garage area. The high-density apartments have conditioned spaces, in the form of other apartments alongside, above and below and open to an enclosed lift foyer, limiting the exposure to external climatic conditions.

Within Australia, a star based rating system is used to assess the relative energy efficiency of residential construction. The number of stars achieved is determined through a computer based thermal modelling program that determines average annual energy usage required to maintain a house within a particular thermal comfort range, over a set time and in a particular climate zone. Energy Efficiency Rating (EER) provisions for detached dwellings began to be introduced in the Building Code of Australia in 1991 and have been adopted by the States to varying degrees. EER provisions for multi storey residential developments are to be included in the BCA from 2005. Such provisions already exist in Victoria, where all dwellings must achieve an average house energy rating of at least 5 stars for all the dwellings in the building and a minimum house energy rating of at least 3 stars for each dwelling as determined by an accredited assessor. The range of possible star ratings is from 1 to 5, with 5 being the optimum level. The star rating is derived from the annual total energy load, expressed in megajoules per square metre per annum (MJ/m²/annum). The new software is still in the development phase and calibration issues related to a pre-existing large area bias are yet to be resolved. As a result, the case study dwelling performances will be discussed in terms of the annual total energy loads and not in terms of the star ratings.

To set the context of this emerging energy code for medium and high-density dwelling, the energy efficiency of the case study attached dwellings was compared with that of a similarly constructed detached, brick veneer on slab dwelling (Fig.6). This three-bedroom, one bathroom dwelling (case study 8) had a similar internal area (104 m²) to a number of the apartments.



Fig.6 Case Study 8 – Comparative Detached Dwelling

5. Impact of improved ventilation modelling on apartment energy efficiency

One of the drivers to improve Australia's Nationwide House Energy Rating Scheme (NatHERs) was the need to improve ventilation modelling in tropical and sub-tropical climates. This may also provide designers with a tool to augment passive design principles and improve the thermal performance of residential dwellings (Commonwealth of Australia, 2004). The development stage of the new software allows simulations using both the old and new ventilation models and the results of these simulations are shown in Table 1.

Table 1. Impact of Improved Ventilation Modelling on Energy Efficiencies

Case Study Dwelling	Heating Load MJ/m ² /annum	Cooling Load MJ/m ² /annum	Annual Total Load MJ/m ² /annum	Decrease in Annual Total Load
Attached 1	36.5 – 36.9	88.1 – 53.7	124.6 – 90.6	28%
2	16.5 – 16.5	54.6 – 43.8	71.1 – 60.4	15%
3	18.4 – 18.4	47.2 – 37.0	65.6 – 55.4	16%
4	40.3 – 40.3	72.9 – 67.3	113.2 – 107.9	5%
5	6.8 – 6.8	72.9 – 78.0	79.8 – 84.9	+6%
6	19.1 – 19.1	72.8 – 64.3	91.3 – 83.4	9%
7	21.2 – 21.2	55.5 – 65.5	76.7 – 77.7	+1%
Detached 8	17.0 – 17.3	125.1 – 97.4	142.1 – 114.8	20%

The study found that energy efficiencies improved between the two programs by an average of 16% for the medium density case studies. Except for case study 4, the energy loads for the attached dwellings in the new program are lower than those achieved for case study 8, the detached dwelling.

Modelling for improved natural ventilation assumes that the dwelling will have access to this ventilation. Increasing suburban and urban densities triggered an examination of the impact decreased access to natural ventilation on energy efficiency for the medium density dwellings. This was achieved by increasing the external shielding levels in the new software from moderate (suburban) to heavy (inner urban). This changes the patterns of airflow around the case study dwelling by replicating the impact of buildings located in close proximity as occurs in inner urban areas. The result was an increase of an average of 9% in the annual total energy loads for the medium density case studies 1 to 4.

Heavy external shielding, that is the close proximity of neighbouring buildings, was assumed for the high-density case studies and the impact of this can be seen in case studies 5 to 7 in Table 1. For two of the high-density dwellings, the cooling and annual total loads actually increased. These apartments have adjoining apartments or enclosed lift foyers on three sides, and so have almost no potential for cross

ventilation. To increase ventilation, the designers included louvered doors behind the entry door to increase internal ventilation while retaining a degree of security. The potential impact of these doors could not be modelled. The designers also used a thermal modelling program to test a range of shading options, providing an example of the potential for the use of thermal modelling to augment passive design principles and address complex ventilation issues.

6. Impact of orientation on energy efficiency

The dwellings were modelled at eight orientations throughout 360°, corresponding with the four cardinal and four semi cardinal points of the compass and the results are as shown in Table 2.

Table 2. Impact of Orientation on Energy Efficiency

Case Study Dwelling	Heating Load MJ/m ² /annum	Cooling Load MJ/m ² /annum	Annual Total Load MJ/m ² /annum	Increase in Annual Total Load
1	39.5 – 46.0	53.6 – 57.7	93.0 – 103.6	9%
2	12.7 – 17.6	46.9 – 55.8	59.6 – 73.4	27%
3	18.0 – 18.0	36.1 – 49.0	54.0 – 67.1	17%
4	39.6 – 59.4	68.8 – 83.5	108.3 – 143.0	32%
5	1.6 – 6.0	71.9 – 85.2	73.6 – 91.3	24%
6	5.7 – 16.3	53.9 – 63.7	59.0 – 80.2	35%
7	12.8 – 15.5	56.2 – 69.3	69.1 – 84.9	18%
8 (detached)	15.8 – 17.8	89.1 – 98.2	104.9 – 116.0	10%

Orientation plays a significant role in energy efficiency with the total annual energy loads at the worst orientations increasing above the optimum level by between 9 and 35%. For five of the attached dwellings, the increases were recorded against optimum performance totals that were low (54.0 to 69.1 MJ/m²/annum) when compared to the detached dwelling. Two dwellings achieved totals comparable with the attached dwelling and for case study 4; the annual total energy load at the worst orientation exceeded the levels achieved for case study 8, the comparison detached dwelling.

7. Impact of insulation on energy efficiency

Wall insulation is not required in attached dwellings in Queensland and ceiling insulation is not relevant to this discussion as none of the upper level apartments were examined. In this instance, insulation refers to the thermal insulating properties afforded by the apartment's proximity to adjoining conditioned spaces in the form of neighbouring apartments alongside, above or below the selected apartment. According to the AGO,

Modelling showed that attached dwellings were 36% more efficient on a per square metre basis in comparison with separate dwellings (AGO, 1999).

When both the attached and detached case study dwellings were modelled at the presented orientations and with the same degree of external shielding (heavy), the attached dwellings were more efficient than the detached dwelling and by an average of 33.7%, as shown in Table 3.

Table 3. Impact of Insulation on Energy Efficiency

Case Study Dwelling	Heating Load MJ/m ² /annum	Cooling Load MJ/m ² /annum	Annual Total Load MJ/m ² /annum	Improved Energy Efficiency
1	36.9	62.2	99.1	21%
2	16.5	57.5	67.6	47%
3	18.4	42.3	60.8	52%
4	40.3	76.3	116.4	7%
5	6.8	78.0	84.9	33%
6	19.1	64.3	83.4	33%
7	21.2	45.5	77.7	38%
8 (detached)	17.3	108.5	125.7	comparison

The least efficient attached dwelling was again case study 4, which is only 7% more efficient than the detached dwelling. The layout of this apartment exposes a long axis to external conditions. This apartment is also partially located above a garage and as a result, has the least area of wall, floor and ceiling spaces shared with adjacent insulating conditioned areas. The more attached dwellings resemble detached dwellings in their exposure to climatic conditions, the higher the annual total energy loads.

The number of simulations involved prevented the examination of more complex combinations of conditions such as the combined impact of poor orientation and increased external shielding, which would be the worst-case scenario for sub-tropical and tropical residential dwellings as urban densities increase.

8. Conclusions

The key assumption behind the research that underpins the study and this paper is that there is an expanding market in both Australia and elsewhere for information on energy efficient building practices. As energy efficiency regulations increase, this need will grow and create significant demand for information on available assessment tools for creating sustainable layouts (orientation, solar access and the like), rating energy efficient designs and products that deliver energy efficiency (solar technology).

Reducing energy consumption is by far the most practical and affordable way to reduce the environmental impact of residential development. Energy efficient design that removes the need for heating and cooling systems and the use of energy efficient lighting and appliances are solutions that are available immediately and often with little if any cost implication. While the percentage of energy use for heating and cooling is low by comparison with southern states, it is increasing and alternative solutions need to be developed before the trend for air-conditioning becomes a consumer expectation.

A number of potential benefits arise from the study that supports the notion that medium and high-density developments can contribute toward the goal of creating solar cities. These benefits include:

- The increasing percentage of medium and high-density apartments may reduce Australia's per capita consumption of personal floor space. The largest of the case study apartment had a similar internal floor area to case study 8, which was the smallest of the detached dwellings examined;
- Thermal modelling assumes the dwelling will be closed and conditioned when the temperature exceeds set parameters. The results indicate that the case study apartments are approximately 33.7 % more efficient than detached dwellings at maintaining the same internal temperature range; however,
- However this level of comparative efficiency reduced as the number of adjoining apartment (alongside, above or below) reduced and the apartment functioned more as a separate dwelling;
- The example of the use of thermal tools to assist designers assessing the impact of a range of ventilation and shading devices, demonstrates the potential for the use of programs to augment passive design principles in addressing complex ventilation issues;
- This combination of design tools is set to become increasingly important as increasing urban densities mean that access to natural ventilation is reduced.

In conclusion, while it is recognised that at the present, only a small percent of energy is used to heat and cool dwellings in tropical and sub-tropical climates such as in SEQ, this percentage is set to increase. Australia needs to learn from the experience of its SEA neighbours and act to reduce the recent increase in air-conditioning before the trend becomes established. It is critical that this aspect of energy consumption is reduced as Australia's ecological footprint is still far in excess of the world average, which is itself in excess of what the planet can actually support.

Acknowledgements

The research undertaken for this paper was part of a Cooperative Research Centre for Construction Innovation (CRC-CI) project.

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DEVELOPMENT OF A HYBRID WIND CATCHER/TOWER AND HEAT CONVECTOR FOR HEATING NATURALLY VENTILATED SPACES

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Abstract

A hybrid wind catcher and heat convector system was developed in which a wind catcher encapsulates the incoming air, which can be heated or cooled via a wall mounted convector unit. The developed system incorporates a solar water heater and a low-voltage photovoltaic extract fan in addition to the wind catcher terminal and convector unit. In this paper, the analysis of performance monitoring under real winter weather conditions of a wall mounted ventilation heat convector were discussed. For this purpose, the wall-mounted convector was installed in a laboratory room of the Engineering Building of the School of Construction Management and Engineering. Air and hot water temperatures and air speeds were measured at the entrance to the convector and in the room. The hot water temperature was controlled for 40°C, 60°C and 80°C. The results of the thermal performance investigation showed that the system contributed greatly to the room heating, particularly at water temperature of 80°C, and supplied adequate quantities of fresh air to the room. The calculated average thermal effectiveness of the heating convector unit was 0.43. Such a system will be able to provide ventilation air at supply temperatures above room temperature for eliminating the problems of cold draughts in winter with lower energy consumption than conventional systems.

Keywords : Natural ventilation, Wind catchers, Hybrid systems, Indoor air quality, Heat convector, Heating effectiveness.

1. Introduction

The application of natural ventilation techniques such as wind catchers systems in modern buildings will help to enhance indoor air quality, minimize energy consumption and the release of harmful emissions to the environment (Elmualim and Awbi 2002). The problems associated with applying natural ventilation in general and wind tower/catcher in particular, are the lack of control, and hence the inadequacy of providing satisfactory internal conditions, and heat losses in winter as suggested by the monitoring of wind towers/catchers in real buildings (Elmualim and Awbi 2003). Hybrid ventilations systems help to maintain satisfactory indoor environment by combining natural and mechanical systems in order to avoid the cost of energy usage of full year-round air conditioning systems (van Heemst 2001; Delsante and Vik 2002; Heiselberg 2002). The integration of wind catchers with other renewable sources will make them attractive and their performance can be improved at low energy costs.

An integrated wind catcher/convector was developed. The incoming fresh air through the wind catcher/tower can be heated or cooled via the convector prior to entering occupied spaces. The integrated wind catcher/convector system consists of a wind catcher terminal for supply and extract air utilizing natural draught assisted by low voltage photovoltaic extract fan, a convector unit for heating and cooling of the air and a solar heater for heating the water passing through the convector unit as can be seen in Fig.1. The performance of the integrated system was investigated using tests under real weather conditions, CFD modelling and controlled lab tests using fan powered duct for the operation of the convector unit only. In this paper, the results of the performance investigation using tests under real weather conditions for the operation of the heat convector unit are presented.

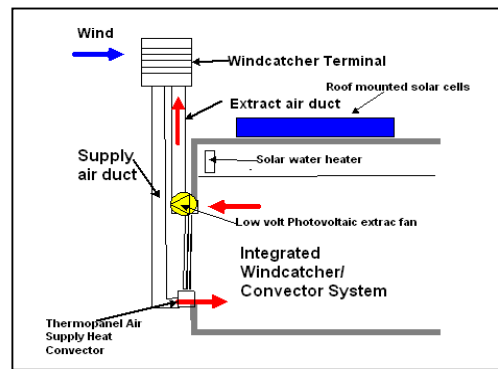


Fig.1 Integrated wind catcher/convector prototype system

2. Laboratory Tests under Real Weather for the Heat Convector Unit

An integrated wall mounted supply air convector with a heat exchanger system was installed in a laboratory room (Room G13) in the Engineering Building of the School of Construction Management and Engineering. This hybrid ventilation system operates by bringing in fresh air through an opening in a wall with the assistance of an exhaust fan or natural draught. The incoming air is then heated by the heat convector. This part of the investigation presents the results of the performance of the convector system which is being monitored during the winter months of 2002. In this experimental investigation, the extract fan was not operated as the work was carried out to investigate the performance of the wall mounted vent air supply convector due to natural draught only (wind and temperature difference).

The wall mounted heat convector was installed in a single storey laboratory building. The room has a floor area of approximately 37 m² and a volume of 135 m³. The vent convector was installed in a window pane at a height of 1.280 m above floor level (Fig.2). The convector (Fig.3(a)) consisted of a telescopic rectangular wall unit (355x355 mm), "a" in Fig.3(b), fitted with exterior louvers to prevent ingress of rain, insects and birds, "b" in Fig.3(b). The wall unit has a specially designed self adjusting, aerodynamic wind damper, "c" in Fig.3(b). The system comes complete with a frost-free convector unit fitted with a thermostatic valve sensor placed in the air flow duct to control the temperature of the incoming air, "d" in Fig.3(b). A rear self adjusting plastic shutter is fixed to the heat convector to prevent reverse flow out of the room, "e" in Fig.3(b). The front cabinet consisted of enameled finished steel and a detachable cover. The cabinet is fitted with polyester or allergy EU 8 filters, "f" in Fig.3(b).

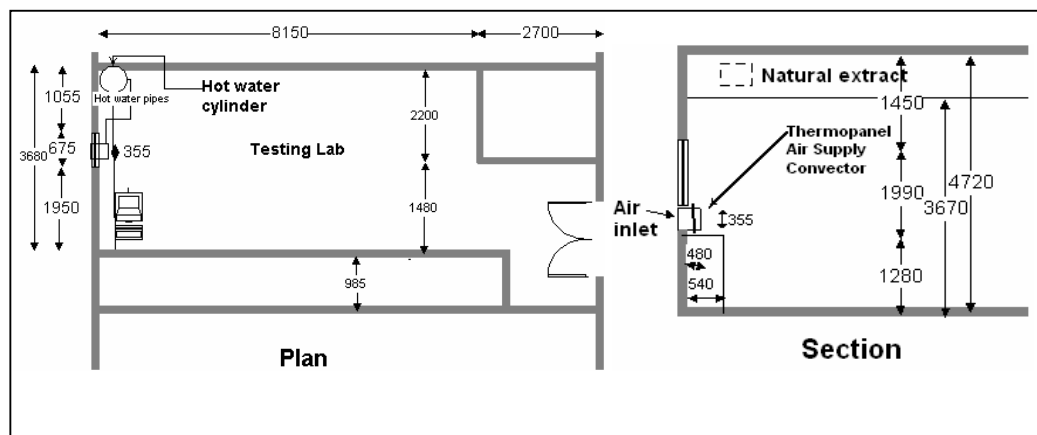


Fig.2 Laboratory test set-up showing installation of the wall convector

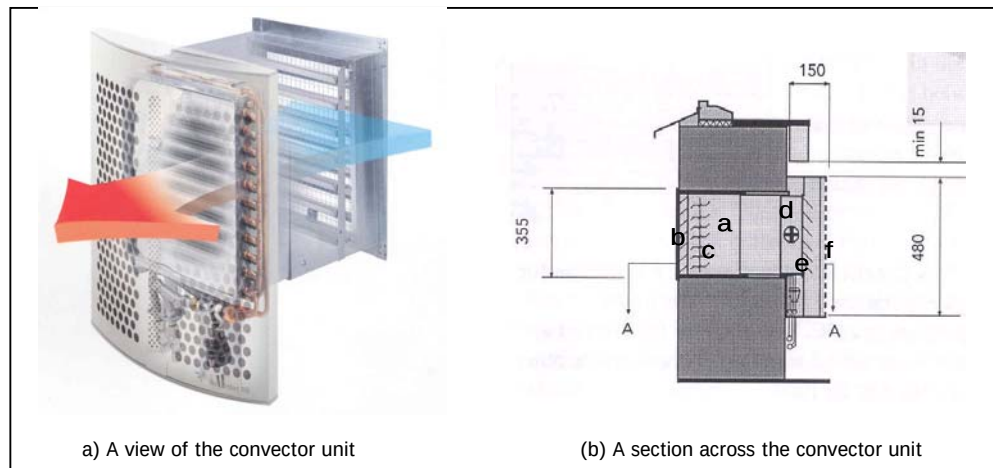


Fig.3 Components and dimensions of the wall mounted heat convector

A hot water circuit was constructed for supplying and controlling the hot water to the convector. A domestic size hot water cylinder (height of 900mm, diameter of 400 mm and a capacity of approximately 113 L) was connected to the supply convector with 15 mm copper pipe covered with 9 mm thick insulation. The cylinder was fitted with a 3 kW emersion heater connected to a control unit to control the temperature of the hot water supply to the convector. The hot water circulated using CE Circulating pump with three-speed controls (CP35, 230V-50Hz). The hot water circuit fitted with isolation valves and drain taps to control the water volume. Pressure gauges were fitted before and after the heat convector to measure the water pressure difference. A flow meter was connected to the hot water pipe circuit to measure the water flow rate (Fig.4).

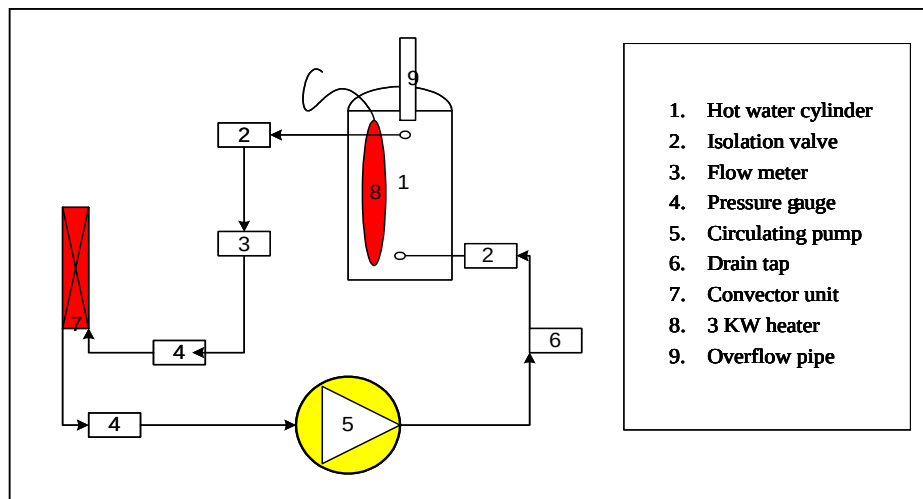


Fig.4 Schematic of the hot water circuit

Monitoring tests were carried out under real weather conditions. During the tests external and internal temperatures were measured using thermocouples connected to Yokogawa Hokushin Electric YEW data logger (model 3088 Hybrid Recorder) connected to a PC for data entry and manipulation. A hot wire anemometer connected to the data logger was used to measure the air speed inside the wall duct unit after the wind shutters and dampers and before the heat convector. Two thermocouples were connected to the hot water pipes to measure the hot water temperature before and after the heat convector. Inside the test room, four thermocouples were positioned in front of the unit to measure the temperature of the air leaving the air supply unit. Another three thermocouples were positioned 1 m away from the unit at heights of 0.5, 1.2, and 1.5 m above floor level in addition to another two

thermocouples positioned 1 m away from the center of the supply air convector and 0.5 away on each side. The air speed and relative humidity inside the test room were measured using a Solomat MPM4100 Environmental Monitoring System.

The circulating pump was in operation during all tests. Measurements were taken for four sampling periods for durations of approximately 2 days during which time the hot water temperature was controlled at 40, 60 and 80 °C to investigate the thermal effectiveness of the convector. Tests for the hot water temperature at 40 °C were carried out during 22-25 February 2002, and 20-22 February 2002 for the hot water controlled temperature at 60 °C while tests for controlled hot water temperature at 80 °C were carried out during 17-18 January and 25–27 February 2002. Measurement readings were recorded at an interval of 10 minutes in all tests. The effectiveness of the heat exchanger incorporated with the wall mounted vent convector was calculated. The heat exchanger effectiveness is defined by the following formula (Holman 1997):

Effectiveness = $\mathcal{E}$ = actual heat transfer/maximum possible transfer.

It can be calculated either by the heat lost by the hot fluid or the heat gained by the cold fluid. The effectiveness of the heat exchanger was calculated for the real weather and controlled lab tests using the following formula:

$$\mathcal{E} = \frac{T_{air2} - T_{air1}}{T_{w1} - T_{air1}}$$

where:

$\mathcal{E}$ is the effectiveness of the heat exchanger

T_{air1} the air supply temperature

T_{air2} is the outgoing air temperature from the vent convector unit

T_{w1} is the maximum supply water temperature.

3. Results and Discussion

Table 1 gives the conditions and the date for the tests under real weather and the average temperatures for the supply and return of the hot water to the heat convector. In test 1 the hot water temperature was controlled for a set-point of 80°C which then repeated in test 4. For test 2 and 3 the hot water was controlled for a set-points of 40 and 60 °C, respectively. The maximum temperature of the hot water supplied to the convector in the test with hot water temperature controlled at 80°C was found to be about 74.1 °C with an average value of 67.0 °C. During the test with hot water controlled at 40 °C, the temperature difference between the supply and return water was approximately 3 K. In the other two tests the temperature difference was around 10 K. However, the temperature of the return hot water from the heat convector was found to be fluctuating during the tests with higher water temperature controlled at 60 and 80 °C.

Table 1 Conditions and average water temperatures for the tests

Hot water temperature for test	Date of test	Supply water temperature	Return water temperature	Average wind speed at 10 m (m/s)
Test 1, 80°C	17-18/01/02	67.5	63.5	3.4
Test 2, 40°C	22-25/02/02	38.4	35.1	6.1
Test 3, 60°C	20-22/02/02	51.0	40.2	6.1
Test 4, 80°C	25-27/02/02	67.0	58.0	6.1

In test 1, the maximum temperature of the hot water supply to the convector was found to be about 76.6 °C before entering the air supply convector unit with an average value of 67.5 °C. The temperature of the return hot water from the heat convector was found to be fluctuating with an average value of 63.5 °C as can be seen in Fig.5.

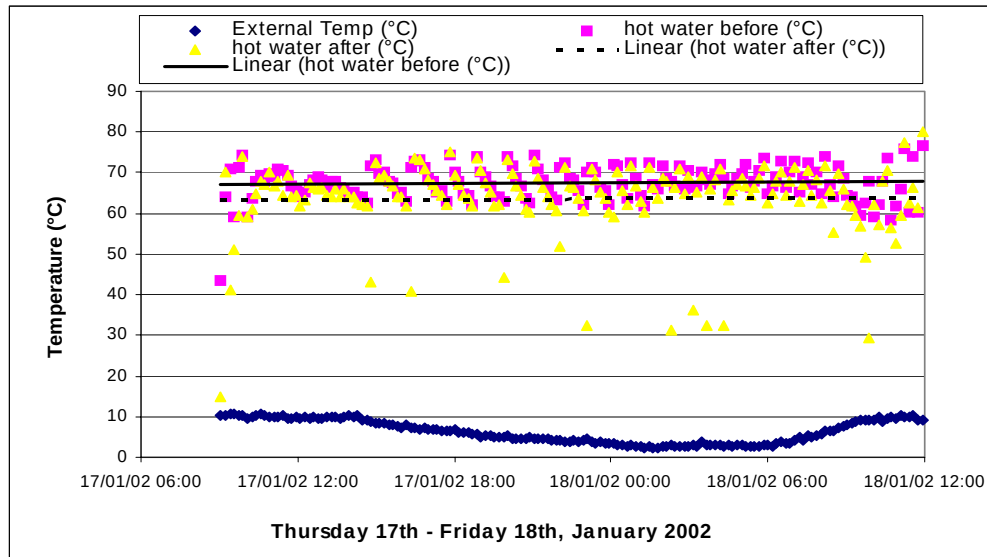


Fig.5 Variation of supply and return hot water temperatures in test 1

In this test, test 1, the distribution of the internal temperatures, 1m away from the unit and at heights of 0.5, 1.3 and 1.8 m, followed a similar trend to that of the measured external temperature with an average temperature difference between inside and outside of 12 K (Fig.6). The air temperature increased slightly with increase in the height above floor level. During the colder period of the test at the early hours of the morning (00.00-06.00 am) of the 18/01/02 where the external temperatures dropped below 3 °C, the measured internal temperatures were found to be in the range of 13-15 °C. It was observed that the air flow inside the convector unit was very irregular, particularly during the morning of the second day of the test. Fig.6 also shows the calculated ventilation rate due to the heating convector. The ventilation rate for the whole monitoring period was found to vary in the range of 0.008 and 0.052 m³/s (8-52 l/s). The ventilation rate dropped to below 0.002 m³/s (20 l/s) at around 09.00, 15.00, 00.00 in the first day and at around 11.00 hours the next day of the monitoring period.

The distribution of the internal temperatures, 1m away from the unit and at heights of 0.5, 1.3 and 1.8 m, followed a similar trend to that of the measured external temperature for most of the duration of the monitoring in the other three tests, 2-4. Fig.7-Fig.9 show the monitoring results for the three test conditions, Tests 2-4. During the colder period of test 2, with water set-point temperature of 40 °C, at the early hours of the second morning (04.00-05.00 am) where the external temperatures dropped below 3 °C, the measured internal temperatures was approximately 10.4 °C with temperature difference between inside and outside of 8 K (Fig.7). The maximum temperatures difference in test 3 and 4, with water set-point temperature at 60, and 80 °C, was approximately 10 K (Fig.8, Fig.9). Generally, the measured internal temperature during the tests increased marginally with increase in the height above the floor. The vent convector was more effective in providing heating at higher water set-point temperatures.

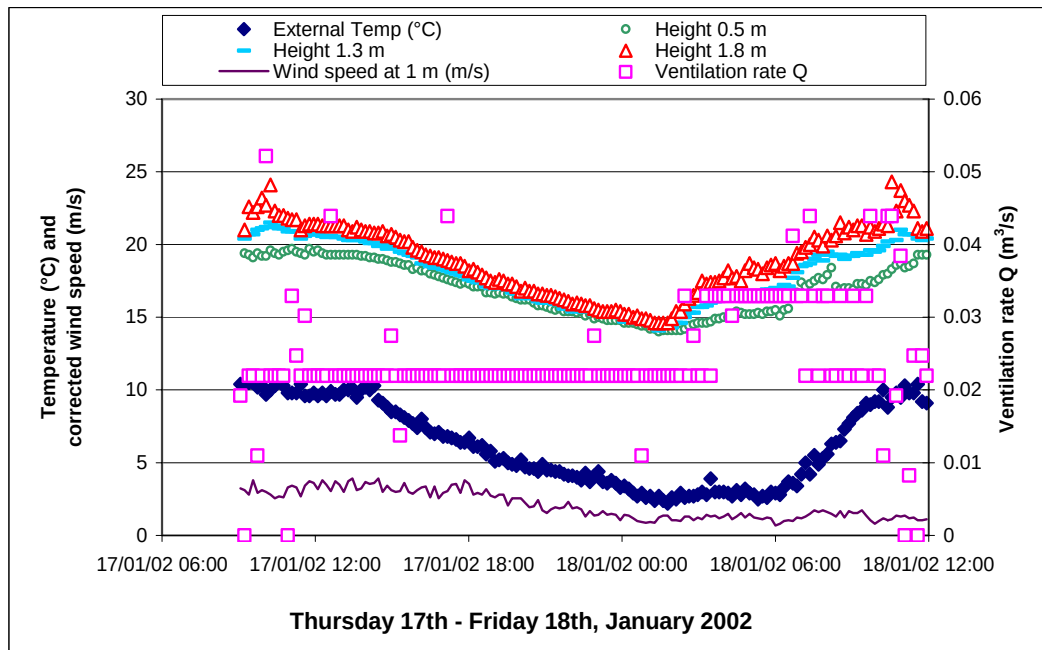


Fig.6 Variation of the temperatures and ventilation rate during Test 1 with water set-point temperature of 80°C

It was observed that the air speed inside the convector unit was very regular in those three tests, as the position of the anemometer was pushed away from the aerodynamic damper. Fig.7-Fig.9 also show the ventilation rate results for the three tests. During test 2, with water set-point temperature at 40 °C, an average air flow of 0.148 m³/s (148 l/s) was recorded giving a average ventilation rate of 4 ac/h for the room (approximately 15 l/s per person if ten occupants were in the space). There were little variations in the air flow in the tests 2-4. However, as the air speed inside the convector was measured before the aerodynamic dampers, allowances should be made for the pressure losses due to the convector, the plastic shutters and the front cabinet. Which will results in a reduction of the air flow through the convector unit.

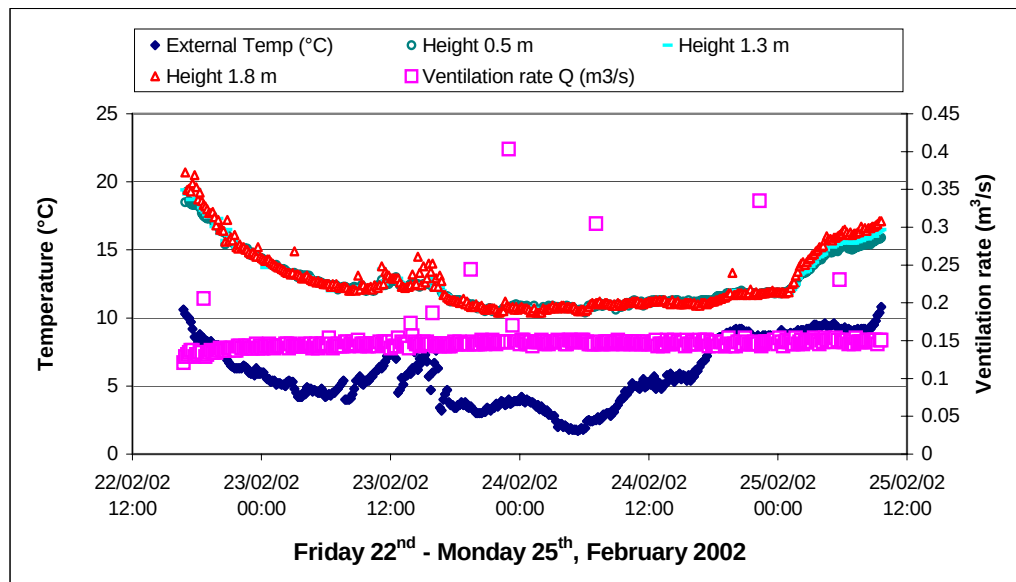


Fig.7 Temperature and ventilation rate variations in Test 2 with water set-point temperature of 40°C

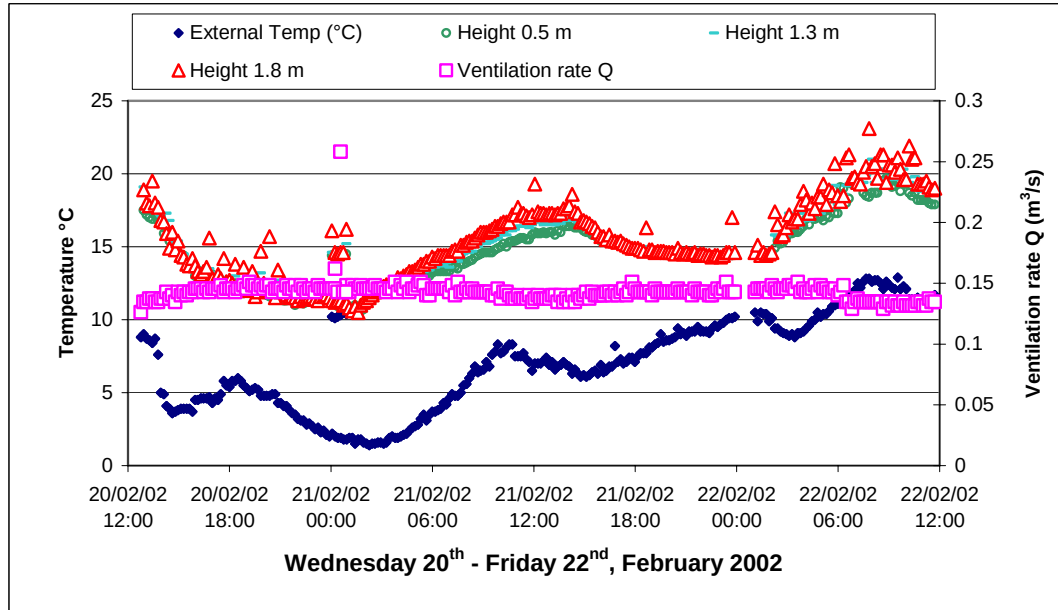


Fig.8 Temperature and ventilation rate variations in Test 3 with water set-point temperature of 60°C

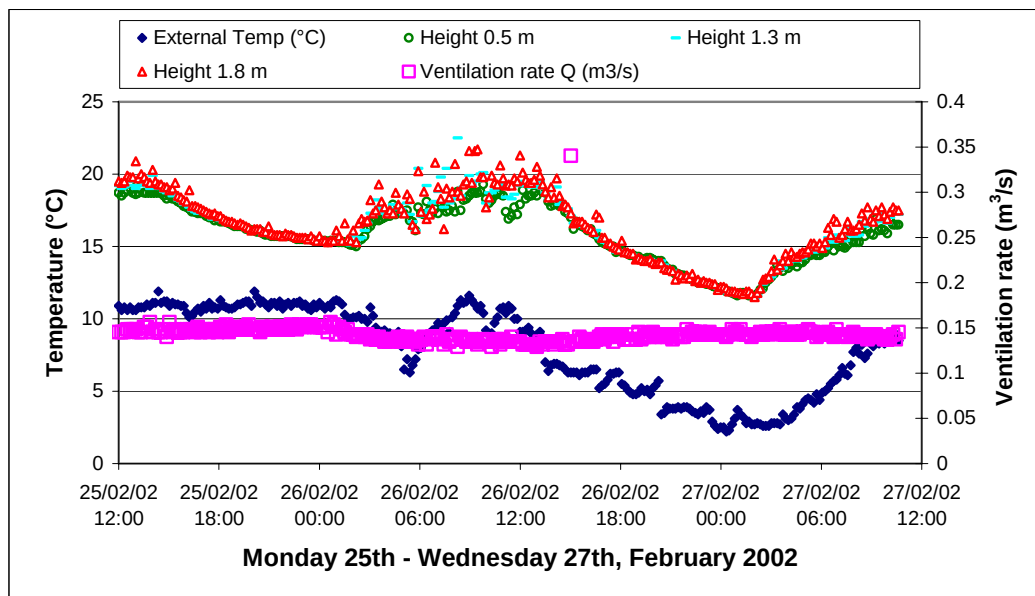


Fig.9 Temperature and ventilation rate variations in Test 4 with water set-point temperature at 80°C

The calculated effectiveness in the real weather tests was 0.35, 0.61, 0.51, and 0.36 for tests 1-4 (Table 1), respectively, where the water temperature set-points for these tests was 80, 40, 60 and 80 °C, respectively for tests 1-4. From these results it can be concluded that the heat exchanger is more effective at hot water set-point temperature in the range of 40 - 60 °C.

4. Conclusions

Integrative natural and mechanical ventilation systems in a hybrid system will facilitate achieving adequate indoor air quality at low energy costs. A hybrid wind catcher/heat convector was instigated here. The integrated hybrid system consists of a wind catcher terminal exploiting natural draught (wind

and temperature) and assisted by a low volt photovoltaic extract fan, heat convector for pre-heating/cooling the incoming air and a solar water heater. The performance of a wall mounted air supply heat convector was investigated under actual winter weather conditions. The internal temperatures and air speed inside the duct of the vent convector were measured during the winter month of 2002 for various test conditions. In the first test the hot water temperature was controlled at 80 °C and at 40, 60 and 80 °C for tests 2, 3 and 4 respectively. Monitoring periods were above 2 days in each test. The system was found to regulate the air flow to the occupied space with an average volumetric air flow of 148 l/s which is also later validated by conducting the controlled lab testing. The ventilation rate was in excess of 4 ac/h for the room in which the unit was installed. However, lower ventilation rate of 0.2 – 2.0 ac/h were measured in some tests depending on weather conditions. The temperature of the test room was greater than the external temperature by about 8 to 12 K at a distance of 1 m away from the front of the cabinet of the heat convector for tests with hot water set-points temperature of 40 and 80 °C, respectively. The average effectiveness of the heat exchanger was 0.43. The heat exchanger was more effective at low temperatures.

The investigation showed that the wall vent convector will improve the indoor air quality and contribute to the heating of occupied space by supplying a heated outdoor fresh air, particularly, at high hot water set-point temperature of 60 and 80° C. At lower hot water set-point temperature of 40 °C, the system will provide air at a temperature close to room temperature but will still help eliminate the problems of cold draughts in winter and provide sufficient warm air with moderate energy consumption. By incorporating the wall mounted convector with natural ventilation opening such as wind catchers for heating purposes in winter, problems of cold draught and heat losses can be eliminated and further contribute to the heating of spaces with little energy consumption. The convector can also be used for cooling in summer. Supplying the heat exchanger with chilled water or water at ground temperatures can further enhance the performance of wind tower/catchers for summer operation. Having said that, the construction and performance evaluation of a prototype of the integrated wind catcher/convector provide an interesting area for future research and development. The results of the performance investigation of a prototype wind catcher/convector will be shared in future publications.

Acknowledgement

The author would like to acknowledge the support of Wetterstad Consultancy and Thermopanel, Sweden.

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A RETHINKING IN DESIGN APPROACH FOR A TROPICAL BUILDING : THE EMPHASIS ON RENEWABLE ENERGY AND ENERGY EFFICIENCY

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Abstract

Through the 8th Malaysia Plan, renewable energy (RE) and energy efficiency (EE) are gradually becoming the focus of main discussion with RE being defined as the "fifth fuel" in Malaysia. It has been generally reported by Malaysian Energy Center that most commercial buildings consume about sixty to seventy per cent of electrical energy to cool the interior. Most buildings in Malaysia are not designed for energy saving. It is essential that the future architectural design in Malaysia highlights and incorporates passive design elements to reduce heat gain in the interiors. This will reduce the dependency upon active systems that necessitate the burning of fossil fuels to cool the environment. This paper highlights the development of domestic buildings namely the Traditional Malay Village House and modern house designs in addressing the issues of energy consumption. The passive design elements that contribute to reducing heat gain on the building fabric supplemented by active technology systems are briefly described. The studies indicated the importance of Schools of Architecture in Institute of Higher Learning to review their curriculum and adjust the syllabus towards the emphasis on sustainable development. A paradigm shift is needed in thinking towards green architecture and the design approach for the next generation of Malaysian buildings is proposed.

Keywords : Passive design elements, Renewable energy, Energy-efficient building designs, Sustainable development.

1. Introduction

The progress in economic development has expanded buildings into towns, cities and capitals resulting in deforestation. The clearing of jungles has affected the microclimate to be warmer than before. Thus to maintain thermal comfort we have to resort to the active systems that uses conventional energy from burning the fossil fuels. Air-conditioning, a popular and convenient solution, has been known to be one of the contributory factors in releasing the chlorofluorocarbon that depletes the ozone layer of the atmosphere. The inevitable population increase will subsequently increase the demand for more air-conditioners and increase further the demand for energy. To overcome this dangerous trend building designs should incorporate more on the passive design elements before resorting to the use of electrical devices or appliances to mitigate the high temperatures and the high humidity. So far at present the practice in building design and the application of active systems have not been energy efficient (1). An awareness program should be directed to the building professionals and the public and education should be addressed to the students of architecture.

2. Background

During pre-Colonial period the indigenous people of Malaya live in the Traditional Attap Village House, featuring the passive solar design elements, high pitched roof with high ceilings and generous openings. They are often constructed from thin and light construction materials (timber and attap) with elevated floors and very few internal partitions (Fig.1).



Fig.1 The Malay Traditional Village House

Under the Colonial rule, the British who came from a cold country and sensitive towards the tropical heat, designed a detached house for their own comfort and eventually this building became the starting point of an urban house. The Colonial House is of heavy masonry construction (Fig.2). It maintained the high ceiling with less internal partitions. The rooms were spacious with a great number of openings. Due to the characteristics of the Malaysian wind i.e. unpredictable and multi-directional, some forced effort was needed to generate air movement and the 'pungkah' fan was introduced by the British (Fig.3), literally using the manpower of the Indian coolie to swing the vertical ceiling fan by hand. With the advent of electricity, this was later replaced by electric fans.



Fig.2 The British Colonial House

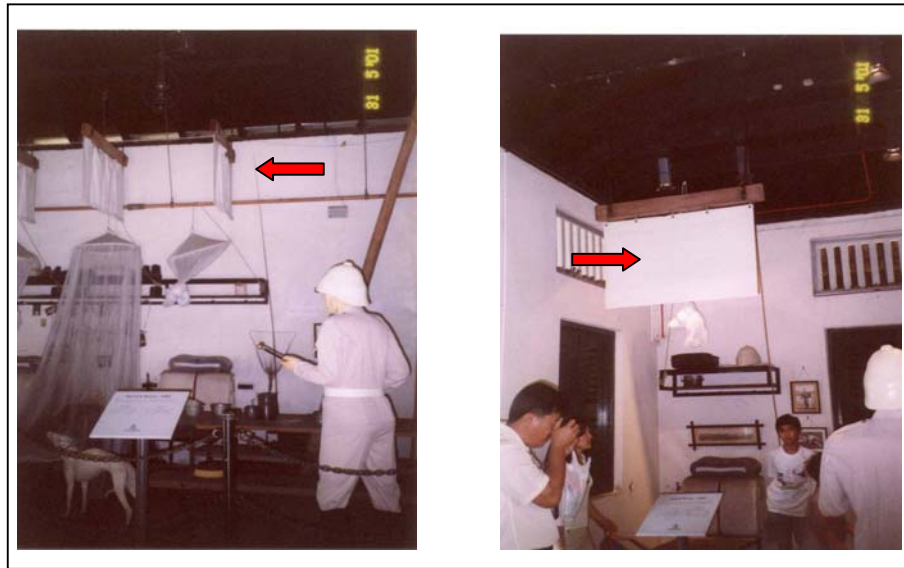


Fig.3 The Pungkah Fan invented by the Colonial British

There was a gradual change in lifestyle after Independence especially with the progress of the construction industry. The prosperous economy results in the construction of large houses with plenty of rooms and internal partitions. Low ceilings are then possible that allows for a two-storey bungalow. Interiors are frequently cluttered with furniture thus preventing an efficient indoor air movement. Openings are not generous because of privacy. Apart from the daily use of electric fans, air-conditioning has become commonplace to overcome thermal discomfort. Thus passive designs have taken a backseat and energy guzzlers apparatuses are in command (Fig.4).



Fig.4 A modern bungalow house in Malaysia

After observing existing designs of ceiling fan in the market it was found by personal observation and measurement of air velocity using a pocket anemometer, that the designs are inefficient in creating the cone of air movement. One has to turn to a higher wind speed dial for a wider cone of air movement. The higher the air movement generated by switching to a higher speed the more energy it consumes. The characteristics of Malaysian wind are that they are erratic in its wind velocity, multi-directional and lacking in the required wind speed for generating electricity averaging about less than 0.8 m/s when the required velocity should be about 1.2 meter per second and above. Hence, sole dependence on natural wind for thermal comfort indoors is unreliable. To overcome the thermal discomfort, one resorts to using electric fan at a faster velocity than required and/or using air-conditioning. Air-conditioning is a commonplace item which not only an energy guzzler but also releases chlorofluorocarbons (CFCs) that is detrimental to the environment, especially to the ozone layer in the atmosphere. As population increases the usage of air-conditioning would also increase and further aggravate the ozone layer condition. The trend should be reversed without compromising human thermal comfort. Malaysians

need a lot of air movement to rid off the radiant heat during the daytime and also plenty of air movement at night to rid off the high relative humidity. The ideal comfort condition for Malaysians without resorting to mechanical aids is to be under shade and experiencing air movement concurrently. To emulate this situation indoors may not be possible because when walls are erected wind is prevented from entering the interior and that is when the problem of thermal comfort begins. Fig.5 shows the author experiencing the thermal comfort and it was from here that the search for cooling the building fabric passively was mooted.



Fig.5 Ideal natural comfort condition in Malaysia

3. Present Situations

Most present day architects and mechanical engineers are overseas trained thus foreign ideas and knowledge have been inculcated and applied in their approach to solve local problems. Some have been successful in implementing these ideas and some were imposed by the ignorant clients whom for the sake of profit insist on beauty more than environmental performance. The lack of understanding on material thermal performance, wrong choice of trees or shrubs for shading, wrong orientation of glazed windows and openings facing the sun path are among the most of the common mistakes made by building professionals. Georgian windows are appropriate for buildings in the United Kingdom, however, there are quite a number of such designs prevalent in Malaysia. The Georgian window maximizes sunlight to enter the interior and this is the very reason that we should avoid so as not to lower any further the temperature of the air-conditioners. The lower the temperature the more energy is consumed and also more CFCs are produced as waste products. The greater the gap between the indoor temperature and outdoor temperature the more CFC is produced. We should be and gradually adjust our body comfort to accept a temperature of at most 28°C. The Georgian window is one example, and there are many more foreign elements that are not suitable for Malaysian climate.

The architects must be sensitive in this aspect if they were to be solar architects. Not understanding the basic behavior of having fully glazed façade facing the sun's path morning, afternoon and late evening that create a green house effect indoors is inexcusable and is tantamount to indirectly contributing to global warming. Several environmentally failed buildings create heat islands and several heat islands warms up the globe.

Another common mistake is the lack of understanding of the behavior of indoor air. To get rid of stale indoor air by passive means any normal architect would provide an atrium, roof monitors or in the earlier days the common jack roof. It just does not work anymore and present day Malaysian climate need some mechanical force to provide comfort at a suitable rate.

4. Passive Building Design Elements

A paradigm shift is needed in designing buildings where first we have to explore the passive design technology bearing in mind the energy that can be saved, before importing ideas which are alien to our cultures. Before proposing a building design one has to do a detailed site analysis of the building site. It is important to be aware of the endowments given by nature and to make full use of its quality into the design. One should understand the principle of the land and sea breezes and what it does. A combination of the wind behaviour at land and sea phenomena and wind behaviour at valleys for a building site is the most ideal condition one can get to utilize the advantages of those two natural locations. The choice of trees whether grown naturally or trees planted later on are also an important consideration. Having the best condition of a building site but marred by the wrong choice of trees would prevent the desirable indoor climate. Hard landscaping is to be at a minimum to avoid reradiation of surface heat that creates heat island and when extraordinary hot days do occur water spray on top of roofs or walls may be the answer to cool the surroundings (2).

Building materials is constantly being researched to find the best thermal performance. But no matter what the material is, any direct sunlight into the house would defeat the purpose of having a good thermal performance material. The material used for the building envelope should be supplemented with efforts to reduce radiant heat by the design of building such as the shape and orientation, roof shape and roof pitch, sun-shadings of all types, roof and wall sprays, reflective materials including white paint and insulation materials. When the building fabric is prevented from heat, at the same time there must be efforts to encourage air movement inside the building. Such initiatives include wind deflectors, shaping and orientating the building shell to maximize exposure to the wind, building with open plan and air shafts to encourage stack effect, double walls and roofs and other fenestrations (3).

5. Active Building Elements

It is difficult to design for a total passive solar building design without the aid of mechanical systems. The dependence upon wind proves futile because of its unpredictability. Three major drawbacks of wind characteristics in Malaysia are that they are not only erratic but of varying speeds and multidirectional (4). To aggravate the situation further for designers, approximately 30% to 50% of the year is calm. Calm conditions are considered as wind speed of less than 0.3m/s. Designers would use prevailing wind data as reference but they become irrelevant at the microclimatic scale when future adjacent lands are developed at a microclimate scale. Due to the unpredictability of wind, to rely solely on natural ventilation may not be a true solution of achieving thermal comfort. When cooling by natural means are not achievable, clients will opt for easy solutions by resorting to mechanical aids such as air-conditioning and fans as mentioned above. These are much easier and convenient to control because comfort can be experienced at the flick of a finger. Hence comfort becomes costly. Mechanical systems are necessary for our current lifestyle. These mechanical systems provide pleasant indoor conditions in any type of weather and should be designed and used judiciously at appropriate places of a building. Their use is more for "people comfort" rather than cooling the building fabric.

By reducing heat gain on the building fabric one can conveniently resort to using fans to generate indoor air movement. This is cheaper than air-conditioning. If air-conditioning must be used, then optimum temperature setting should be adopted and the gap between the indoor and outdoor temperatures minimised.

The use of sensors prevents wastage of energy. The use of energy-efficient equipment and appliances will further reduce energy consumption. Finally, in situation where costs are not the constraints, the use of photovoltaic systems offers an alternative means for solving the environmental problems. After all, in Malaysia there will be bright sunny skies almost throughout the year.

6. Conclusions

The Ministry of Energy, Water & Communication building at Putrajaya (5) is the first building of its kind in Malaysia encompassing energy efficient building based on the passive and active technologies. A benchmark of energy design and features, consumption was set at 135kW/hr/m for future and existing

buildings. Eventually, the benchmark may be made mandatory for future buildings to follow suit, thus the time when the professional services of solar architects and solar mechanical engineers are required. Fig.6 shows possible future trend of low energy cooling technologies been applied to buildings as proposed earlier in the above paragraphs. This example is an extreme case exemplifying the points made earlier. It is hoped that with future use of the photovoltaic system electrical appliances can be used all day and night without worrying about energy consumption cost. Standard of living will then be raised without affecting the environment. Hence, if housing population increases the additional consumption does not deplete the fossil fuel further.

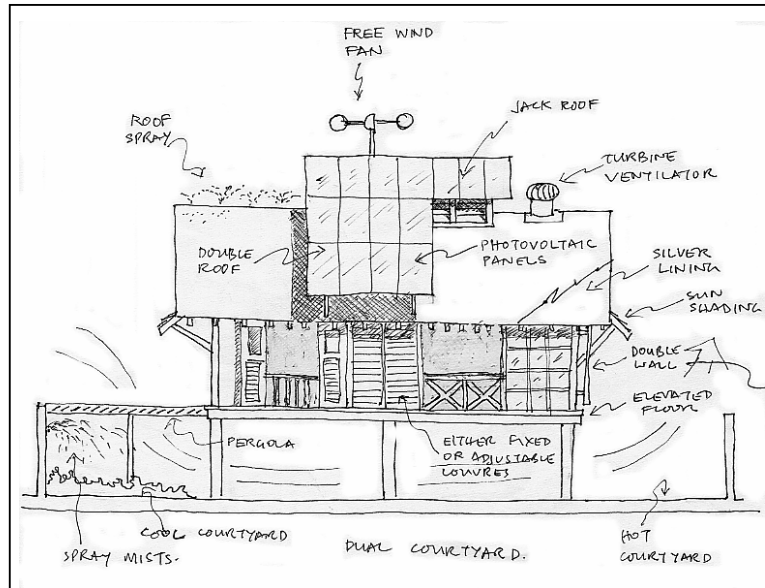


Fig.6 The True Malaysian Tropical House

The design approach for the next generation of buildings should be considered with emphasis on passive solar design elements to prevent heat absorption from the sun to the building fabric in order that indoor climate can be cooled by low energy mechanical and electrical installations. The selection of energy-efficient appliances is also critical to prevent on waste energy. As far as budget allows the usage of renewable energy such as the solar (include sun and wind), biomass and hydro, to generate electrical energy for power consumption is encouraged. Green thinking (6) in day-to-day living such as switching off lights and air-conditioning / fan when leaving the room or warming up the water before boiling and sun drying of clothes all contributes to energy efficiency and savings in energy resources.

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LOW ENERGY OFFICE BUILDING IN PUTRAJAYA, MALAYSIA. CASE STUDIES AND INNOVATIONS

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Abstract

The Ministry of Energy, Water & Communications (MEWC) have moved into their new Low Energy Office Building, LEO Building, in Putrajaya Malaysia in September 2004. This building is a National Demonstration project aimed at promoting energy efficiency (EE) in buildings. The project is also part of a wider program aimed at developing the capacity of the Malaysian building industry in EE building design. The target for the Energy Index of the 17,800 m² building (A/C area) development is an equivalent electricity consumption of 100 kWh/m²year. Among the energy saving features are well insulated walls and roof, exterior window shading, energy efficient lighting controlled adjustable to occupancy and daylight availability, energy efficient office equipment, a comprehensive energy management system, and implementation of a series of best practice solutions for the mechanical and electrical systems. The building also demonstrates the use of renewable energy, where a 3-kWp grid connected photovoltaic system is installed on the roof.

The building is designed in accordance to the Malaysian Standard MS 1525: Code of Practice for Energy Efficiency and Renewable Energy in non-domestic building. This entails, that the building is designed for an illumination level of 300 – 400 lux. Installed lighting and small power loads are each reduced to approximately 8 W/m², compared to a typical load of 15 – 20 W/m² for each respectively. The extra cost for the energy efficiency features in the LEO building is 10% greater than the normal construction costs, or RM 5 million. The energy savings compared to traditional design without energy efficiency features are 100 – 150 kWh/m²year. With the current price of electricity in Malaysia of 0.29 RM/kWh the estimated payback time is therefore less than 10 years.

During 2004 - 2005, with the assistances of DANIDA, the energy performance of this building will be monitored and evaluated, and the results will be disseminated to academia and practitioners. The experience from the LEO building monitoring programme will be used in developing a new building code and standards for the private and public building sector in Malaysia. The building will also be made available to visitors from the public, academia and professionals as part of the capacity building and promotion programme on energy efficiency in buildings in Malaysia.

Keywords : Energy Efficiency in Buildings, Building Codes and Standards, Monitoring Programme.

1. Introduction

In September 2004, the Ministry of Energy, Water & Communications (MEWC) have moved to its own 17,800 m² building in the Federal Government Administrative Capital, Putrajaya, situated between Kuala Lumpur and the new Kuala Lumpur International Airport.

The Government of Malaysia wants their new MEWC building to be a showcase building for energy efficiency and low environmental impact, and design support from the Danish International Development Assistance – DANIDA program was requested and granted. The building shall demonstrate integration of the best energy efficiency measures, optimised towards achieving the overall best cost-effective solution.

The Danish and local experts have since January 2001, in cooperation with Malaysian architects and engineers, optimised the overall design of the building and its energy systems for minimum energy consumption. A computerized design tool was introduced as a key instrument in the optimization of the building design and the design input of the energy systems. In August 2002 the detailed design of the

building has been finalised, and the turnkey contractor, Putra Perdana Construction Sdn Bhd has started construction.

An ambitious goal was set for the energy efficiency of the building: Energy savings of more than 50% compared to conventional design. The energy saving features is achieved at an extra construction cost of less than 10% of the total building costs, giving a payback time of less than 10 years.

The cost target of maximum 10% extra costs for the energy efficiency measures have been confirmed through the design and build tender. The computer modelling using the Energy-10 computer software has predicted more than 50% energy savings. A subsequent energy monitoring follow up program is in progress. The energy monitoring during use will add vital credibility to the predictions, that major energy savings and environmental benefits can be achieved in the building sector of Malaysia.

The new MEWC LEO building Fig.1 and Fig.2 demonstrates the feasibility of the energy efficiency measures according to the new Malaysian Standard MS 1525:2001 "Code of Practice on Energy Efficiency and use of Renewable Energy for Non-residential Buildings". Following this code, the LEO building must have an energy consumption less than 135 kWh/m²year. The predictions are, that the LEO building will have an energy index close to 100 kWh/m²year. This is a very good performance compared to typical new office buildings in Malaysia and the ASEAN region, having an Energy Index of 200 – 300 kWh/m²year.



Fig.1 The East Façade of the LEO Building



Fig.2. The Thermal flue stack to generate natural ventilation in the atrium

The energy efficiency measures that are expected to contribute to achieving the goal of an Energy Index of 100 kWh/m²year are:

- (i) Creation of a green environment around and on top of the building.
- (ii) Optimisation of building orientation, with preference to south and north facing windows, where solar heat is less than for other orientations.
- (iii) Energy efficient space planning.
- (iv) A well insulated building facade and building roof.
- (v) Protection of windows from direct sunshine and protection of the roof by a double roof
- (vi) Natural ventilation in the atrium
- (vii) Energy efficient cooling system, where the air volume for each building zone is controlled individually according to demand
- (viii) Maximise use of diffuse daylight and use of high efficiency lighting, controlled according to daylight availability and occupancy
- (ix) Energy Efficient office equipment (less electricity use and less cooling demand)
- (x) Implementation of an Energy Management System, where the performances of the climatic systems are continuously optimised to meet optimal comfort criteria at least energy costs

2. Site and Climate

The climate in Malaysia is hot and humid. Temperatures over the year and day varies typically between 25°C and 35°C, and the humidity is always high. This has important implications for the design of modern energy efficient, air conditioned office buildings. In the office working areas, a controlled, conducive environment is essential for occupant comfort and for productive output.

The local temperature outside the building can be reduced by using the cooling effect of trees, greenery and water areas. In cities with little greenery, the "heat island effect" occurs, means causing air temperature to be several degrees higher than in green areas. An air temperature of 35°C instead of 28°C is critical to both comfort in the city and cooling load of its buildings. The green layout and the large water areas of Putrajaya help to create optimal comfortable, local micro-climatic conditions for buildings and people.

In Malaysia, daylight is available during the normal office hours throughout the year. Therefore, daylight can be an important light source to help reduce energy use for artificial lighting, provided adequate building design, as discussed later in this paper is incorporated in the project development.

3. Comfort and Indoor Air Quality

Human thermal comfort depends on a range of climatologically and physiologically related parameters as shown in the diagram. In a tropical climate context, a person will be increasingly uncomfortable with increased air temperature, humidity and radiant temperature (temperature of the surfaces surrounding the person). Increased air velocity and reduction of the clothing level can help in improving the comfort level.

The recommended indoor temperature range is from 23°C to 26°C and the recommended relative humidity is 60% - 70%. As both the required temperature and humidity parameters are lower than outside air, full climatization is normally required for the working areas, in order to satisfy optimal human comfort and working condition. Buildings therefore have to be tight, and the fresh air intake has to be controlled for optimum quality of the indoor air. In the LEO Building, intake of outside air is controlled according to CO₂ level of the indoor air, and thereby controlled according to the occupancy level. The more people in the building, the more fresh air intake required.

It is noted that low temperature and low humidity is uncomfortable, unhealthy and expensive. Office air temperatures lower than 22°C to 23°C mean that people will have to dress up with warmer clothes, and the cooling load of the building increases. In the LEO Building, a reduction of the office air temperature from design level of 24°C to 20°C increases the energy consumption by 33%!

In the LEO Building, the quality of the indoor air is further improved by the use of electronic air cleaners, instead of normal fibre filter to clean the incoming air from particle pollutants.

4. Daylight

Natural light is the preferred light source for the human beings. This perception has now also been scientifically proven: People prefer daylight, be it in the offices or in shops, as our children learn more and better in daylight schools. Furthermore, daylight is a free source, which is available throughout the normal office hour.

The challenge in daylight design of buildings is to design windows and shading which lets daylight in, prevent sunlight to enter the building, and reduces glare problems from the windows. In the LEO building, these criteria are achieved through a combination of exterior shading and a glazing, which allows 65% of the light through, and allows only 51% of the heat through. The atrium allows daylight access to deeper parts of the building, thereby improving energy savings and user comfort.

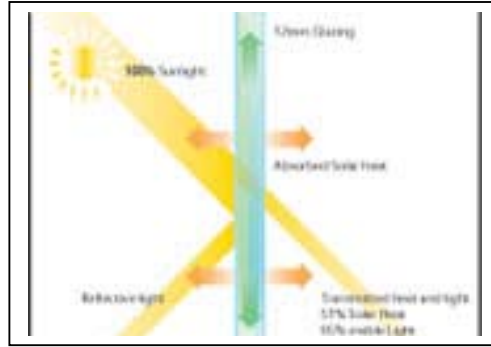


Fig.3 Illustration of heat and light transmission through a glass

In order to fully utilise daylight to offset artificial lighting, the artificial lighting has to be controlled so that it is automatically shut off when daylight is sufficient to satisfy the lighting need, which is an illumination level of 300 – 400 lux. In the LEO building, a daylight responsive control system on lighting system is combined with a motion detector, which automatically shuts off lighting and reduces cooling once an office is unoccupied.

In the future, advanced glazing will become available. Glazing that filters the sunlight such that visible light has preference and the solar heat is avoided. These spectrally selective glazing reflect the invisible infrared and ultraviolet and heat away from the building. Such spectrally reflected glazing, which normally will be combined with sealed double windows will significantly improve energy efficiency of buildings, and more architectural freedom with respect to façade design will be possible.

5. Building Envelope

In the LEO Building, the windows are primarily orientated to the North and the South. This orientation receives less direct sunshine, and only shallow out shading is required to shade off the sun. East and west orientation receives more sun, and the sun is more difficult to shade off due to the low sun angles for the radiation in the morning and in the afternoon.

Exterior shading is most efficient, as the sun is stopped before it enters the building. In the LEO Building, two types of window façade are used: The punch hole window facades in the lower floors, and curtain wall windows with exterior shading louvers in the upper floors. Towards the east, shading is deeper to protect against the low morning sun. The windows constitute 25 – 39 % of the façade area, depending on orientation. The western façade has virtually no windows. The window glazing is a 12 mm thick light green tinted glazing.



Fig.4 The "Punch Hole" windows provide shading to the windows

The walls of the LEO building consists of 200 mm aerated concrete and exterior surface have light colors to reduce solar heating of the walls. The lightweight concrete wall has an insulation value which is 2.5 times better compared to traditional brick wall.

The roof of the building is insulated with 100 mm of insulation, compared to normally only 25 mm of insulation. Furthermore, the roof surface is protected by a second canopy roof, which prevents direct solar radiation onto the roof. Along the perimeter of the roof, green landscaping provides shading and improves the aesthetics of the roof areas, which can be used for various functions.

On top of the atrium, there is a two storey high thermal flue (solar chimney). The air in the glazed cavity is heated by the sun, and the rising hot air pulls air out of the atrium, and fresh air is entered at the bottom of the atrium.

6. Office Appliances

Office equipment such as computers, printers and copy machines, are responsible for increased electricity consumption, and thereby also responsible for additional increase in cooling load. Therefore, special emphasis has been made in the LEO Building to reduce the electricity consumption for equipment, and a guideline for procurement of energy efficient office equipment has been produced.

Simulation with the Energy-10 computer tool confirms the significance of office equipment on the overall energy consumption. Using energy efficient office equipment, the electricity consumption for the equipment can be reduced from 25 to only 10 kWh per m² per year. In addition to this, the cooling load is reduced by further 10 kWh per m² per year.

The main energy consuming office equipment in modern office is the Personal Computer, with its screen. Energy consumption is reduced by purchase of energy labelled computers with software that automatically reduces energy consumption during idle periods. Furthermore, LCD screens are much more energy efficient than the traditional bulky CRT screen. Also, LCD screens provide better user comfort with less reflection than the CRT screens, and they take up much less space on the desk. Therefore, all in all, the extra cost of flat screen, now typically less than RM 1,000 can easily be defended from an overall perspective.



Fig.5 CRT Screen



Fig.6 LCD Flat Screen



Fig.7 Laptop

Portable laptop computers are much more energy efficient than stationary computers because they are optimised for maximum battery life. The extra price for a laptop compared to a desktop computer with LCD screen is now less than RM 1,000. This extra investment is very attractive given an extra flexibility and the energy consumption per PC is reduces to approximately to 30 W for a laptop. For comparison, energy consumption for stationary computer with CRT screen is around 150W.

7. Cooling, Lighting and Transport

The largest energy consumption for an office is for its cooling and lighting, which normally accounts for 50% - 60% and 25% - 30% of total energy consumption respectively. The rest of energy use is for pumps, motors and lifts for vertical transport. Finally, energy is used for office equipment, the plug loads.

Apart from being free, daylight is also a very efficient light source, measured in light (lumen) received compared to the unwanted heat (watts) that accompanies the light. Diffuse daylight with an efficiency of around 120 lumen/watt is twice as good as traditional fluorescent lighting around 60 lumen/watt.

In the LEO Building, high efficiency light fixtures are installed. This, in combination with a reduction of the illumination in offices according to the new standard, reduces the installed lighting load from typically 20W/m² to only around 10W/m². The illumination level is reduced from 500 lux to approximately 335 lux in the office space.

The mechanical and electrical (M&E) equipment for the building also include high efficiency motors (HEMs) for pumps and fans, with variable speed drives (VSDs) for optimum operational efficiency. The VSD's reduce motor power and electricity consumption drastically for part load condition, which is the normal load condition.

Each floor has its own air handling unit (AHU) and it is subdivided into smaller zones, where the provision of chilled air is controlled with a Variable Air Volume (VAV) damper. The VAV damper controlled. The VAV damper controls the chilled air volume to the zone according to the temperature setpoint.

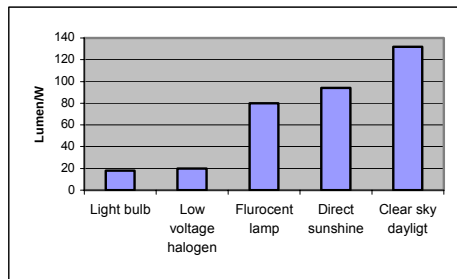


Fig.8 The light intensity of different light source

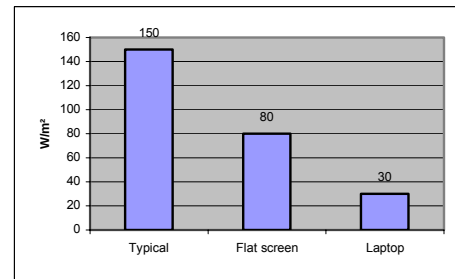


Fig.9 Power index of various services in office building

8. Energy Management

A comprehensive energy management system (EMS) is a prerequisite for actually achieving the low energy consumption, for which the building has been designed. The energy management system monitors on a continuous basis the energy consumption of the building. This allows for the comparison of actual energy consumption with predicted consumption and with typical previous consumption, and action can be taken if abnormal high energy consumption is registered.

Energy management requires the installation of adequate metering as a means of measuring the energy used and temperatures archive. As the saying goes "you cannot manage what you cannot measure". In addition, the EMS shall incorporate a computer software tool, which helps the building energy management to optimise the performance of various energy systems for cooling and lighting, such that optimal user comfort is achieved at least costs in purchase of energy.

The LEO Building will be equipped with a comprehensive Energy Management System. For each floor and each section (east or west wing), energy consumption for cooling, lighting and plug loads is monitored individually. Furthermore, temperatures in various parts of the zone are monitored. The detailed monitoring data of the LEO Building will be made available for further study by academia and professionals.

Successful energy management can only be achieved if there is a competent energy management authority in addition to the traditional building management services. The Ministry has therefore created a special position for energy manager. He will be responsible for the day to day energy management activities including advising the organisation related on energy management activities.

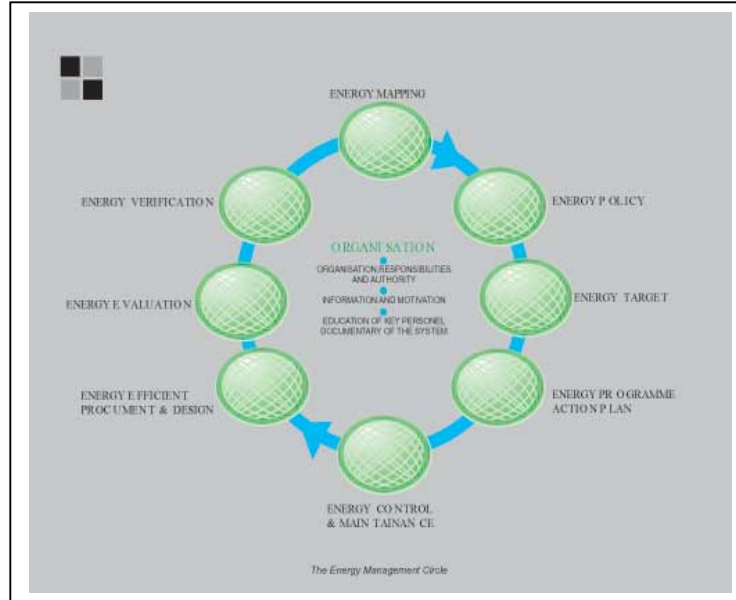


Fig.10 Energy Management Cycle

9. Discussions

The use of computer design tools means that an overall optimisation of the building energy design can happen at the drawing table. Extra costs for some energy saving building elements can be offset by reduced costs for other elements, such as reduced investment costs for the cooling system caused by a more efficient design building envelope, that reduces the maximum cooling load. Furthermore, using life cycle calculations, extra costs for energy saving features can be offset by savings in energy costs over the life cycle of the building.

The LEO Building has been optimised using the *Energy-10* computer software from National Renewable Energy Laboratory, Denver US. Among the many computer design tools available, Energy-10 was chosen, as it is very user-friendly, yet sophisticated, calculating the energy balance of the building hour by hour throughout a year.

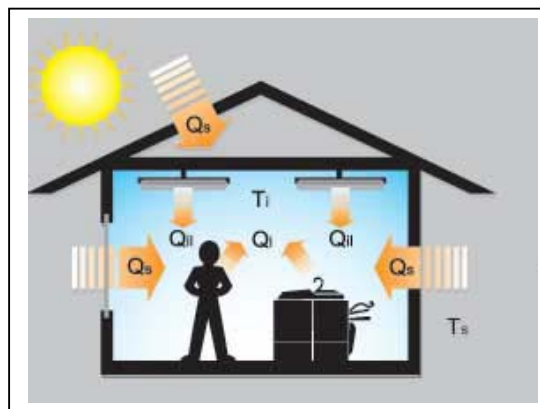


Fig.11 Heat sources into a building

The diagram shows the effect of applying the main energy saving features, one by one. It is seen, that reduction of the internal heat gains from lighting and office equipment is of major importance. It is noted, that the increase of the room temperature by only one degree reduces energy consumption by 10%. Therefore it is also very costly to have too low room temperatures in the 20 - 22°C region.

The extra costs for the energy efficiency features of the LEO building have been RM 5.0 million, or 10% of the total building costs. With an electricity price presently at 29 cent per kWh, the extra costs will be paid back within the first 10 years of the building lifespan. Energy efficiency is very cost-effective, it should be applied throughout the building sector, and the implementation of *Malaysian Standard 1525:2001 Code of Practice the Use of Energy Efficiency and Renewable Energy for non-domestic buildings*, is seen to be well justified.

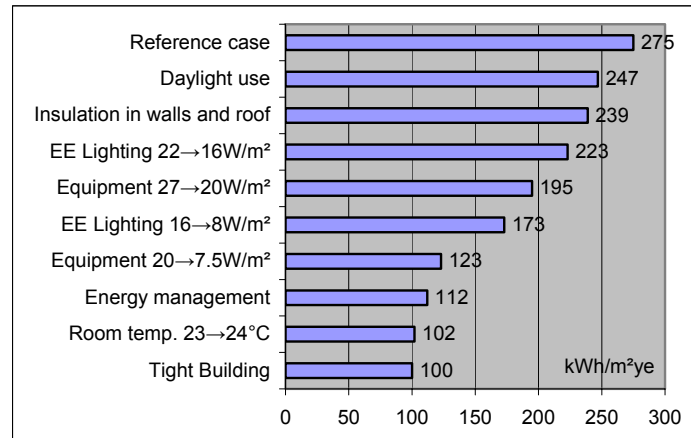


Fig.12 Energy saving features applied one by one

10. Conclusions

The building and the system design were analyzed and optimized. A comprehensive list of EE features was integrated in the project tender. The results of the computer simulations of the LEO building in comparison with conventional building is shown in Fig.13.

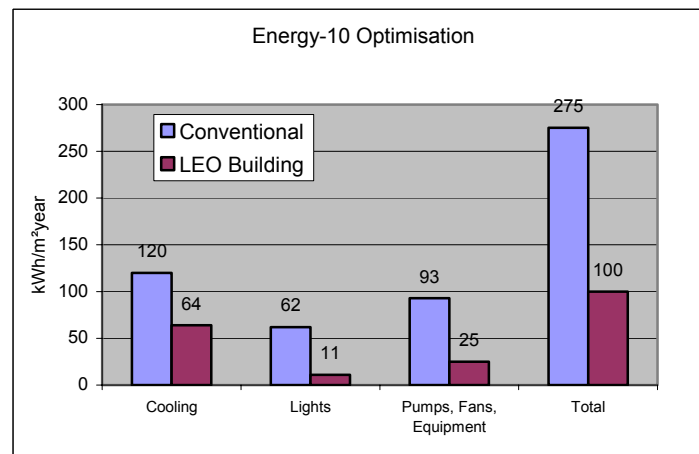


Fig.13 Predicted overall energy saving for the LEO Building

11. Acknowledgements

The demonstration project is supported by the Ministry of Energy, Water and Communication, Economic Planning Unit and DANIDA (Danish International Development Assistance). The achievement is based on a positive and fruitful cooperation between MEWC, the Putrajaya Holding Project Team, JKR Putrajaya Team, Main Contractor and the DANIDA Team.

COUNCIL HOUSE 2 (CH₂), MELBOURNE CBD : A GREEN BUILDING SHOWCASE IN THE MAKING

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Abstract

The Council House 2 (or CH₂) is a leading green building commissioned by Melbourne City Council. This paper outlines the leading edge technologies and approaches that have resulted in this building. It outlines the initiatives and passes on some of the main stories and lessons from the project, which is due for completion in late 2005. The lessons and the information in this paper have been obtained through a researcher, funded by the Australian Greenhouse Office, from the Centre for Design at RMIT University who worked in collaboration with the CH₂ project team to document their experience. This was facilitated by the strong commitment by the client, Melbourne City Council and the rest of the project team. The stories highlight the business case for CH₂, the pre-appointment phase, appointment of project team, team building workshop and the design development phase. The method for collecting the information included reviews of relevant documentation and interviews with key agents, including Melbourne City Council (MCC) staff, the project designers and other consultants. Finally this paper outlines some of the best practices in the implementation of green buildings aiming to incorporate technological innovation while maintaining focus on the human values - continuing to design for the user. It is hoped that this building will also provide a platform that leads to further research into the relationship between the environmentally responsible, energy efficient performance of buildings and the physiological aspect of human beings such as comfort, humidity and eventually productivity at the workplace.

Keywords : Green building, Technological innovation, Energy efficient, Environmentally responsible.

1. Introduction

The City of Melbourne has set a formidable task for itself - to build a revolutionary new building that harvests sunlight, cool night air, water, wind and rain to create a lasting landmark for one of the world's most liveable cities - through the design of Council House 2. It is affectionately known as CH₂ to differentiate it from the currently used Council House building, which is on the adjacent site and has become known as CH₁, both are located on Little Collins Street right in the heart of Melbourne Central Business District. This striking building will set a new international standard in ecologically sustainable design. It also offers a financially responsible way of meeting the Council's long-term need to house staff and will breathe life into an under-used part of central Melbourne.

Construction of CH₂ began early in 2004. It made a large step towards meeting its sustainability goals when the Green Building Council of Australia gave the design stage of the building a preliminary 'six star rating' – world leader status – under the new method of comparing the environmental performance of commercial properties, called Green Star. The Green Star rating aims to become a national standard for Australia for green buildings. The tool's comprehensive evaluation process rates the building in relation to its planned management and commissioning, the health and design for well being of its occupants,

accessibility to public transport, water usage, energy consumption, the responsible choice of materials, land use and pollution.

The aim of this paper as a whole is to give those who participated in the project a voice in telling its story. It is part of a larger research project including a report outlining the main processes, lessons and outcomes of the design phase. This comprehensive report will follow once the building is completed. Further, monitoring of CH₂ operation is also being planned for the future. This paper will specifically outline the leading edge technologies and approaches that have resulted in this building. Furthermore, it not only outlines the initiatives but passes on some of the main stories and lessons from the project that is due for completion in late 2005.

2. CH₂ Building Project

CH₂ is to be a leading edge example in the procurement of sustainable buildings. The aim is for the building to become a 'lighthouse' design for future central city developments in Melbourne. The approach taken towards sustainability is one that incorporates and draws on social, economic and natural aspects. CH₂ visually and functionally reflects the sustainable principles its design embodies as this paper will highlight. There were many aims for the building. These were distilled to four key themes established through the initial two week workshop:

People: provide a healthy, comfortable, adaptable and stimulating working environment for its primary users (staff) and visitors. The building should be welcoming, accessible and easily navigated, and should provide a positive social environment.

Eco exchange: the building should respond and interact with its natural environment, in a responsible way, throughout its life cycle. It should do this with: its use of natural resources (e.g. materials, water), efficiency of form and design, efficiency of construction and operation, the ability for effective reuse, the minimization of waste, the maximization of the use of renewable energy sources during its operation and an overall aim to reduce carbon dioxide emissions to zero.

Green print: it should also provide at least the same area of green cover as its footprint bearing in mind that this area can be measured vertically as well as horizontally. That is, there should be as many leaves on the building vertically and horizontally as if the land was still under native vegetation. Further the building should be read as a work of art, including where possible inspiring works and influences. And finally the building should inspire a new relationship between the city and nature.

Eco-nomics: the idea of 'more from less' - that is, no longer having a focus on minimizing costs but balancing costs with good building construction, optimal operating condition and focusing on people and the environment while maximizing value and benefits throughout its life cycle.

[we distilled it] to four instead of sixteen objectives. At the end of the workshop, they knew four characteristics of this project, and all of them knew them—even the secretary.

Greg Foliente, Principal Research Scientist, team leader EVERGEN, CSIRO

This two week workshop, otherwise known as charrette, set the framework for the project. The people who were involved were¹:

- i. Melbourne City Council departments: City Projects and Arts and Culture and the Design Team Leader and in the Project Management role
- ii. DesignInc – Architectural

¹ The website is www.melbourne.vic.gov.au for those seeking further information on these organizations.

- iii. Donald Cant Watts Corke - Quantity Surveying
- iv. Bonacci Group - Structural and Civil Engineering
- v. Lincoln Scott - Services Engineering
- vi. AEC - Ecological Sustainable Design
- vii. TDC - Vertical Transport

3. Our approach to the paper

This section highlights the crucial preparation and planning activities, particularly the design planning through a charrette, describe the innovative design methods, elements and technologies and conclude with the lessons from the project.

3.1 Approach to the review of project design

The preliminary phase is a critical stage of the project in ensuring that the project team understands the brief, the timelines and the expectations at every stage of the project. At the preliminary stage the project team needed to gain a detailed understanding, through discussion with the Joint Steering Panel and other key people, of the strategic goals and objectives of the project against which the project will be evaluated. These reflected the Council's commitment to 'triple bottom line' (TBL) sustainability, including environmental, social and economic objectives. In addition to the goals that are formally articulated in the design brief the expectations of other stakeholders such as rate payers, residents, visitors to the city, the business and design communities, environmental organizations, state and federal governments (among others) were taken into account.

To capture the lessons from this preliminary phase, it was agreed that there would be a series of interviews carried out with key players in the project. These interviews asked questions designed to bring out their stories and their experience, both positive and negative. The aim of the interviews was to uncover the behind-the-scenes experiences of those participants in the design and construction phases of the project.²

3.2 Approach to the review of design phase of CH₂

The main aim for this phase was to review and document the Council's unique approach to the design of CH₂, focusing on: the critical issues, obstacles encountered, how these obstacles were overcome, and key lessons learned throughout the design process. Things that were reviewed included:

- The business case for CH₂
- Pre-appointment phase
- Appointment of project team
- Team building workshop
- Design development phase
- Planning approval process
- Documentation phase; and
- Tender selection phase

The methodology included a review of relevant documentation and interviews with key agents, including Melbourne City Council staff, designers and other consultants. The output was a report including schematic illustrations of the processes. This paper forms the summary of the larger report.

² To facilitate the ethical implementation of this research technique an ethics approval was sought and received from RMIT University. This ensured that the rights of those participating were protected.

4. Description of Process and Technologies

CH₂ has been designed to be a highly energy efficient and sustainable building, with all its systems and spaces forming an interconnected and inter-related whole. Much like a living organism, the building requires all of its limbs and organs to be fully integrated and able to function in unison. We use the term 'biomimicry' to describe this attempt to learn from nature and 'mimic' it into the design. Below is a brief outline of this biological synergy (where relevant to the paper, some of these are elaborated on later in the text):

- Leaf structure: air cleaning and processing, combined with collecting energy and dissipating heat.
- Growth plane: roof terrace supporting living plants and grasses for the enjoyment of building inhabitants.
- Bronchia: enclosed duct spaces for delivery of vital gases.
- Root: network of connections to ground, provision of public services, buttressing to the city plane, sewer mining for non potable water.
- Stem: primary core structure and arterial volume providing network of reticulated fluids, gases and nervous system of building for control of cooling, heating and ventilation.
- Epidermis: external layer of skin for protection from the elements.
- Dermis: sub-layer of skin composed of enclosed spaces to filter wind, light and sound.
- Antennae: vertical mast carrying vegetation and weather monitoring equipment for control of cooling, heating and ventilation.
- Bark: external ventilation module for waste and toilets, with inhabitable external balconies.
- Soft body: the internal activity zone of the building where climate is modified for people.

The primary influence on the design was the natural termite system. Mick Pearce, MCC design champion, had previously used this concept successfully, in for example the 'Eastgate' building in Harare, 1992-1997. He transformed the simple design and system termites build to control the temperature of a mound into the air conditioning systems of the building. The main principle used is very simple: cold air descends, warm air ascends. The physiology of a termite mound is that they build towers that are comparable to human lungs – including a function based on the same principle as gas membrane diffusion. They 'outsource' the function of digestion to fungi that they cultivate in gardens in their mound. These work like our digestive system. Temperature and humidity control is essential for their survival and the survival of the fungi. They also mine water for drinking and cooling. Thus, termites have evolved an architecture that harvests solar and wind energy, water and food through fungi using symbiosis.

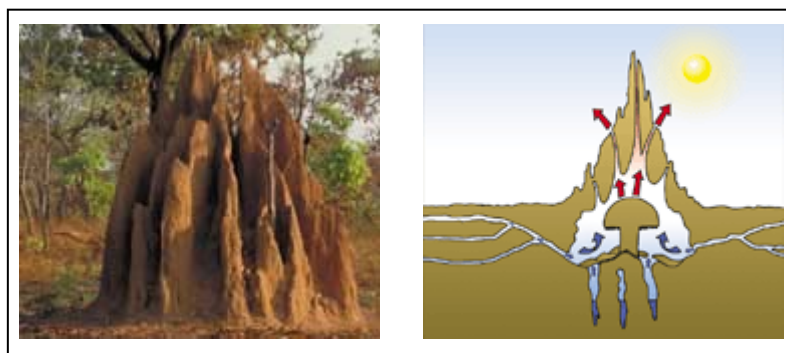


Fig.1 The Termite Mound and physiology working process

Before the initial meeting with the full design team, Mick Pearce utilized this previous experience and synthesized it into a working design. The sectional diagram below describes the process and technologies being included in the design.

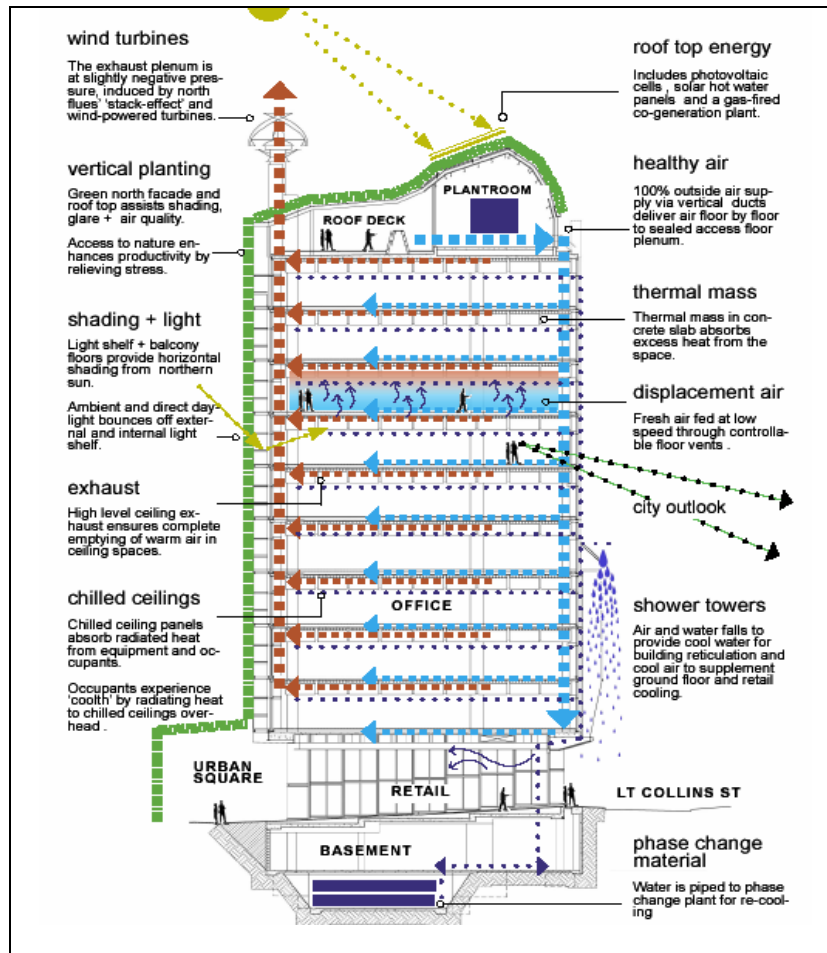


Fig.2 Translation of termite mound concept into CH₂ building (DesignInc)

Other elements of the thermally efficient design concept for CH₂ were the use of thermal mass, ventilation stacks and water for cooling through chilled ceiling panels, beams – the water cooled by the coolth stored in phase change material tanks. We briefly outline these elements as follows:

Thermal mass. The vaulted 'wavy' ceilings are made from pre-cast concrete and therefore have high thermal mass that, as it is in contact with the indoor air, helps the building spaces to remain cooler during the day as the thermal mass absorbs some of the excess heat. This heat is then released during night purging.



Fig.3 Southern and northern facades (DesignInc)

Ventilation stacks. Ventilation stacks have been designed to the north and south of the building. To the north the stacks have been designed to be dark increasing in size up the building to support air movement, whilst reducing windows sizes. That is, largest windows at street level where there are the least natural light gradually reducing window sizes until at the top there is the most natural light and therefore the smallest windows.

Chilled beams and ceiling panels. Cold water will be used to remove most of the unwanted heat from the building. The panels and beams simply run chilled water through them: the water absorbs the heat from the air cooling it and taking the heat away.

Phase change material. The design includes the use of a phase change material to cool the water for the chilled beams and panels. This is often referred to as the 'battery' of the building – storing the coolth generated from the shower towers and chillers to be used when needed. Thus it will efficiently help to keep the water circulating through the chilled panels and beams at the desired temperature.

Shower towers. The final feature of the design that aids in the control of the indoor air environment is the shower towers on the southern façade. Outside air is drawn in from 17 metres or more above street level and channelled into the shower towers on the south side of CH₂. The towers are made from tubes of light-weight fabric 1.4 metres in diameter. As the air falls within the shower tower it is cooled by evaporation from the shower of water. The cool air is supplied to the retail spaces and the cool water is supplied to the phase change material 'battery' where the 'coolth' is stored for the rest of the building when required.

The brief descriptions above inform us that the construction materials and elements used are not unusual. On the contrary, these are common materials but put to use in an innovation way. Furthermore, materials were selected using a review process developed by CSIRO and product guidelines such as EcoSpecifier were used.

5. Main Lessons Learnt for Discussion

The building is currently being constructed; and it receives a lot of interest from all parties across the globe. Our research has brought out key lessons learnt from the design stages of CH₂ and are presented as six factors below.

Lesson 1: Participatory design exercise

For the design of CH₂, it was decided from the beginning that participation from all design team members was needed to pursue the design goal. A comprehensive communication network was set up starting with a workshop known also as charrette, which allowed everyone involved to have the same concept of the project. Furthermore, it allowed the raising and resolving of any issue to be achieved collaboratively.

*“the process was supported by a relatively simple but clear brief:
the building needed to be greenhouse neutral
a lighthouse project
improve employee wellbeing
analogous to industry transfer”*

Mick Pearce, Design Champion, City of Melbourne

The charrette process, through its coordinating function between all the design team, significantly reduced the resources and time needed to complete the design stage.

... once we had that team on board, we said 'now we stop the process, your fees are frozen we are now going to pay over and above your fees, to sit with us for two weeks and work as a team in a charrette and just put everything back on the table. ...nothing at this stage is sacrosanct'... it was then January...we said 'don't tell us in November there was a better way of dealing with this...we're paying you over and above your fees so you now have got to put it all on the table'... and that two weeks bonded the team in a way that we hadn't really anticipated, ..., it all happened very quickly, but it worked.

Rob Adams, Project Director, City of Melbourne

When asked why such a positive experience was had by all the consultants of the charrette process, and why such unexpectedly good results we achieved through open collaborative solution development, Rob Adams said:

I'd like to think it's the way you treat people ...There's no assumption that anybody actually knows the answers ...I think quite a genuine open discussion that says everybody's point of view is valued. Doesn't matter whether you've just walked into the office two days before, if you've got a point of view, stick it on the table, we want to hear it, and we also, I think a lot people took risks. I mean we say... the risk ...to make a mistake....

Rob Adams, Project Director, City of Melbourne

In the initial stage, allowing explorations of ideas and suggestions without feeling intimidated had made way for a dialogue and solution development that otherwise would have been much more difficult and limited – it also supported initiatives by all the consultants involved. In all, the charrette contributed towards team building, an important element in the progress of this project.

Lesson 2: Leadership and policy implementation

The significant step taken by the Melbourne City Council for the development of CH₂ demonstrates its vision, mission and values as stated in the 'City Plan 2010 – towards a thriving and sustainable city'.

In reviewing its accommodation options, the MCC set the following requirements for the new premises:

- Accommodation to meet statutory requirements and occupational health and safety regulations
- Accommodate majority of staff except small core of staff to manage councillors' needs
- Modern interactive flexible work environment which is responsive to organisational needs and change
- Latest environmentally sustainable design features
- Long term operational efficiency at least cost
- Comply with planning schemes

The CH₂ proposal therefore had to meet these criteria as well as those set up in response to environmental strategies including the requirements to meet at least a 5 star energy level and the energy targets set out under the Energy Management Strategy and accompanying Energy Policy to guide corporate change. Specific targets being:

- 20% Reduction of energy consumed in Council buildings by 2005 (based on 1996 levels), and
- 5% Increase in the use of renewable energy by 2005 and 10% increase by 2010

The MCC also has a target of zero emissions by 2020 and a strategy called Watermark aimed towards sustainable water management by 2020.

At another level of leadership, MCC is fortunate to have committed people in their team such as their champion designer, Mick Pearce, project director, Rob Adams and finance director, Mark Anderson, among others. Mick Pearce, provided detailed preparation in developing the vision of this project, drew this from

his other projects while simultaneously integrating his other passion – ensuring buildings meet the needs of the users. He is considered by all those interviewed in the project as the visionary for the project:

"[he was] Very, very, very good, a good driver you need someone like him that can think about things – a thinker and a bit of a dreamer ... with enough pragmatisms to actually get things done".

Chris Arms, CJArms and associates, hydraulic engineers

Lesson 3: Business Case

Apart from the leadership quality of the Melbourne City Council in designing the building to meet the needs of its staff, MCC also wanted to achieve other sets of objectives stated earlier. The framework term financial requirements of the council. Thinking about the long term is important in building the business case for a 'green' building project. What should be aimed for is best value over life not the lowest initial cost. The investment in CH₂ was decided on after evaluating every possible accommodation option for MCC over the properties available throughout the city. In short, MCC needed to either do major renovations to all of its accommodation to bring it up to current regulatory requirements, lease new accommodation or build a new building. Several options based on the accommodation requirements of the MCC were short listed: refurbish or staying at current building, lease or purchase another space or redevelopment of the existing council house. The last option was the best scenario as it achieved all objectives, gave the highest ranking in the MCC assessment method and was seen as the option which would provide best environment for council's staff.

The main hurdle was to show the financial credibility of such decision. Getting the finance director, Mr Anderson, on board was the main challenge for the CH₂ team. They needed to convince him that it was a sound investment for the Council to make. The basis for the conversation with Mr Anderson was the investment fund which the Council set up when they sold their electricity company. This fund is strictly administered in a conservative portfolio, part of which is in property. Rob Adams describes the discussions with Mr Anderson and how the business case was presented:

The key...was our finance director Mark Anderson. We needed to convince Mark that we were not going to build CH₂ because we were good designers or good project managers, or for that matter that even that it was good urban design.

What was needed was a business case that used Council's investment funds. This fund provides \$200m which can be invested on strategic projects as long as they give a return of 150% of the current bank rate.

Being a local government, it would be untenable to use monies from Council rates. Therefore Council needed to show through a rationalisation of the property holdings within the investment portfolio that they could provide a sounder investment for Council by constructing CH₂. Much of the current building stock is aging and consists of a number of small buildings distributed throughout the City. In many cases these properties are not producing a good return on investment. The suggestion was that by using this prime central city site for a building with low ongoing operating costs, in particular low energy consumption, would be a better investment for Council. It was argued that as the building contains a mixture of car parking, retail and administrative offices, it would hold its value over its life. Given its construction and energy savings it would be a good investment for the City.

Rob Adams, Project Director, City of Melbourne

This enabled Mr Anderson to stand in front of nine councillors and confidently say "this is a good investment". Given Mr Anderson's credibility and sound financial management, such an endorsement from

the chief financial officer gave the project credibility needed for the Council to approve the project going ahead.

We believe that in years to come, similar discussion or conversation will take place, where triple bottom line issues will challenge any single aspect decision making principles in business transaction. The increasing awareness of corporate social responsibility will further enhance the quest towards sustainable accounting and contribute towards sustainable built environment.

Lesson 4: The charrette process – involving a diverse group of people

Another reason for the success of the charrette process was the diverse group of people who were involved, each adding their own perspective, for example artist. Artists continue to be involved in the project documenting the construction of the building and having input into works to be used in the building.

... some of the good things, and one of them was the role of the artists... they added humour to the meetings, and that had the effect of breaking down barriers between everybody. That enhanced the whole morale of the group, and I think that stayed, to some extent into the whole of the project...It was terrific that the artists were able to appreciate where all the designers and engineers were coming from, and they were clearly coming up with solutions that were taking those sorts of things into account. And that was quite fascinating for me ...

Peter Boxall, Project Consultant, EVERGEN, CSIRO

One of the main issues raised, which would have improved the charrette process, was that it needed more initial preparation and planning. This would have ensured a clearer concept, aims and objectives of the project as envisaged by the client (MCC).

With the workshop itself, things happened very fast, especially in the beginning. We finalised certain things in December, then there was a break, and then the workshop took place in the first two weeks of January. So there was a problem in that Melbourne City Council and I didn't really have enough time to plan the workshop to get the most out of it. Nonetheless it was an innovative idea to have two weeks rather than two days. I think that most projects, throughout the world, tend not to devote adequate time to this initial planning.

Greg Foliente, Principal Research Scientist, team leader EVERGEN, CSIRO

The sharing of information at the earliest possible stage can help reduce the uncertainty at the start of the project. That started with the charrette as the 'ice breaking' session and continued throughout the design process. In fact, because of this initial problem solving time facilitated by the charrette, the design team finished the whole design and documentation, including a guaranteed bill of quantities, within nine months. This included the change over of sites in the first three months. This change of sites was the result of the open questioning of assumption supported by the charrette process. The design team questioned the risk of rebuilding the old Council House and therefore having to relocate all the staff for a considerable amount of time, over the construction of the building on the neighbouring vacant site. This meant some redesign and the building becoming a little smaller than was originally hoped for, but the savings in costs (\$A13M) and mitigation of risk supported this decision.

Lesson 5: Documentation using File Transfer Protocol website

The design time was also reduced through the use of a common electronic plan protocol such as the FTP site for the design and documentation development. The system has been developed to be user friendly so that everyone involved with the project could adapt it to their working methodology. In the design stage this meant that every consultant was responsible for their own drawings and uploading the latest version

from the FTP site to work on – this avoided a lot of double handling. In the construction phase ACONEX is being used for much the same coordination function. There are numerous examples of such construction project management databases available in the market that would allow for complete access and updates to project documentation by consultants.

Lesson 6: Evaluation System - developing a common language

A common language with which to describe environmental initiatives is crucial because sustainability is so complex and there are so many people working on a project of this size. The Green Star rating schemes provided that language, but caution needs to be taken that it is not the star rather than the environmental benefit that becomes the objective. This applies to any rating system of building performances in general. It is in danger of becoming simply a rating tool rather than a reflection of the building's sustainable design process.

Even though CH₂ is considered 'leading edge' having been awarded a preliminary 6 star design rating by the Australian Green Building Council, it still would use 2.5 earths in terms of earth resources in the eco-footprint scale. Such potential complacency must be constantly reawakened and reasserted in the policies and guidelines of future building projects, either newly built or refurbishment. On the other hand, this is a big step towards building and developing habitats that will bring the eco-footprint to one earth. To this effect, the Green Building Council Australia is continually improving the indicator elements to suit changes in the industry and other contexts by conducting feedback exercises to include the widest range of stakeholders possible.

The other caution for systems such as Green Star is to ensure it does not stifle innovation. This could be mainly attributed to the effect of building regulation on construction industry in general. A building may have the potential to improve its sustainability beyond the Green Star framework, if it is just the star rating which is aimed for then a project may not meet this potential. For example CH₂ has been awarded all 5 of the innovation credits available, this means that from a purely pragmatic point of view there is no further incentive to develop or integrate any further innovation.

6. Conclusions

To embark on a project of such a scale requires well founded preparation and transparency in the planning, design and tendering stages. CH₂ has provided a good example of a 'local authority in action', where a knowledgeable client becomes a catalyst for a sustainable project, and where working with stakeholders and the design team in a collaborative environment provides the best possible solution. A decision for a building such as this should only be reached once all aspects are considered based on a triple bottom line approach; and that this approach is understood by all players involved. It is important that all parties are kept informed in the beginning; in this case the groundwork was laid by the intensive charrette. Even though the charrette did not entirely dictate the final outcome of the project (yet to be completed), it has provided an opportunity for a strong direction towards achieving its sustainability agenda. More importantly, the vision of creating a beacon in sustainable building in Melbourne must be followed through with commitment to implement progressive policies and make decisions based on these policies.

Acknowledgements

The authors would like to acknowledge Melbourne City Council, Aus Industry and DesignInc for their contribution of information towards the research.

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NAVY DEMONSTRATION PROJECT

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Abstract

The Navy Demonstration Project is a multi-layered collaborative research project between architects and material engineers whose end product is a 5,400 square foot demonstration building for the US Navy. The project is a unique combination of design and science; a series of experiments with new material development, application, and engineering design. On the one hand, the project was an exploration into as-yet untested design possibilities inherent in wood plastic composite materials, Oriented Strand Board (OSB), Laminated Veneer Lumber (LVL) and I-joists. On the other hand, the project was an exploration of the engineering potentials of these materials. The building is possibly the first in the world to use wood plastic composites extensively and in a wide variety of applications.

The project was initiated by the WMEL to facilitate a production line for a new Commercialization Center for the wood plastic composites for the US Navy. The US Navy recently awarded \$1.6 million to WMEL to build full scale production facilities to demonstrate and assess new products, prove production rates, and attract US manufacturers to the wood composite marketplace. An important part of the commercialization project is to produce case studies and product demonstrations to show producers the feasibility of manufacturing and marketing these products. This project stands as an example of wood composites applications in the foundation piers and building envelope. Other important composite components in this building are sill plates and window components.

Keywords : Sustainable buildings, Rain screen wood plastic composite, Collaborative research, Navy Demonstration Project, Engineering design.

1. Introduction

Both art and architecture share the Greek word *techne* as a root which, in its original sense, means knowledge related to making that is learned, ultimately what we today refer to as craftsmanship. But the ultimate goal for the Greeks was *techne poeisis*, literally poetic technique, which Dalibor Veseley calls *symbolic representation* [1]. In other words, art and architecture are distinguished from technique and the purely technological by the creative, poetic element. For this reason, the engineers wished to collaborate with architects, to bring the poetic, creative, and symbolic in synthesis with the technical to produce something truly unique.

The project was initiated by the Wood Materials and Engineering Laboratory (WMEL) to facilitate a production line for a new Commercialization Center for the US Navy regarding wood plastic composites. The US Navy recently awarded \$1.6 million to WMEL to build full scale production facilities to demonstrate and assess new products, prove production rates, and attract US manufacturers to the wood composite marketplace [2]. An important part of the commercialization project is to produce case studies and product demonstrations to show producers the feasibility of manufacturing and marketing these products. This project stands as an example of how to use wood composites in the foundation piers and the building envelope; both as a rain screen and as typical siding products. Other important composite components in this building are the sill plates over the grade beams and the window components (Fig.1).



Fig. 1 US Navy Demonstration Project using wood composite products

2. Background of Project

The Navy has a keen interest in reducing deterioration from environmental and mechanical damage to their large stock of timber structures. The marine environment in which most Navy structures are situated is exposed to extreme weather and environmental conditions like salt water and harsh winds that wreak havoc on buildings in general, and on wooden structures in particular. The Navy is seeking environmentally friendly means to increase building durability and thereby reduce the costs to the Navy for replacing the structures. For example the estimated cost for repairing or replacing damaged residential buildings in the Seattle area is \$1.5 billion [3].

One method of improving the properties of these structures may be found in wood composite products. After pursuing a research agenda with a multidisciplinary team of educational institutions, companies, Naval engineers and WMEL, the Navy has now taken an aggressive policy towards helping to create a competitive marketplace for wood plastic composites.

Wood composites have been manufactured for several decades but they have only found significant acceptance in the building products market in the last five years and predominantly as deck products [4]. In the 1990's a division of Mobil Oil Corporation now called Trex and another company, Advanced Environmental Recycling Technologies (AERT), began producing thermoplastic composites using a fiber based solid wood extrusion method. These solid profiles were then milled to produce more complex profiles for doors and windows. Only recently has the Strandex Corporation (Madison, Wisconsin) developed extrusion technology that can create complex finished profiles in a single process out of thermoplastics with a high wood fiber content [5]. WMEL has been working with Strandex technology for the Navy, under a number of research grants Fig.3.

2.1 Outline of Program

The outline for the program of the project was to design an annex building for the WMEL at in the research park at WSU. Its purpose is to be used to warehouse machinery, store manufactured and test

products and as a depot for non-flammable raw materials to be used in the laboratory. Furthermore the brief required an awning to use as a covered workspace for lab technicians in the summer and for vehicle parking in the winter. Upon considering the site constraints of the problem and a set of pedagogical exercises for the students, the professor gave a general footprint and roof shape for the students to work from. The problem of designing the project was given to the Third Year Architecture students in the second half of their spring semester 2003. The shape of the roof is a simple 1/12 shed roof with a large triangular shape in the back dipping down to the ground and another triangle in the front tipping forward. The building has a dynamic look; it twists over the length of the building, similar to the shape of a wave breaking on the surf. This configuration was chosen because it determines that each portal arch have a unique configuration in order to explore the design potential in the portal arch. Consequently each student had their own design parameters; at one end of the building the portal arch nearly touches the ground and changes its pitch mid span, while at the other end the portal arch begins with the shed configuration and ends with a pitch on the front side. Each student was given one area of the building with a portal arch to design in detail; specifying the nailing patterns, the framing members, decking, roofing and sheathing details as well as the overall form. Concurrently they were asked to work with graduate students in civil or structural engineering to correctly determine the appropriate structural configuration for their design. The class explored various design configurations in wood and wood engineered products for the building's overall structural system. Students produced three final proposals for their specific area after working with structural engineers, material engineers, and laboratory technicians to explore the design and constructive possibilities for various combinations of engineered building materials. The students were encouraged to work with engineered materials for which the WMEL (Wood Materials Engineering Laboratory) holds several intellectual property rights including: LVLs, OSB, I-joists, and plastic wood composites.

2.2 Design of Building

Initially the students considered using Structural Insulated Panels (SIPs) combined with 2x6 pine inserts for flanges and joint connectors to make up box beams framing members out of the SIPs, the sheathing and decking surfaces were also initially envisioned as SIP construction. This exercise convinced us that using a plywood or OSB webbed box beam for the large spans in the building was a structurally and economically efficient method of construction and one that warranted further exploration. After consultations with the structural engineers, the students and professor decided to use portal arches because the portal arch provides lateral stability for buildings requiring large clear spans and gives stability to buildings with long lengths. The final configurations of the portal arches were drawn on the computer to determine the angles of each joint, these sections were then printed at full scale as templates for the layout. The portal arches were built directly on site with LVL (laminated veneer Lumber) for the internal framing members and the flange members. The sheer panels covering the frame were 5/8"cdx plywood nailed pneumatically 4" on center on the perimeter and 6" in the field. The advantage of the LVL was twofold; the product is structurally consistent and we were able to acquire it in extremely long lengths which had the advantage of providing unbroken flanges over long spans. Each portal arch is unique in its three-dimensional shape. There are 9 portal arches and 4 sheer walls in total placed 10' on center. The spans between the box-beams were made with "I" joists.

The idea for the construction was born from knowledge of Frank Lloyd Wright's use of box beams in his later Usonian homes. The advantage of using the engineered materials in comparison with steel and old growth lumber, the materials most often used for box beams, is the relatively inexpensive cost of the materials. Furthermore, neither specialists nor special equipment are needed for construction. Moreover, LVLs and plywood can be environmentally responsible if they are made from secondary milling products that would otherwise be waste. The structural advantage of the portal arch box beam is the lengthy span, the flexibility in the profile. One unit is a complete assembly of columns, beam, roof overhangs, cantilevers, rakes and eaves. The factor limiting portal arches in terms of span according to the Australian wood engineer P.J. Yttrup is the plywood gusset at the knee joint; he calculates the maximum span at about 20 meters. Yttrup describes a steel joint that will extend the maximum span to at least 50 meters [6].

2.3 Design of Rain Screens and Siding Profiles

The second assignment was to design a series of rain screens and siding profiles using wood plastic composites for the building facades. These composites are currently on the market primarily as

decking profiles but industry and the Navy are eager to develop other applications for the material. Wood plastic composites can be environmentally responsible since they can be made from grinding low value wood species into wood flour or from regrinding byproducts from wood mills into a flour-like consistency. The wood flour can then be mixed with either virgin or recycled thermoplastics such as polypropylene, polyvinylchloride and polystyrene. (Unfortunately, the relatively low cost of producing new plastics in comparison with the relatively high cost of recycling used plastics, means that most wood plastic composites use new material). The plastic wood mix, together with some additives, is pushed through a heated die in the extruder giving form to the molten material. It then passes through a cooling chamber and then to a cut off saw. The standard lengths of the material we produced were 20 feet but in a few instances we produced some profiles 35 feet in length. These are above the entry bays on the south facade and will be exposed to dramatic changes in temperature, therefore prone to prominent expansion and contraction behavior. These conditions will test both our pneumatic fastening system and siding spacing.

In one innovative application, wood plastic was used for the piers that attach the portal arches to the concrete foundations. Typical of our collaborative method, the engineers tested the wood plastic for its load bearing and stress bearing potential while the architects and engineers worked together to design the proper size and shape of the profiles. Another experimental application is the used of wood plastic composite profile as a sill plate.

The rain screens will be used simultaneously as cladding for the structure and as removable test panels for new materials, as they are developed. The screens are entirely constructed out of colored wood plastic composites. Again, in a collaborative effort, the designers and wood engineers have explored various add-mixtures for coloring the wood plastic, UV inhibitors to prevent discoloration of the siding over time, different profile designs for the siding, and various attachment possibilities. There are siding materials that look like terracotta products, steel, and wood in their coloration. The material testing racks will be suspended in front of the South facing façade. They are made of slanted LVLs that are bolted to the under side of the portal arch overhangs and to the ground.

3. Discussions and Conclusions

Besides being a vehicle for new material experimentation, the building is a place for the architects to explore the plastic possibilities of wood construction and composite construction techniques. In fact, one of the mandates for the building was to design a unique, memorable structure. As a point of departure we took dynamism to inspire our decisions. The wall on the rear of the building was thought of as a three dimensional form, the superstructure was framed with LVL then a layer LVL battens were applied and varies in width from six inches to two feet. The siding was composed as a gigantic collage made of fields of different wood plastic profiles, oriented differently, and colored differently to make a lively visual play that wraps corners pulls the eye here and there over the length and breadth of the structure and creates visual rhythms and meters. The roof is a large, bending and folding plane that appears to either be just landing or about to take flight; the angled columns on the front façade appear to be anchors holding the roof in place. In actuality, the columns support the test racks for exposing new materials to light and weather. The rear façade is equally dynamic. The windows are three-dimensional sculpted forms, each one unlike its neighbors, protruding from the skin like objects growing on the building surface. The surface itself undulates, continuing the wave motif on the vertical surface.

The inspiration to explore the potential in dynamic form using the wood plastic composite is precisely because of its nature. As a material that is manmade, completely invented, it has no predetermined color or form. Therefore, it can take any form the imagination, and technology (and technique) can provide. The limits are those of the mind rather than the material. The Wood Material Engineering Laboratory is only a first step in what we hope will be many explorations with wood plastic composites in architecture.

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Timber Building in Australia, <http://oak.arch.utas.edu.au/research/portal.asp>

DEMONSTRATION CASES OF THE SUSTAINABLE CAMPUSES RECONSTRUCTION PROJECT IN TAIWAN

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Abstract

This paper presents 16 demonstration cases of the Sustainable Campuses Reconstruction Project in Taiwan. Amongst others, it analyses the representative achievements in the ecological development, the application of solar energy and wind power, the integration of campuses and communities, the improvement of indoor environmental quality, the combination of composting and organic cultivation and the upgrading of local industries. These 16 schools represented local features of different areas and set examples on how to apply sustainable technologies to reconstruct campus environment.

Community participation is one of the factors for the successful implementation of the campus reconstruction projects. Campus reconstructed from sustainable technologies can be expected to be an environmental educate centre and also the unit operation for sustainable development. The process of reconstruction provides an education for sustainability. However sustainable reconstruction technologies differ from each school and transformation could be made accordingly to local environment and circumstances.

Keywords : Sustainable Campuses, Sustainable Buildings, Indoor Environment, Healthy Environment, Environmental Education.

1. Introduction

From the year 2001, the Ministry of Education of Taiwan started what we called the "Sustainable Campuses Reconstruction Project". They expected to reconstruct the existing campuses to be at a more sustainable learning environment which conform to the principles of safety, hygiene, health, environmental protection and ecological circulation. By the application of sustainable reconstruction techniques, the authorities attempted to upgrade and give impulse to the local industries, and promote the competitiveness of Taiwan in the world. The project was completed after three years with a combined effort of the technical professional experts, the authority concerned, the local community and the educators. There were more than 240 schools including primary schools, high schools, colleges and universities that were been partially reconstructed in sustainable concepts in the campus, building and indoor environments. Among them, 16 schools were selected to proceed with the designated reconstruction items of 2002 and 2003. Those schools are located at north, south, east, west and middle of Taiwan. They represent the respective different thinking and actions that were well suited to local circumstances. Moreover, the results have inspired all the participants to make it progress urgently.

2. Orientation of Demonstration Cases

The orientation and brief introductions of those schools are as follows.

(i) School A:

This historical elementary school was established over 100 years ago. It is adjacent to the historic street in the area. Community participation and democratic consultation in the process of school's

environmental reconstruction are the distinguishing features. We orientated it to be the center of local ecological conservation and set example for the reconstruction large scale in the suburbs. Details of the demonstration cases for sustainable campuses are shown in Table 1 and their location in Fig.1.

(ii) School B:

This elementary school is located at the countryside of northern Taiwan used to be well-known for its coal mine but the industry causing the population of the small village to be reduced substantially is on a decline. Thus school is selected to demonstrate a case representing a remote region where there is little development.

(iii) School C:

Although this school is located at the prosperous area of the capital city of Taiwan, it still possesses rich ecological resources. They have participated in the various ecological activities held by International Jane Goodall Institute. We orientated it to be the sustainable environmental education center and the ecological observation hub in urban area.

(iv) School D:

This elementary school is situated at the northwest zone of Taiwan. It has the advantage of abundant wind power. Efforts to plant a lot of medicinal herbs integrating the support and assistance of the community were undertaken to fill in the vacant area of the campus. Consequently, we orientated this school to be the demonstration case for application of wind power in western seacoast of Taiwan.

(v) School E:

It's a private girl high school located at the most bustling city in the middle of Taiwan. We expected it to be an example to demonstrate a case of a reconstruction project for a private school.

(vi) School F:

This school is located at the county which produces rice abundantly in the middle of Taiwan. It was rebuilt after the earthquake of September 1999. The relationship between a school and the community is very close. The local religious organization has financed the development of the school and the pupils' tuition for a long time. We expected to reconstruct this school to be the demonstration case for agricultural countries by introducing the sustainable technologies and integrating the community participation.

(vii) School G:

It's a junior high school located at the mountain area of middle Taiwan and adjacent to the TsaoLing Ecology area which holds plentiful natural resources. The school's buildings were also destroyed by the earthquake in September 1999. The campus also served as the annual camping ground for national boy scouts. Hence, we expected to reconstruct this school to be a base for local environmental education and ecological investigation.

(viii) School H:

This elementary school is situated at the central of Taiwan. It is the same as "school F" and "School G" rebuilt after the earthquake. The academic buildings were designed on the concept of Clustered Classrooms. This is set as an example of combining new educational environment with sustainable reconstruction technologies.

(ix) School I:

This elementary school is situated at west of Taiwan and near the Tropic of Cancer. The Central Weather Bureau had set up the weather stations in this campus. The reconstruction of this school made use of data with local climatic conditions to propose reforms pertaining to the environment. We also orientated this school to demonstrate the combined effects of cultural activities and the integrated development of the community. Consequently, we also orientated this school can be the demonstration of combining the cultural activities and the integrative development of community.

(x) School J:

It's an elementary school near the fishing village in Southwest of Taiwan. It is expected to be a local environmental education center emphasizing on the local culture and history.

(xi) School K:

This senior high school is distinct from the other 15 demonstration cases. It's a vocational school located at the South of Taiwan and chosen to be the research center and the environmental education base. It is expected to develop and integrate the sustainable techniques into their professional programmes, suitable to Taiwan's campuses reconstruction.

(xii) School L:

This elementary school is located at the industrial district in the biggest city of southern Taiwan. The average campus area per student is lower than the criterion issued by the Ministry of Education. This school can be expected to be the example of how to use the limited space and resources to reconstruct a sustainable campus in urban area.

(xiii) School M:

This elementary school is located at South of Taiwan and famous for its mango plantation. The demonstration of ecological circulation is the focal point. The campus was reconstructed to demonstrate case in urban area.

(xiv) School N:

This elementary school is located at South of Taiwan. They have carried out the environmental education in campus community for a long time. We expect it to set an example of how to introduce sustainable technology to reconstruct a campus because of its remarkable success in environmental education.

Table 1. The 16 Demonstration Cases of the Sustainable Campuses in Taiwan

Code of School	Geographical location		Students	Faculties	Classes	Area (m ²)	Campus Area /student
	East longitude	North latitude					
A	121.62	25.00	1830	93	54	27,000	14.75
B	121.74	25.03	85	25	7	11,456	134.78
C	121.54	25.01	400	30	14	17,440	43.60
D	120.81	24.65	408	25	13	13,400	32.84
E	120.67	24.17	2200	158	42	33,646	15.29
F	120.72	23.81	266	21	12	27,322	102.71
G	120.67	23.67	56	15	6	29,752	531.29
H	120.93	24.00	102	20	7	13,685	134.17
I	120.35	23.56	1152	61	36	27,294	23.69
J	120.17	23.06	381	28	13	18,222	47.83
K	120.23	23.01	3800	300	103	20,3000	53.42
L	120.30	22.72	2300	125	70	23,219	10.10
M	120.29	22.69	860	65	32	38,500	44.76
N	120.53	22.74	302	24	13	23,255	77.00
O	121.00	22.63	90	16	6	23,160	257.33
P	121.51	23.87	327	28	13	31,531	96.43

(xv) School O:

It's an elementary school located at the southeast of Taiwan. Most of the students come from the Paiwan tribe, an indigenous tribe of Taiwan. We orientated this school to be the ecological education center to emphasize on the integration of campus and the community. The self esteem of this aboriginal tribe their tradition and their response to local culture and history were also studied.

(xvi) School P:

This elementary school is situated at East of Taiwan and near the Tropic of Cancer, almost a half of its students come from the aboriginals families. The Central Weather Bureau had set up the weather stations in their campus. The reconstruction of this school made use of data of local climate

conditioning to propose the needed reforms corresponding to local environment. Meanwhile, we also orientated it to be the environmental education center of the East Rift Valley.

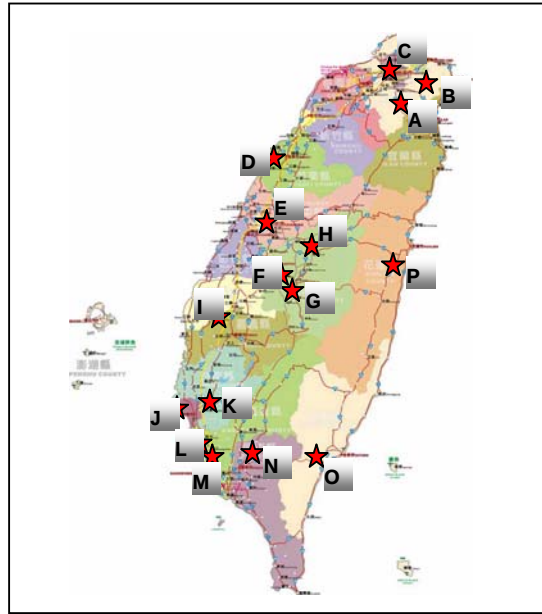


Fig.1 The Location of the 16 Demonstration Cases

3. Achievements and Signification

The reconstruction project emphasizes on the circulation of resource and energy, the responses to local environment, ecological circulation and healthy building. These 16 demonstration cases presented not only the foregoing items but also the items related to local environment. The purpose of this paper is to analyze the primary achievements obtained from the reconstruction process and the results of these demonstration cases. The achievements and its significance are given as follows:

3.1 Rainwater recycling

In Taiwan, annual rainfall is over 2,500 mm and it is 2.6 times of the world's average value. But Taiwan is still short of water due to its steep terrain, unbalanced rainy seasons and inappropriate utilization. So we advocate that campuses could be appropriate places to introduce rainwater recycling and to make students understand the utilization and the importance of rainwater.

Many schools such as "School A", "School B", "School C", "School G" and "School J" realized the importance of rainwater utilization and started to collect the rainwater from the academic building's roofs. After passing the water through some filtering stones, it is stored in tanks which were latter use to flush toilets and for watering plants.

3.2 Application of Renewable Energy

Taiwan is an island without sufficient natural energy resources. In Taiwan, 97.9% of the demand for energy relies on the import from other countries; the rate of application in renewable energy including solar energy, wind power, terrestrial heat and other innovation energy is only 2.86%. Bureau of Energy Ministry of Economic Affairs (2003) According to the statistical data compiled by the Taiwan Power Company (2002), thermal power is the major source of Taiwan's electric power supply. Consequently, the government is accelerating to develop renewable energy to guard against a sustained rise in fuel costs and to reduce the emission of greenhouse gases. However, the motive to popularize the application of renewable energy in campuses is not only focusing on the economic effects but also emphasizing on the value of sustainable education.

For example, in "School O", the administrator took the advantage of local geographical environment to develop the new energy resources. Good use of wind power and solar energy were adopted to decrease the dependency on traditional energy. According to the statistical data, the average daily power consumption was cut down from 70 KW/H to 1.8KW/H after the completion of the Reconstruction Projects in February 2004. The renewable energy was being substituted for traditional energy resources at the rate of over 95%. Besides, "School D" possessed abundant wind power resource due to the advantage of location. Wind power were used to generate electricity use to provide energy for the irrigation of the herb garden whilst "School F" integrate the solar energy and wind power to drive the equipment to purify the water quality in order to improve the quantity and quality of local agricultural products.

These schools are situated at the different regions of Taiwan and represent the various renewable energy applications corresponding to the local climatic conditions. Through the reconstruction process, we expect to give fresh impetus to local industries and technical personnel including builders, architects, designers, community planners and equipment suppliers, etc.

3.3 Composting of fallen leaves

The fallen leaves used to be a burden for the maintenance of school environment. The administrator assigned students to collect the fallen leaves and request the authority of environmental protection to sweep them. However, with this reconstruction project, the importance of ecological circulation were stressed and constitute the content of the learning programme.

In "School M", the authorities of the school respond to the benefits of ecological circulation compost areas which were extended every year. Receptacle were designed and built to collect fallen leaves, which were conveniently used by students and teachers in observing the process of fallen leaves becoming thoroughly decomposed. The compost is applied to fertilize the plants in campus and shared with the neighboring communities. The complete process of collecting and composting of fallen leaves is not only a sustainable education but also a good teaching program of ecological circulation.

3.4 Organic Farms for Purpose of Teaching

In traditional campuses, the function of the botanical gardens laid special emphasis on recognition of plants but neglected the instruction of ecological circulation and organic cultivation. In this reconstruction project, we stressed that the sustainable campuses can sustain great responsibilities to be the educational centers of organic agriculture in every community. Moreover, the organic farms in the sustainable campuses also contribute to the greenery of the urban area. The organic farms in campuses besides promoting the local agricultural product also contribute to enhance tourism through its scenic attractions.

In "School D", they combined teachers and students with the communities to cultivate and develop the gene pool of the local plants. In "School O", they paid attention to grow vegetables and plants in their campus which represent the spirit and culture of the Taiwan tribe. In "School P", they made full use of the vacant land in campus to cultivate the local edible wild herbs and combine advanced organic cultivation technologies in their teaching plans.

3.5 Healthy Building

Healthy building plays an important role in the reconstruction project. Unfortunately, most schools neglect the significance of indoor environmental quality and are ignorant about the application of green materials for a long time. This phenomenon can be seen by only a handful of application for the subject of healthy building showed in Fig.2.

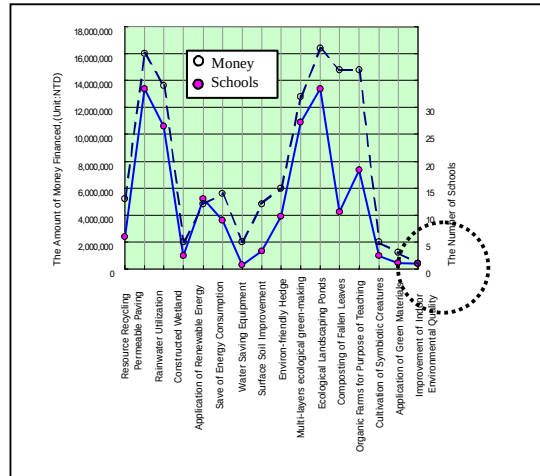


Fig.2 The factors of healthy building were neglected by most schools

Students spend most of their time in classrooms during the period when they are in school. The quality of indoor environment has close relation with the students' learning effects and affects the health of users of classrooms including students and teachers.

3.5.1 Application of Green Materials Many interior decoration materials be applied to school buildings are unhealthy to users. Therefore, we proposed the use of the green materials which conform to the four principles namely, health, recyclable, ecology and high performance.

In "School M", they attempted to apply the recycled green material instead of using the traditional wooden materials paved on the floors of classrooms.

3.5.2 Improvement of Indoor Environmental Quality The improvement of indoor environmental quality mainly emphasizes on acoustics, thermal and daylight.

"School A" proposed the improvement strategies to solve the problems of noise in classrooms. They applied different absorbing materials to improve indoor sound absorbency and to reduce the reverberation time. Meanwhile, they designed the teaching plans focusing on the topic of sound. The audio-visual classroom of "School F" was suffering for the problem of sound concentration because of the shape of the roof. They solved it by application of suitable absorbing materials. In "School P", the atmosphere environments of the top floor classrooms were hot and uncomfortable in the afternoon. They tried to apply three different methods to isolate the heat. The three methods were compared for their benefits and were included into the teaching programmes.

3.6 Reuse of the idle space

The population of Taiwan is aging and shrinking. Some schools located in remote districts are facing the challenge of reducing the number of classes and some are even to the extent of closing down. Consequently, more and more vacant space was idled in outlying campuses. Regeneration and reuse of the idle space is one of the important topics in the process of campuses reconstruction. The proposed regeneration and reactivation of idle space in campuses was a significant task for existing schools.

For example "School B" and "School P" reconstructed the idle school buildings outside the main campus and transformed them to be showrooms displaying the application of energy and resources. Recently, In "School B", the idle space were used for community gathering and environmental education. In "School P", they planted local edible wild herbs in the vacant land and integrated the cultivation and recognition of these herbs with environmental teaching plans. In "School N", they reconstructed the vacant land to be an ecological park emphasizing on the topics of water recycling, application of renewable energy, construction of wetland and multi-layers ecological green-making.

4. Conclusions

The 16 schools are located at different area of Taiwan and represent the different type of campuses. From the process and achievement of these 16 demonstration cases, the following conclusions can be drawn.

- (i) Community participation is an important factor in making the reconstruction project successful.
- (ii) The reconstruction process and result can be combined with related learning programs.
- (iii) Every sustainable campus reconstructed by the sustainable technologies can be expected to be the environmental education center and the basic unit of operation for sustainable development.
- (iv) The application of green materials in sustainable campuses can be promoted by combining the green building materials label system.
- (v) The essence of education is not restricted to the knowledge provided by textbooks. Sustainable life experiences and the concepts of environmental protection can be learned through by the process of reconstruction.
- (vi) The sustainable reconstruction technologies cannot be applied to every school. However, they could be transformed accordingly to respond to the local environment and circumstances.
- (vii) Each school should take advantage of its unique characteristics for developing its reconstruction programme.

Acknowledgements

The authors are indebted to the school principals, teachers, and students for their understanding and cooperation during the long process and sampling activities. We also thank our colleagues participating in the field investigations, and in the laboratory analysis.

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STRUCTURAL BOND PERFORMANCE OF LIGHTWEIGHT CONCRETE

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Abstract

Oil palm can be found in abundance in Malaysia and the solid waste production of oil palm shell (OPS) is over 3.13 million hectares. The use of OPS as an alternative to the conventional gravel aggregates in concrete is a means of efficiently managing this waste product, converting it into a useful product and hence another step towards sustainable development. An experimental investigation was conducted using OPS as coarse aggregate in structural lightweight concrete. Tests conducted on OPS concrete in fresh and hardened conditions were slump, air content, density, compressive strength and pull-out bond properties. In the pull-out test, both plain and deformed bars of 10, 12 and 16 mm diameters were used. The 28-day air-dry density obtained is within the limit of lightweight concrete and the developed 28-day compressive strength was more than 28 MPa. The obtained pull-out results were higher than the required values as per standard.

Keywords : Agricultural solid waste, Oil Palm Shell (OPS), Lightweight concrete, Compressive strength, Bond strength

1. Introduction

In view of the importance of sustainable development in the new millennium, alternative materials such as OPS, an agricultural solid waste to replace the natural aggregates in concrete have to be utilized. Malaysia is the largest producer of oil palm in the world with the solid waste production namely OPS of over 3.13 million tonnes annually (Mannan 2001). Sabah, Malaysia alone has an oil palm area coverage of over 1.13 million hectares (Mannan and Ganapathy, 2004). The main focus of utilizing OPS in the Malaysian concrete construction industry is due to its widespread availability. The utilization of OPS as coarse aggregate in concrete is a means of efficiently managing this waste product, converting it into a useful product. Concrete using OPS as coarse aggregate has been found useful as structural lightweight concrete, with the ability of producing concrete strengths of more than 25 MPa and it can be used for the construction of low-cost houses and precast concrete members in buildings (Mannan 2001).

OPS are lightweight and of various sizes. These are the desirable characteristics for lightweight aggregates and hence make OPS a good substitute as lightweight aggregates for the production of lightweight concrete.

This paper discusses the laboratory investigation of the engineering properties of lightweight concrete using OPS as coarse aggregate, which includes the compressive strength and structural bond behavior.

2. Materials and Properties

In this study, the raw materials used in the production of lightweight concrete samples were obtained locally and these include ordinary Portland cement (ASTM Type I), river sand, OPS, potable water and type-F naphthalene sulphonate superplasticiser.

2.1 OPS Aggregate

The hard shells were directly obtained from local oil palm mills. Before the OPS aggregates could be used, they were left under a shed for air-drying. Once the OPS were dried, sieving was done to separate the OPS from any impurities. The physical and mechanical properties of the OPS aggregates are shown in Table 1. OPS are of various shapes such as curved, flaky, elongated, roughly parabolic

and other irregular shapes. The concave and convex surfaces of the shell are fairly smooth, whereas the edges are rough and jagged. The shells also have varying thickness, depending on the species of the oil palm tree from which the palm nut is obtained.

Table 1 Physical and mechanical properties of OPS aggregates

Maximum size, mm	12.5
Shell thickness, mm	0.5 – 3.0
Bulk density (loose), kg/m ³	507
Bulk density(compact), kg/m ³	593
Specific gravity (saturated surface dry)	1.17
Fineness modulus	6.08
Aggregate impact value, %	7.51
Aggregate crushing value, %	8

2.2 Mix Proportions

The quantity used for each batch of mixing was 9.18 kg of cement, 15.26 kg of sand and 5.55 kg of OPS. The free water/cement ratio was 0.38. The mix proportion was in the order of 1:1.66:0.60 (C:S:OPS) by weight (1:2.14:1.62 by volume). The cement content used in this study was 510 kg/m³ and this is within the range for lightweight concrete (Mindess et al., 2003). The OPS used were in saturated surface dry (SSD) condition, whereas the sand was in air-dried condition. The superplasticiser added was 1.4 litres per 100 kg of cement, which is within the recommended dosage provided by the manufacturer.

3. Test Methods

3.1 Test Specimens

100 mm cube samples were used for the compressive strength evaluation whereas 100 mm diameter x 200 mm height cylinders were used for bond strength determination. To prevent evaporation from the fresh concrete, all test specimens were immediately covered with plastic sheets upon casting and left in the laboratory for one day. The specimens were then demoulded and cured in water at room temperature for the remaining days until the age of test.

3.2 Fresh Concrete Properties, 28-air Dry Density and Compressive Strength Tests

The fresh concrete density and air content were obtained in accordance to BS 1881: Part 107: 1983 and ASTM C 231 respectively, whereas the workability was measured using the slump test in accordance to BS 1881: Part 102: 1983. The 28-day air-dry densities were obtained according to ASTM C 567 and compressive strength tests were done in accordance to BS 1881: Part 116:1983.

3.3 Bond Test

The samples used for the bond strength test were similar to those used by El-Hawary (1999) and this test was conducted using a universal testing machine (Model: Shimadzu UH-300 kN). The steel bars used in the pull-out tests included R10, R12, R16, Y10, Y12 and Y16. The steel bars were placed in the centre of the specimen and both ends of the sample were provided with an unbonded length of 25 mm each. Plastic sheets were used for making the unbonded length to the bars. The main purpose of these unbonded lengths was to protect the bar from the confining pressure of concrete at the supports. The load was applied at a uniform rate as per ASTM C 234 until failure to obtain the ultimate load. The bond strength was computed by the following formula:

$$\tau = F / (\pi \times d \times l) \quad \text{Eq. 1}$$

where τ = bond stress (MPa), F = applied load (N), d = nominal bar diameter, l = embedment length (mm)

4. Results and Discussion

4.1 Slump and Air Content

The slump obtained was in the range of 50 to 70 mm which is within the required range for the workable concrete. The air content of the fresh concrete was 5.5% and this is relatively high. This could be attributed by the highly irregular shapes of the OPS which prevented full compaction to be achieved. In addition, the porous nature (high water absorption) of the OPS could have contributed to higher air entrapment in the concrete paste.

4.2 Fresh and 28 Days Air-Dry Densities

The fresh concrete density was in the range from 2010 to 2065 kg/m³. The 28-day air-dry densities were in the range of 1930 to 1995 kg/m³ and this is within the range for structural lightweight concrete (Clarke, 1993). The 28-day air-dry density of this concrete is approximately 16 to 20 percent lighter compared to the normal weight concrete of 2400 kg/m³.

4.3 Compressive Strength

The compressive strength of hardened concrete is presented in Fig.1 and the compressive strength continues to increase with age. In this short-term investigation, the strength gain indicates that the OPS does not deteriorate once bound in the concrete matrix. The 28-day compressive strength obtained was approximately 65 percent higher than the minimum required strength of 17 MPa for lightweight concrete (ASTM C 330). From the tested samples, it was observed that the compression failure in the concrete was mainly caused by the failure in the bond between the cement paste and the OPS aggregate.

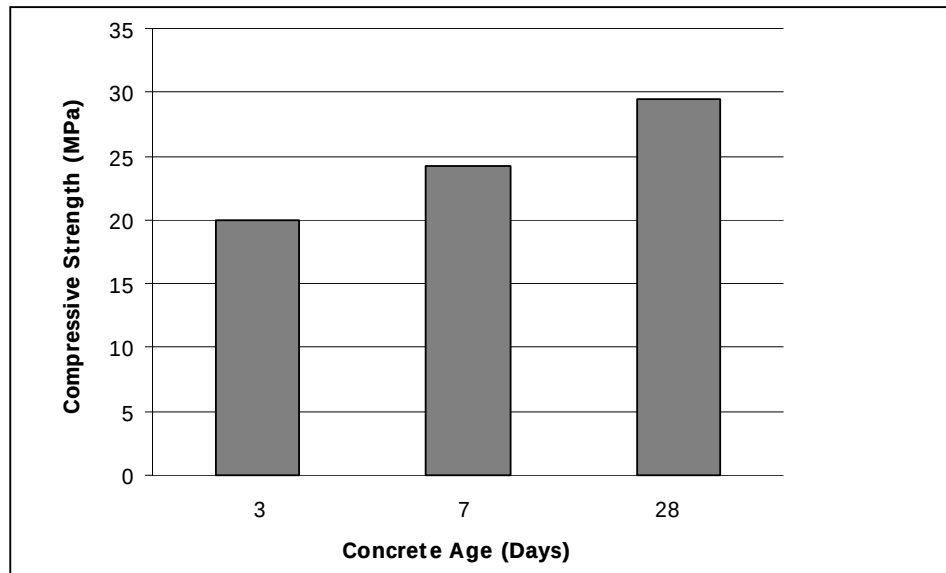


Fig.1 Compressive strength of hardened concrete (OPS concrete)

4.4 Structural Bond Properties

The results for the pull-out test incorporating both plain and deformed bars of 10, 12 and 16 mm diameter bars are presented in Fig.2 and Fig.3 respectively. Higher values of bond strength were obtained for specimens having deformed bar compared to values obtained for specimens having plain bars. This is because deformed bars have larger contact area and mechanical interlocking between the bars and the surrounding concrete due to the projections on the surface of the deformed bars. In this study, the bond strength of specimens with deformed bars having the same diameter was in the order of 1.9 to 2.4 times higher than that of specimens with plain bars.

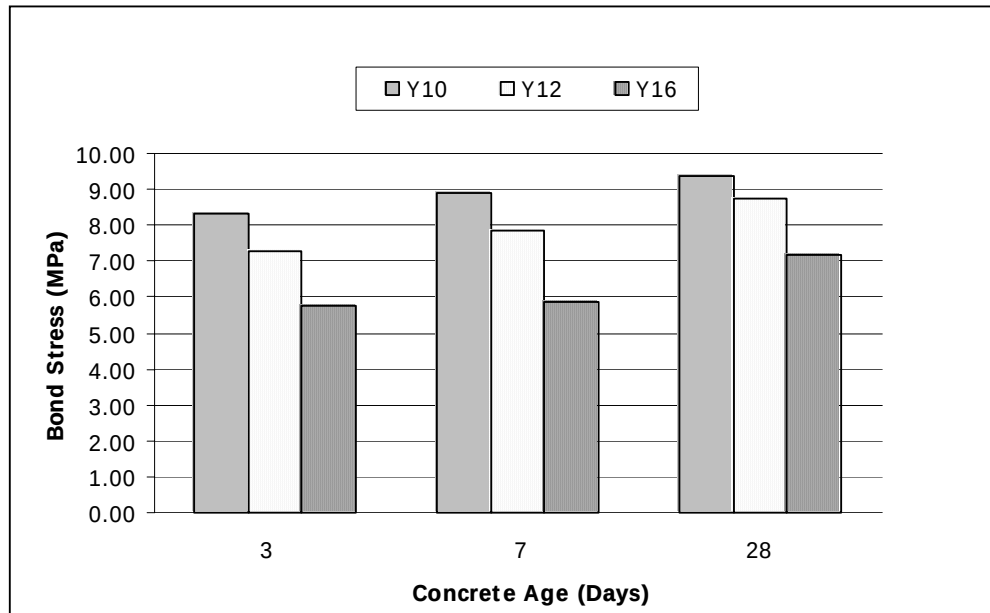


Fig.2 Bond strength of hardened concrete (OPS concrete) using deformed (Y) bars

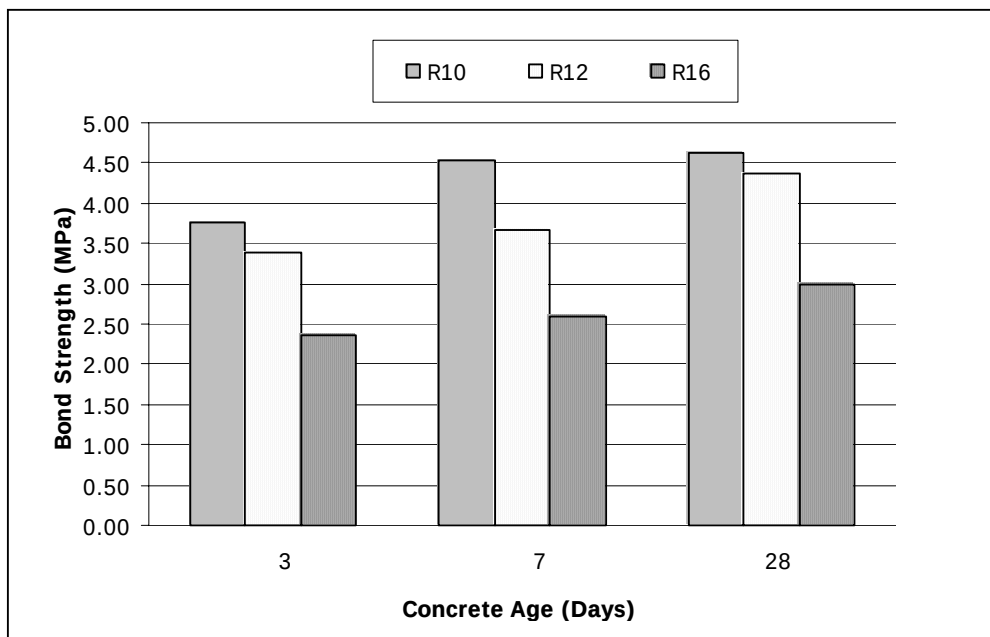


Fig.3 Bond strength of hardened concrete (OPS concrete) using plain (R) bars

For both plain and deformed bars, concrete with smaller bar diameter produced higher bond strengths. This can be explained by the lower confining stress on the bar. As the bar size increased, the concrete cover to the reinforcement is reduced. Consequently, the confining pressure on the reinforcing bar from the surrounding concrete is also decreased and resulted in the decrease of bond strength. Similar trends were reported elsewhere (Short and Kinniburgh, 1978; Kankam, 2004).

At all ages of the pull-out tests, plain bars failed by pulling out of the concrete without any visible cracking of the concrete cover. As for deformed bars, all samples failed by cracking of the concrete cover. The failure was very sudden and was accompanied by the formation of longitudinal cracks. When the cracks formed, the bond forces were directed outward from the bar surface and these forces caused anchorage failure by cracking of the confining concrete cover.

5. Conclusions

The investigation concludes that the properties of OPS concrete are comparable to structural lightweight concrete in terms of the slump properties and air dry density. The compressive and structure bond strength is also comparatively higher than lightweight concrete, with smaller diameter bars giving higher strengths. With these advantages, the potential of OPS concrete for use in the Malaysian construction industry, particularly, for low cost housing should be further explored.

Acknowledgements

This project is sponsored by Ministry of Science, Technology and Environment under IRPA grant no. 03-02-10-0033-EA0031.

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USE OF RECYCLED FIBRES AS CONCRETE REINFORCEMENT – AN EXPERIMENTAL INVESTIGATION

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Abstract

Landfill of fibrous waste has caused numerous problems on environments and cost millions of dollars on waste management and creation new landfill space. However, this kind of waste may prove to be valuable in some applications and this landfill practice represents a severe waste of resources. Therefore, a cost-effective solution to convert the waste into useful products is worth exploring. It is well known that concrete, as one of the most commonly used construction materials on the earth, has advantages of good durability, inexpensive, architectural and structural flexibility, and adequate compressive strength and stiffness. However, concrete also has disadvantages of low tensile strength, low ductility and low energy absorption. In order to increase the tensile strength of concrete, research has been carried out in the past decades and has identified that adding a small fraction of short fibres to the concrete is an effective way to improve tensile properties of concrete. In this study, we aim at utilizing the fibrous waste as virgin fibre replacement for concrete reinforcement. The tests performed include unconfined compression, flexural and shrinkage tests by following the standard procedures (Australian Standard). Our initial findings have shown that recycled fibres from carpet and fabric waste are effective reinforcement to improve brittleness and ductility in concrete while the strengths are a bit lower.

Keywords : Sustainable environments, Recycled materials, Carpet waste, Concrete reinforcement.

1. Introduction

It is well known that plain concrete has advantages of good durability, inexpensive, architectural and structural flexibility, and adequate compressive strength and stiffness. However, concrete also has disadvantages of shrinkage cracking, low ductility, low energy absorption and being brittle under tension. Over the years, many materials such as steel shavings, glass fibres, carbon fibres, high-density polyethylene fibres and recycled fibres from tires have been used to reinforce concrete. For example, Keyvani and Saeki (1997) investigated the use of steel shavings as a substitute for steel fibres in concrete. Auchey and Dutta (1996) studied the use of high-density polyethylene fibres (HDPE) in concrete under extreme freeze-thaw conditions.

In the past, virgin synthetic fibre reinforcements have been used successfully for many years to maintain the quality of concrete construction works. It has been found that the tensile properties and cracking resistance and crack propagation of concrete slabs can be significantly improved by incorporating a small amount of fibres into concrete mix (Wang, 1997). However, the application of those virgin fibres in concrete has been limited due to their costs.

On the other hand, the municipal solid waste generated is about 21 million tons per year in Australia according to the Australian Bureau of Statistics (ABS 8698.0.1996-1997). Among the solid waste, about 2% (i.e., 42,000 tons) are fibrous textiles, which are made of cotton, wool, polyester, nylon, polypropylene, etc. and in the form of raw fibre, yarn, woven and knitted fabric, clothing and carpet. In the current practice, those fibrous wastes are mainly disposed in landfill. This practice requires constant creation of new landfill spaces, imposes many problems on environment (e.g., pollution in land, air and waterway around landfill), and also costs millions of dollars in waste management. Furthermore, if the waste materials prove to be valuable in some applications, especially where virgin materials are not necessarily required, this landfill practice represents a severe waste of resources.

Herein, motivated by financial incentives and environmental constraints, we are proposing to evaluate performance and economic benefits that will be gained by using fibrous waste material instead of virgin fibres as reinforcement in concrete slabs for building industry. Specially, Australia is a huge continent with extreme weather conditions that include rainforests, deserts, mountains, tropical areas and temperate variations. That means that we are facing extensive challenges in maintaining our buildings over a vast and difficult content.

In this study, our specific objectives are:

1. to reuse synthetic fibres and small strips of fabrics extracted from wasted carpet and bed linen as reinforcements in concrete;
2. to perform compression test, flexural test and drying shrinkage tests on the concrete specimens with and without those fibre reinforcements;
3. to compare the results obtained to determine whether such reinforcement can effectively improve energy absorption or toughness and stability of the base courses and enhance the load-bearing capacity.

The successful implementation of this research project will be very important to building industry, waste management, environmental protection, textile and carpet industries.

2. Materials and Preparation of Specimens

In this study, fibres for reinforcement are disassembled from a wasted carpet and a few different dosage rates of fibre inclusion in concrete are utilized for comparison.

2.1 Fibres Extracted from Carpet Waste

A piece of typical carpet consists of a face layer, one layer of primary backing and one layer of secondary backing is shown in Fig.1. The two layers of backing are jointed by CaCO₃-filled styrene-butadiene latex rubber (SBR) while the face layer tufted into the primary backing layer.

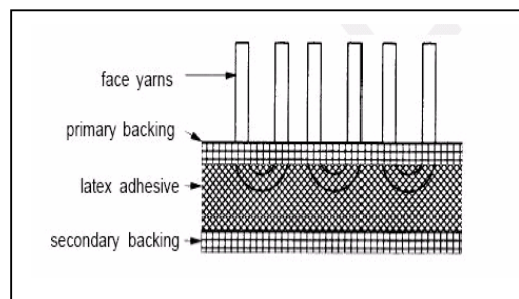


Fig.1: Tufted Carpet Structure (Wang, 1997)

Nylon 6, nylon 66, wool, wool blended fibres are most frequently used in carpet face layer. Among them, nylon fibres are a kind of synthetic fibres and have great abrasion resistance, exceptional durability, versatility and reasonable pricing. They can be dyed in a wide variety of colours and easily made into numerous styles and texture and thus are commonly used in residential and commercial applications. Wool fibres, which are natural fibres obtained from sheep's skin, give warmth and luxurious quality and have moderate soil and stain resistance.

The primary backing layer is made of polypropylene tape yarn while a secondary backing is made of cheap natural vegetable fibres. Polypropylene fibres are hard and tough and have great resistance to chemical reaction and stains. Flax and hemp fibres often serve as secondary backing layer.

In this study, a roll of tufted carpet and bed linen wastes from a local landfill site were collected. From the carpet, three types of yarns were disassembled. By using burning and stain tests, the face layer is

identified as nylon 6 textured yarns with 20mm in length as shown in Fig.2. The primary backing is made of polypropylene tape yarn while the secondary backing is made of flax yarn. Those yarns of two backing layers were cut into 20mm in length for comparison purpose. For the bed linen made of polyester fibres, generally, polyester fibres have high strength and high elastic modules. This polyester bed linen fabric was cut into strips with a length of 20mm and 5mm width. In this way, four kinds of candidates for fibre reinforcements are obtained.



Fig.2: Nylon Yarns Disassembled from the Face Layer of the Wasted Carpet

2.2 Concrete Mix Designs

A basic concrete mix consisted of cement, sand, aggregates and water with and without fibre reinforcement. The components and their properties are as follows:

Cement: Portland Cement GP. The cement binder, which is very fine in size, is comprised of various ratios of 3CaO , Al_2O_3 , 2CaO , SiO_2 , 3CaO , SiO_2 , 4CaO , Al_2O_3 , Fe_2O_3 , and other minerals;

Sand: washed river sand, which is free of clay with an average diameter of 0.01mm;

Aggregate: Coarse aggregate is composed of gravel and rock. The aggregate particles used in this study were angular rather than round so as to provide higher strength. The aggregate is class 2, 10mm, 10/7 standard, crushed aggregates from demolition of concrete and asphalt construction materials (donated by a local recycling company called Resourceco).

Water

Fibre reinforcement: nylon, polypropylene and flax fibres with 20mm in length from the face layer of the tufted carpet waste at various dosage rates respectively.

The weight proportion of each component in specimens were 1.0 (cement)/ 0.44 (water)/ 1.71 (sand)/2.6 (aggregate). The dosage rate by volume fractions of each type of fibres is 0% (plain concrete), 0.1% (only for shrinkage), 0.5%, 0.75% (only for shrinkage), 1.0% (only for strength) and 1.5% (only for strength) respectively.

The concrete mix designs for strength testing are shown in Table 1.

Table 1. Concrete Mix Designs

Mix	Type of Fibre	Fibre Dosage Rate			
		0% (plain concrete)	0.5%	1.0%	1.5%
1	None	√			
2	Nylon		√		
3	Nylon			√	
4	Nylon				√
5	Polyester		√		

2.3 Preparation of Specimens

For each mix, three cylinder specimens for compression tests, three beam specimens for flexural tests and three for shrinkage tests were made and cured in accordance with AS 1012.8, AS 1012.9, AS 1012.11 and AS 1012.13 (Australian Standards) respectively.

A large industrial mixer was used for mixing. Sand, aggregate, water and cement were all measured using electronic scales and then the ingredients were mixed in a wheelbarrow dry to achieve a uniform consistency. Once the ingredients were mixed, they were then put into the industrial mixer and the water then added. The mixing time was 10 minutes for the wet mix. The concrete was then filled into the moulds for the cylinders and the beam specimens. The mould for making compression specimens has a right cylinder shape with 100mm in diameter and 200mm in height. The mould for making flexure test specimens has rectangular beam shape and a cross section of 350mm x 100mm. The mould for making drying shrinkage test specimens also has rectangular beam shape with 280mm in length and a cross section of 75mm x 75mm. The moulds were coated with oil so that the specimens could be removed the next day. The specimens were vibrated on a vibrating table until the air bubbles had disappeared. A trowel was used to smooth the surface of each specimen after vibration. The specimens were then left to dry, before the moulds were stripped the next day and put into a temperature-controlled rooms for curing for 28 days.

3. Experiments

The testing procedures were carried out at the University of South Australia's civil engineering laboratory. On the day of testing, the specimens were removed from the temperature controlled rooms to the testing room, their actual dimensions were measured and then averaged, to give an accurate result for use in subsequent calculations.

3.1 Compression Tests

The ends of cylinder specimens were smoothed with a piece of sandpaper and then the diameter and height of the specimens were determined using vernier callipers. Once the critical information is recorded a rubber cap is then placed on the top of the compression specimen and then placed inside the testing chamber. The compression tests were conducted using a hydraulic loading apparatus in accordance with AS 1012.9 (1999). For each specimen, the compression strength was then determined by the result of the maximum load divided by its cross-sectional area.

3.2 Flexural Tests

The flexure test was undertaken in accordance with AS1012.11 (2000). The beams were turned on their side for an even distribution of loading via a four point loading set-up. The maximum tensile stress in the beam at peak load was taken as the flexural strength given by:

$$\sigma = \frac{PL}{BH^2} \quad \text{eq. 1}$$

Where P is the maximum load, L denotes the beam span length (460mm), while B and H are the beam width and the beam height respectively.

3.3 Shrinkage Tests

Shrinkage tests were conducted according to AS 1012.13 (1992). The shrinkage mould dimensions are 280mm long x 75mm deep x 75mm wide. The length dimension is approximate as the gauge studs attached to the ends of the moulds vary as they are tightened. The temperature in the drying room is maintained at 23°C and the relative humidity is maintained at 50%.

4. Results and Discussion

The testing results for compressive, flexural strength and shrinkage are summarised in Table 2 and 3 respectively. The results are discussed in the following sections.

Table 2. Test Results for Compressive and Flexural Strength

Mix	Dosage (kg/m ³)	V _f (%)	Compressive Strength		Flexural Strength	
			MPa	SD*	MPa	SD*
1	---	0	55.3	0.779	5.52	0.325
2	5.7	0.5	55.1	0.437	6.33	0.162
3	11.4	1	56.8	0.225	5.92	0.406
4	17.1	1.5	54.6	0.722	5.87	0.419
5	6.75	0.5 (polyester)	---	----	5.75	0.251

*SD = Standard Deviation

Table 3 Summary of Shrinkage Results

Air Drying Period	Mix 0%	Mix 0.1%	Mix 0.5%	Mix0.75%
Days	(10 µm)	(10 µm)	(10 µm)	(10 µm)
7	410	383	330	410
14	633	563	490	547
21	753	687	630	700
28	837	770	730	788
56	1027	980	900	875

4.1 Compressive and Flexural Strength

The results of compressive strength tests indicated that concrete with waste fibres might have the same or lower compressive strength than plain concrete. The fibres might have caused a strength reduction or delayed the development of compressive strength with age. This result is similar to other researchers (Wang, 1997). However, it was observed during the testing that the failure pattern was different between plain and fibre concrete. The plain concrete specimens failed in a brittle manner, shattering into many pieces once the peak load was reached. In contract, specimens with fibre failed in a more ductile manner, the fibres holding the concrete together and absorbing more energy. The failure patterns of plain and fibre concrete are compared in Fig.3(a) and (b).

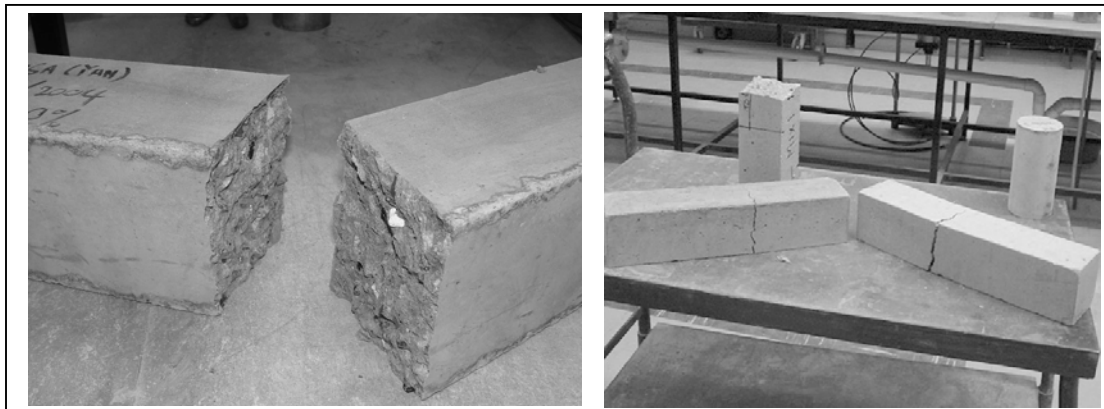


(a). Specimens Without Fibre

(b). Specimens With Fibre

Fig.3: Compressive Failure - Specimens With and Without Fibre

For the flexural test, similar strength was obtained for plain and fibre concrete with various dosage rates, where fibre concrete having a slightly higher strength. Again, the failure pattern was quite different between plain and fibre concrete. The plain concrete specimens broke into two pieces once the peak load was reached (Fig.4(a)) while the fibre concrete specimens exhibited a ductile behaviour with more energy absorption. It was observed during the testing that fibres acted as an energy transfer bridge and held the specimen together. The higher the dosage rates of fibres, the less the cracks developed along the depth of the beam cross-section.



(a). Specimens Without Fibre

(b). Specimens With Fibre

Fig.4: Flexural Failure - Specimens With and Without Fibre

4.2 Shrinkage

One of the causes that resulted in the early deterioration of concrete involves volume changes in concrete due to shrinkage and moisture loss. As concrete cures and dries, tensile stresses are created due to hydration and loss of moisture. The tensile stresses cause the concrete to shrink. Drying shrinkage cracking is related not only to the amount of shrinkage, but also the modulus of elasticity, creep and tensile strength of the concrete.

The shrinkage results were measured with a comparator of the length changes of the specimens with an accuracy of 0.001 mm and recorded at different ages (from 7 days until 56 days). The shrinkage results of concrete with various dosage rates and plain concrete are compared in Fig.5. The free shrinkage of concrete with 0.75% of waste fibres was about 15% lower than that of plain concrete. However, when the dosage rate reduced to 0.1%, the free shrinkage was about the same between

fibre and plain concrete. It was also observed that the effect of fibres to free shrinkage of concrete increased with the time. However, further research is required to measure the shrinkage with longer period of time, say one to two years.

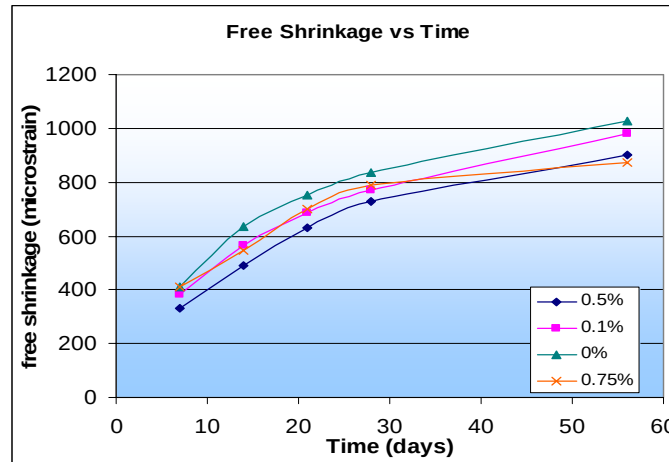


Fig.5: Free Shrinkage at Different Ages for Concrete With and Without Fibres

5. Conclusions

In this study, we have utilized the fibres disassembled from carpet and fabric wastes as reinforcement in concrete. Compression, flexural and shrinkage tests were performed on the concrete specimens with and without those fibre inclusions and the testing results were compared. From this initial investigation, it was found that although the compressive and flexural strength could not be improved with additional fibres, the brittleness and ductility of concrete could be improved by those fibre reinforcements significantly, as well as energy absorption and free shrinkage of concrete. This means that the fibrous waste materials are still valuable and have great potentials to become a cost-effective resource and provide performance enhancement for concrete blocks in building industry where the use of virgin materials are not necessarily required. However, it should be mentioned that the above conclusions are based on a limited number of test specimens; further research is being carried out with more testing specimens and dosage rates.

Super plasticizer was not added for the initial testing discussed in this paper, bad workability was experienced for mixes with 1% and above while mixing concrete. The fibres attached themselves to the blades of the mixer during the mixing. They had to be removed by hand when the mixing was completed and then to be blended manually.

There are many advantages in reusing such fibrous textile and carpet waste. For example, environmental pollution (e.g., methane and toxic leachates) caused by landfill of those waste materials can be alleviated. Landfill usage and cost of land tipping can be reduced. An additional benefit to be realized would be the conservation of the virgin fibre sources; air pollution reduction and energy consumption savings resulted from processing virgin fibres used as reinforcements in concrete.

The results derived from this project will have a significant impact not only on the building practice but also on the future operations of waste management, such as waste collection, sorting and reusing activities state wide, nationally and even world wide.

Acknowledgements

The assistance of final year students John Liedig and Joulène Nour in carrying out the experimental testing is gratefully acknowledged. We would also like to express our appreciation to Adami's Sand and ResourceCo for their donations of sand and aggregate.

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USE OF SMALL SECTIONS FOR MODERN TIMBER STRUCTURES

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Abstract

Malaysia is known for its greenery with a green cover of more than 60%; relatively high by any international standards. Traditionally, the country is famous for its tropical forest products export and currently one of the major producing countries in the world. With the increasing awareness on environmental issues particularly, the threat posed by global warming, Malaysia has recently embarked on new policies and guidelines regarding sustainable management of our forests as well as moving towards development of more plantation forests in the country. However, one of the greatest challenges encountered is the long gestation period for the latter investment and low rate of return associated with it. Besides current incentives provided by the government which includes tax relief, another means to mitigate the problem is through the development of more value-added products from small log sections derived from these plantations.

This paper deals with the possible use of small tropical hardwood cross-sections for erecting building elements. Glued-laminated boards will be explored as a means to replace massive timber, concrete and steel beams. Composite concrete-timber floors, as well as trusses and shell structures to cover large roofing areas will also be presented.

In conclusions, sustainable timber constructions are possible provided there is cooperation between wood-related partners, from the forest manager to the building contractor. Maintain the quality of the product throughout its different transformations is essential. A quality assurance scheme shall be endorsed to guarantee the characteristics of the end product will enhance confidence of potential clients.

Keywords : Sustainable forest management, Timber structures, Small sections, Manufacturing, Quality assurance.

1. Introduction

Malaysia has long been known as one of the leading tropical hardwood producers in the world, and more recently, as a nation serious with its sustainable forest management practices. To date, for instance, seven of the states in Peninsular Malaysia have been certified to Malaysian Timber Certification Scheme, a scheme developed based on the indicators outlined by the International Tropical Timber Organization (ITTO). The country is also committed to a high green cover of not less than 60%, a high figure by any international standards. Though noble from the environmental and long-term supply points of view, this commitment has led to the effect of immediate shortage in raw material supply of particularly popular species, resulted in escalating cost in all wood-based materials. In addition, for an economically viable large-scale plantation program across the nation to take place, major challenges lie in the long gestation time and low rate of return. It is strongly believed that apart from the attractive incentives provided by the government, a more practical method is through the development of more economical and technically viable solutions using the small sections derived from our small logs.

2. Forest Industries and wood-based resources

Forestry sector plays an important role in the socio-economy of Malaysia. In the year 2001, the export of timber and timber products amounted to RM 14.33 bil. (USD 3.77 bil.). There were more than 5,000 timber-processing mills, with about 3,200 furniture mills that depended heavily on rubberwood (*Hevea brasiliensis*) plantation timber as raw material. There were 12 particleboard and 14 medium density fiberboard plants, most of which made use of rubberwood as their main source of raw material too.

Besides, there were 176 timber preservation plants and 279 kiln-drying facilities that were involved in the preservation and drying of rubberwood (Singaram et al., 2002).

Timber is derived primarily from the natural forest in Malaysia apart from a small percentage from the plantation forests such as those of *Acacia mangium*. The total forest area of the country is about 20.11 mil. ha., about 62.4% of its total land area. Approximately 20% (3.84 mil. ha.) of the total land area is classified as *protected forest* that is totally protected for environmental and conservation reasons. They are found in the form of wild life sanctuaries, nature reserves and national parks. For the sustainable production of timber, a total of about 10.56 mil. ha of forests have been identified and gazetted as Permanent Forest Estate (PFE) and that harvest is done on a 30-year and 55-year cycle depending on the quality of the tree stock. The balance of 5.71 mil. ha. are allocated for development purposes such as housing, road construction and township establishment etc. Timbers are clear-felled in these development areas. A breakdown of forest area by region is given in Table 1 (Singaram et al., 2002).

Table 1. Estimated forest area (mil. ha) – 2001

Forests Regions	Permanent Forest		Other forests	Total	Log production ($\times 10^6 \text{ m}^3$)
	Protective	Productive			
Peninsular Malaysia	1.90	2.90	1.10	5.90	5.13
Sarawak	1.03	4.97	3.79	9.79	12.40
Sabah	0.91	2.69	0.82	4.42	2.48
TOTAL	3.84	10.56	5.71	20.11	20.01

Malaysia started its fast-growing timber plantation in 1970's. Began with Pine (*Pinus caribaea var hondurensis*) which was meant for a proposed pulp and paper mill project that did not materialize hence its planting was terminated. In the 1980's, Compensatory Forest Plantation Project was initiated in Peninsular Malaysia with the planting of *Acacia mangium*, *Gmelina arborea* (Yemane), *Eucalyptus spp.* and *Paraserianthes falcataria* (Batai). However, Acacia became the major species planted because of its adaptability to almost all the planting sites and the availability of seeds then. For some technical reasons, the planting of Acacia was discontinued in Peninsula. In East Malaysia, the planting of Acacia is mainly for pulp production (Singaram et al., 2002).

In addition, other "slow" growing species such as Teak (*Tectona grandis*), Sentang (*Azadirachta excelsa*), Mahogany (*Swietenia macrophylla*), Engkabang (*Shorea macrophylla*) and Durian (*Durio zibethinus*) are also being planted by the government and the private sectors. On the other hand, the rubber trees planted earlier for the purpose of latex production became the main source of supply for wood-based industries particularly in West Malaysia owing to its abundant availability and technological breakthrough in its utilisation.

3. Small Wood Sections

The definition of a small wood section varies from countries to countries and mainly depends on the available tree supply. In USA, where abundant supply could be made available resulting from new wildfire protection and overstocked forests management, small-diameter wood is measured as everything below six (6) inches in diameter (15 cm). In Malaysia, there is no widely accepted limit to make the distinction between regular and small round wood diameters. One thing is certain though;

large trees are becoming more difficult to find. Therefore mills have to adjust and process a greater amount of smaller diameter trees in order to cater for current market demands.

There are relatively few Malaysian documents dealing with the use of small log sections for structural uses probably due to the fact that the country has abandoned the construction of large timber structures. Nowadays, most of the Malaysian logs are used in the furniture industry, wood-based processing industry (plywood, fiberboard, particleboard), moulding, and for the production of lumber (graded/ ungraded boards, kiln or air dried). All these applications do not expressly require large log sections, except for some wide boards.

The use of rubberwood (*hevea brasiliensis*) in the furniture industry is the leading example in Malaysia. It was partly due to the depletion of Ramin trees from the forests that led to the use of small rubberwood sections. However, to reduce the tendency to warp and twist of this juvenile timber species during drying, most of the rubberwood furniture is reconstituted from boards of not more than 10 cm wide and 90 cm long. Mastering finger jointing and gluing techniques have resulted in a RM 4 bil. (USD 1 bil.) annual export industry within 20 years (Bumiputra Commerce, 2003).

In short, Malaysia has already embarked on the conversion of relatively small wood sections into certain value-added products. But the emergence of global markets, in which governments have less control over import and export of goods, threatens even the well-established national industries in general, the wood transformation industries in particular. Therefore, it is advisable to look for new market opportunities in order to avoid supply saturation, which inevitably results in price dumping wars and loss of profit margins. The utilization of small wood sections for engineered timber structures is seen as a new alternative in this country.

4. Timber Structures

Timber structures are not widely used for buildings in tropical countries in general, in Malaysia in particular, despite the fact that most of tropical hardwood species have superior characteristics than softwood species grown in temperate climates. Colonialism has undeniably played an influential role in the development of the country and its architecture. Weather conditions are another reason often brought forward to explain this situation. Moreover, termites and fungi attacks have destroyed many wood structures and are still creating problems nowadays with some buildings, in which architects and engineers have not adequately dealt with the specific characteristics of the construction elements made of wood. Besides, the current Building by-laws which restrict the use of combustible materials in urban development also hinder wider use of timber construction in the country.

Fortunately, there are also existing timber structures to show the wood potentialities. Probably the most visible, but nevertheless rapidly disappearing, is the timber Malay house. Are these houses still around because they were built without the supervision of architects or engineers? This is questionable, but one thing is certain; the traditional Malay house created a near-perfect solution to the control of climate, multifunctional use of space, and flexibility in design with a sophisticated prefabricated system. Generations after generations have worked to improve the system, which resulted in cost-effective solutions and adequate construction details.

Construction details are the key to a sustainable structure. Some keep the water away or allow it to dry before getting trapped. Others prevent the attacks by termites or fungi. Wood is a hygroscopic material. It swells and shrinks with a change of moisture content. Particular care shall be given to connection details. Connections shall be able to keep transferring loads even if the wood elements change their sizes over time. This is particularly true in outdoor environments or in structures simply protected from the rain (without being totally enclosed).

Several types of timber structures are adapted for use of small sections. The wood either works in conjunction with other materials or is processed into larger elements like trusses or glued-laminated (glulam) beams.

4.1 Trusses

Round wood or small boards can be used with adequate connections to form trusses of different geometry and free spans. The Olympic information booths in Salt Lake City, USA, are examples of the use of small diameter round wood in spatial trusses (Fig.1). All sections were equal or inferior to six (6) inches in diameter (15 cm). The truss members were assembled with dowel-nut connections.



Fig.1 Round wood trusses (www.fpl.fs.fed.us)

For longer spans, another truss system is presented using only boards, wood panels and screws connections. The “Ariane” truss system developed in Europe by Professor Jean-Luc Sandoz can economically span from 20 to 60 meters (Sandoz, 2004). The truss members are composed of one or several layers of planks depending on the design load. The members are connected together with screws and reinforced with laminated veneer lumber (LVL) panels to guarantee the shear strength of the system. If the truss is kept visible, interesting architectural effects can be obtained by giving different shapes to the LVL plates (Fig.2).



Fig.2 Ariane trusses

4.2 Glued-Laminated Beams

Glued-laminated (glulam) beams are generally large structural elements (Fig.3). They are cost-effective solutions to replace the largest sawn timber sections or even to create bigger and longer elements. They are manufactured by gluing smaller pieces (boards or laminations) together. The thickness of the laminations depends on the shape of the finished beam. Curved glulam beams require thinner laminations, as thin as 18 mm for important curvatures. Thicker laminations, up to 35 mm for hardwoods, may be used for straight beams. If the boards are not as wide as the required width of the structure, they can be bonded together edgewise. Due to the improvement of the finger-jointing technique and the dispersion of defects, like knots, glulam beam strength properties are generally higher than the design properties of the wood composing the beam.

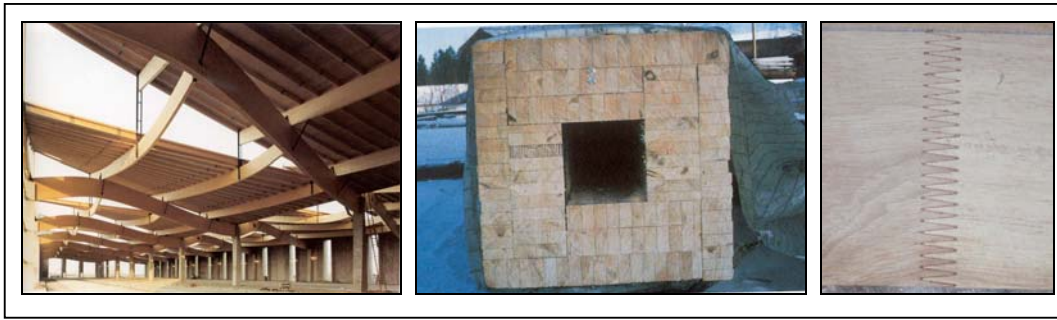


Fig.3 Glulam beams

4.3 Shell Structures

Shell structures are well suited for wood planks of small thickness (Fig.4). The ability of bending the wood without excessive machinery (often using only gravity) and the easy assembly of the elements together with screws or bolts have attracted architects and engineers to work together with some really astounding results. These lightweight structures are challenging the engineers but the final structure can nevertheless be cost-effective due to several factors including reduced foundations, increased column-free area, no false ceiling (the beauty of the wood is put forward rather than hidden away), and reduced erection equipment.

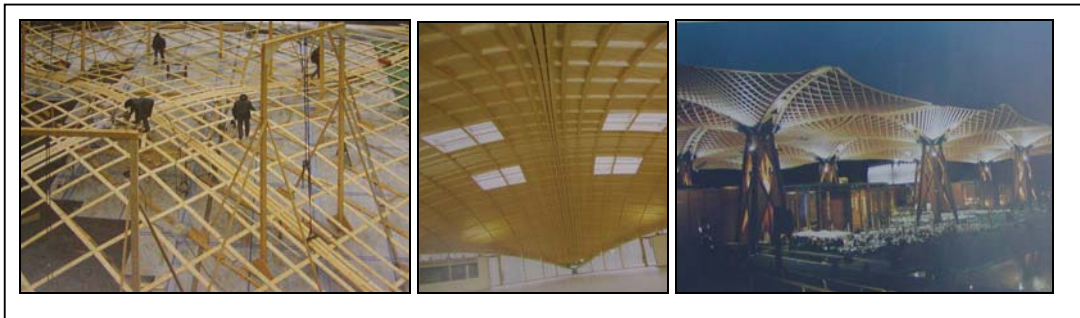


Fig.4 Shell structures

4.4 Composite Floors

Small board sections in association with concrete can be used to create heavy-duty floors or when vibration and impact sound transmitted by regular wooden floors are problematic issues. The composite structure is structurally sound with concrete working in compression and timber in traction. The link between the two materials is the key to provide the required strength and stiffness of the floor. Several shear connectors have been proposed over the years with different rigidity. Nails, screws or bolts are generally considered to be the least rigid of all connectors because they tend to split and crush the wood, incurring slip under load. Structural adhesives are considered the most adequate solution for a rigid connection but with the disadvantages of cost and difficulties of on-site application. Between these two extremes, several solutions have been proposed and fully tested to assert the stiffness of the composite structures and their ease of application. Two different systems are illustrated in Fig.5.

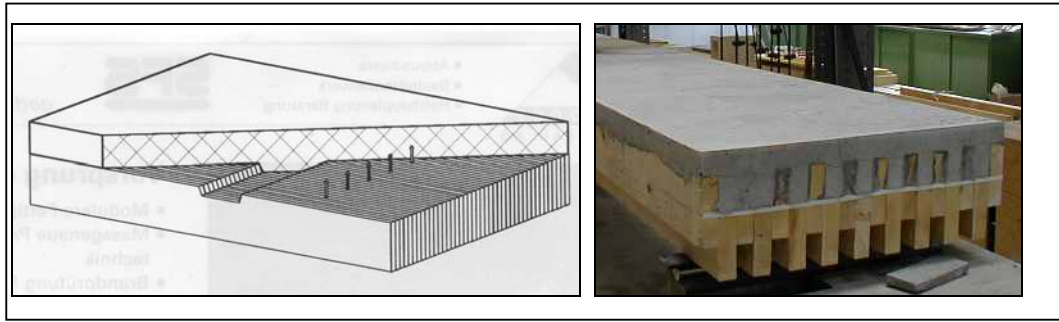


Fig.5 Wood-concrete composite structures

With the concrete distributing the load over several boards, it is possible to create a group effect resulting in higher design loads than if the weakest board properties were used to design the composite floor. This is especially interesting for tropical timber with so many wood species available on the market. This rich diversification has resulted in the classification of the wood into strength classes.

5. Quality Assurance

The quality of a product and more importantly the constant quality of a product is essential to its acceptance by the public. This is no exception with buildings and the elements they are composed of. Structural components are probably the most important elements requiring quality and reliability, as they compose the skeleton, on which all the other parts of the building are attached to.

Quality and reliability depend on the quality of the input materials, the control of their transformation and the respect of their intended final use. This is applicable to timber structures and more so to timber structures made of small sections, as more manufacturing processes are often required to overcome the limitations set by the size of the input material.

5.1 Manufacturing

Quality control of product manufacturing is primordial. As an example, in 2001 the Malaysian public work department (JKR) suspended the use of prefabricated timber roof trusses in its buildings due to a series of collapses. One reason for this suspension was the lack of quality assurance in the manufacture of the product. The timber industry reacted quickly to understand what led to this drastic measure and how it could be reversed. This was particularly important, as the prefabricated truss was the last major structural application of timber in the country with a turnover of estimated at about RM 500 million (USD 135 million) (Tan et al., 2002).

Based on the work jointly carried out by the system providers, associations and government agencies, two quality documents were amended. The first document relates to the general preparation and construction of prefabricated timber roof truss system. The second document relates to the preservative treatment of timber members to be used in the prefabricated timber truss system. Furthermore, to demonstrate the viability of the new quality assurance scheme, the four Malaysian providers of the system were requested by JKR to build a mock-up roof truss construction in accordance with the requirements of the new quality documents. The suspension was lifted in 2002, once the relevant parties restored JKR confidence in the prefabricated system.

5.2 Erection

Water is affecting the quality of wood. If the wood element is not allowed to dry rapidly, decay and fungal attacks will occur, more rapidly in tropical environment than in any other climates. Therefore, it is important to protect the timber elements when they leave the sawmill or manufacturing plant until they are protected against the rain on the erected structure.

If transportation of the elements is done during the rainy season, the truckloads should be covered. Once on site, the elements should be protected from direct exposure to the weather and maintained in dry condition. Where a dry covered area is not available, a waterproof cover should be used to prevent moisture penetration. A good air circulation should also be maintained between and around the

elements. Elements shall be stored on temporary supports above ground. The spacing of the supports depends on the length and slenderness of the elements.

Wet timber is very slippery. No erection should take place when a risk of falling off a wet structure could result in serious injuries. As with any construction site, adequate safety measures shall be enforced to prevent accidents. Due to the wider use of nails with small wood sections, the danger of walking on nails sticking out of planks should not be overlooked. Besides, adequate site cleanliness shall be maintained to avoid walking on debris.

Working with small timber sections has the advantage of easy on-site adjustment. It is very easy to cut, notch, and drill during erection to facilitate the tight fitting of the elements. Care shall be taken not to reduce the strength and stiffness of structural elements so that it becomes unreliable for its intended use. The role of the on-site engineer is therefore important.

6. Conclusions

It is timely to reexamine the current research direction in the use of small section timbers in the country taking into consideration both technical advancement in timber research and development in many advanced nations and global market trends. With the commitment of Malaysian government towards sustainable forest management, more and more smaller logs are emerging in the market. Although limited success prevails in the use of rubberwood primarily for furniture application, it is essential to explore other possibilities such as the use of such sections for structural applications in order to make the wood-based industries more resilient to globalization, particularly. The examples illustrated here are by no means exhaustive, but perhaps serve as an important step in the correct direction.

Acknowledgements

The work presented here has been funded by the Forest Research Institute Malaysia's Fellowship Fund. The authors would also like to thank FRIM for the supports and the appointment of Mr. Pierre A. Favre under the Fellowship.

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IMPACT OF LIQUID MEDIA AND pH VALUES ON DURABILITY OF SOIL COMPACTED SPECIMENS

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Abstract

The increase in population, especially in urbanized areas, results in an increase in the production of solid wastes. However, due to limited landspace, the disposal of municipal solid waste (MSW) will require integrated management landfills. Incineration is an efficient method of reducing MSW. This paper investigates the durability of four different mixtures after being compacted using the modified effort.

The aim of this study is to evaluate the use of sewage slush ash (SSA) as a new construction material namely lining material in pavement or as soil stabilization in civil engineering. This will take place by exposing all the mixtures to the worst conditions by soaking them in different soaking media to study their durability effect. The SSA was used as an enhancer to the material durability where cement replacement for up to a certain ratio of the mixture could give economical benefits in construction. The mixtures composed of different percentage of sandy soil, sewage sludge ash (SSA), ordinary Portland cement (OPC), cement kiln dust (CKD) and crushed dolomite dust (CDD). Soaking took place in different media, acidic media (pH=4), basic media (pH=9) and sewage water from Zeinein station in addition to tap water. The physical and chemical properties of the mixtures and PH values were determined in the investigation. X-ray diffraction analysis and differential thermal analysis (DTA) were undertaken. The unconfined compressive strength was determined for samples after soaking period of 1, 3 and 6 months.

The results showed that modification of SSA produce mixtures as proposed above can help to get rid of environmentally harmful materials, whilst enhancing soil stabilization as soil strength increases, especially for sand. The research has proven that modified SSA provides good results when use as construction lining material and soil stabilization purposes.

Keywords : Sewage sludge ash, Crushed dolomite waste, Lining, Landfills, Soil waste management.

1. Introduction

The amount of solid waste increases every year due to the economic growth resulting environmental pollution, a serious social problem. In undeveloped nations, environmental laws are so limited that considerable investment are needed to treat or recycle industrial wastes; treat sludge from sewage water treatment; or processing solid wastes produced from the quarry. Recently, due to intensified environmental regulations, the increased cost of treating the waste and the restrictions imposed by the authorities for protecting the environment have pushed researchers to find suitable methods for reusing and recycling the preheated fines resulting from the manufacturing of cement through the dry process. By the 2005, Egypt production of cement will reach 30 million tons per year with more than 1.5 million tons (CKD) in the dry lines thus causing a serious environmental problem. The crushed dolomite produced from the dolomite quarry (located at Attaqa-Cairo desert road) causes air pollution hence the read to dispose it in a healthy way. The scarcity of landfill sites has motivated efforts to reuse various types of wastes as construction materials. It is essential to evaluate the used materials either as flowable or lining ones when compacted with sandy soil as a way of soil stabilization. Ordinary Portland cement (OPC) must be added to this waste materials to act as a pozzolanic material to enhance the mixture when compacted with sandy soil. Abdel-Ghani (2002), studied the durability effect on the sandy soil stabilized by 10% cement kiln dust (CKD) which was enhanced by adding 2% silica fume (SF). Abdel Fadil et al. (1997), also studied the durability effect on a sandy soil stabilized by 9% (OPC).

(Abdel Salam et al. (1997), studied the effect of 20% and 40% of crushed dolomite (CDD) with (OPC) and compacted with sandy soil. (Amin et al., 2003), studied the effect of 4% sewage sludge ash (SSA) on the compacted specimens containing 90% sandy soil + 10% (CKD). Zeedan and Hegazy (2004), added 4% (SSA) to a mixture of (91% sand soil+5% (OPC)) so as to enhance short term unconfined compressive strength (UCS) after curing for 28 days and 24 hours soaking in tap water. Zeedan and Amin (2004), studied the effect of using two mixtures, mixture (i): (71% sandy soil + 20%(CDD) + 5%(OPC)), mixture (2): (51% sandy soil + 40%(CDD) + 5%(OPC)) and added 4%(SSA) so as to enhance short term of unconfined compressive strength (UCS) after curing for one and three months, respectively.

The aim of this study is to evaluate the use of (SSA) as a new construction material to be used as lining material in pavement or as soil stabilization in civil engineering. This will take place exposing all the later mixtures to the worst conditions by soaking the later compacted specimens in different soaking media to study their durability effect. The sewage sludge ash (SSA) was used as an enhancing material due to its properties. Its replacement up to a certain ratio of cement has an economic impact.

2. Experimental Investigation

2.1 Materials

2.1.1 Soil The soil used within investigation is reddish yellow, poorly graded siliceous sand. Some geotechnical properties and soil classification are given in Table 1. X-ray diffraction technique was used to identify the mineralogical composition of the tested soil. The major mineral found in this soil was quartz. The cementation materials are mixtures of gypsum, calcite, kaolinite and halite. A complete chemical analysis of the soil is given in Table 2.

Table 1. Geotechnical Properties of the Tested Soil

Sand size particles (%)	99
Fine materials (passing sieve opening 0.075 mm) (%)	1
Coefficient of curvature, $C_c = (D_{30})^2 / [(D_{10} \times D_{60})]$	1.07
Coefficient of uniformity, $C_u = D_{60} / D_{10}$	2.78
Specific Gravity, G_s	2.67
Specific Surface Area (cm^2/gm)	70
Classification Symbol (USCS)	SP
Classification Symbol (AASHTO)	A-3

Table 2. Chemical Analyses of the Tested Soil

Si O_2 (%)	$\text{Al}_2 \text{O}_3$ (%)	$\text{Fe}_2 \text{O}_3$ (%)	Ca O (%)	Mg O (%)	SO_3 (%)	Cl^- (%)	Na_2O (%)	K_2O (%)
94.13	1.74	1.33	0.28	0.29	0.10	0.24	0.24	0.30

L.O.I (%)	Total soluble salt (%)	Organic matter (%)	pH	Ca CO_3 (%)	Ca SO_4 (%)
0.95	2.68	-	7.27	0.51	-

2.1.2 Sewage Sludge Ash (SSA) The (SSA) was collected from the primary and secondary settling tanks. For saving energy, it was dried in natural atmosphere for 4 months. The sludge was burnt at 6500°C for 4 hours to get rid of all the organic matter and water and all microbial organisms of the obtained ash, the chemical analysis is given in Table 5. The sewage sludge ash (SSA) contains 43% of silicon dioxide including iron and calcium as active minerals. The X-ray patterns for burning sludge powder shows no peaks therefore; it is an amorphous material with high specific surface area.

2.1.3 Ordinary Portland Cement (OPC) The cement was obtained from Helwan Portland Cement Company. The chemical analysis of the OPC additive, based on average values is shown in Table 5. X-ray diffraction analysis was carried out to identify the mineralogical composition of OPC. The Phase-

Composition of OPC is composed of: Alite C_3S (61.32%), Belite C_2S (12.22%), Aluminate C_3A (7.12%) and Celite C_4AF (10.64%). The physical properties of OPC are composed of: Specific surface area ($3370 \text{ cm}^2/\text{g}$). The initial setting time and final setting time are 1hr 40min and 2hr 10min respectively.

2.1.4 Cement By-Pass Dust It is also known as cement kiln dust (CKD) and was obtained from Helwan cement factory. The CKD is a waste material found in large quantities during the preheating of the raw materials of the cement manufacturing using the dry process. The chemical analysis of the CKD shows that CaO constitutes 55.35% out of which, 50% is free lime. It also contains alkalis with pH equal 12.2. X-ray diffraction analysis was carried out to identify the mineralogical composition of CKD which consisted of different minerals depending on the contribution of raw materials initially in the cement production. Portlandite ($\text{Ca}(\text{OH})_2$), wallastonite (CaSiO_3), rankinite (3CaOSiO_5), Calcite (CaCO_3) and quartz (SiO_2) were identified. The CKD used in this study is a very fine material with a specific surface area of $2500 \text{ cm}^2/\text{g}$.

2.1.5 Crushed Dolomite Dust (CDD) (CaMgCO_3) Three grain-size analyses were performed on samples of dolomite dust. The results were nearly identical. The dolomite dust consists of 100% passing the No. 4 sieve and 20% passing the No. 200 sieve. The coarser size particles tend to be highly angular in shape due to the crushing operation. Complete chemical analyses are given in Table 3.

It has to be noted that the Chloride content as Cl^- (water soluble) = 0.089%, while the sulphate content as SO_4^{--} (acid soluble) is 0.324%.

Table 3. Chemical Composition of the Additives

	Si O ₂ (%)	Al ₂ O ₃ (%)	Fe ₂ O ₃ (%)	Ca O (%)	Mg O (%)	SO ₃ (%)	Cl ⁻ (%)	Mg O (%)	L.O.I (%)
(SSA)	43.5	10.07	6.19	13.42	3.44	4.4	0.50	0.07	-
(OPC)	21.05	5.45	3.42	63.41	2.09	2.39	0.02	0.18	1.9
(CKD)	14.12	4.75	2.13	55.35	2.48	5.80	3.96	0.58	12.60
(CDD)	2.51	0.50	0.57	37.60	15.20	0.20	-	0.02	43.00

3. Soaking Media

(i) *Tap Water* Tap water washed as uncontaminated soaking media for convenience and because of its similarity to the ground water in the field. The chemical analysis of tap water is shown in Table 6.

(ii) *Alkaline Media* Prepared by adjusting the pH to 9 by diluting the Na OH.

(iii) *Acidic media:* Prepared by adjusting to the pH to 5 by diluting the HCL.

(iv) *Domestic Sewage Water Media* This sewage water came from Zeinein waste water treatment station and used for soaking specimens. It contains both inorganic and organic compounds. The organic matter can be divided into three major groups; carbohydrates, protein, sand and fats. The prime factor that distinguishes the sewage is the presence of micro-organisms; bacteria and microbial materials which grow and adapt to all the inorganic and organic components of sewage, Ali (1998). The chemical analysis of sewage water is shown in Table 4.

Table 4. The Chemical Analysis of Tap Water & Domestic Sewage Water

Parameters	Tap Water	Domestic Sewage Water
pH	7.2	7.3
Chloride ,Cl ⁻	42	93
Sulphate ,SO ₄ ⁻⁻ (mg/L)	26	202
Phosphate, PO ₄ ⁻⁻ (mg/L)	-	7.7
Ammonium, NH ₄ ⁺ (mg/L)	-	22
Alkalinity, Na ⁺ , K ⁺ & Mg ⁺⁺ (mg/L)	32	266
Total dissolved salts (mg/L)	160	476

4. Experimental Work

Four mixtures of compacted specimens were prepared as follow:

Mixture 1: 91 % sandy soil+ 5% OPC + 4% SSA.

Mixture 2: 86 % Sandy soil + 10% CKD + 4% SSA.

Mixture 3: 71 % sandy soil + 20% CDD + 5% OPC + 4% SSA.

Mixture 4: 51% sandy soil + 40% CDD + 5% OPC + 4% SSA.

4.1 Preparation of Soil

The four mixtures and compacted specimens went through the following steps:

- i. The soil was air dried, pulverized and passed through sieve opening No.4 (4.75mm).
- ii. Equal weights of soil were mixed with the additive quantity and predetermined optimum water content; tap water is used for mixing operation.
- iii. Mixtures were compacted using the Harvard miniature apparatus, using the modified effort according to Test Methods (ASTM D 698).
- iv. The mould is removed from the base and the excess soil from the top and bottom of the mold are carefully trimmed away. Half hour is enough for finishing the mixing and compaction process (ASTM D558).
- v. Immediately after preparation, the molded specimens were covered to prevent evaporation and loss of water. Then the outside surfaces were protected by plastic bags. The specimens were left for 24 hours in the laboratory before transporting them to the curing containers. The specimens in the box were covered with continuously wetted burlap. One Month curing period was believed to be enough for obtaining hardened stabilized soil having the ability to resist safely the applied loads.

4.2 Soaking System and Time of Soaking

After completion of the curing period, the group of the cured specimens were cured using tap water. The samples in the container remained submerged for 1, 3 and 6 months. The second group of the cured specimens were taken from the curing medium and immersed directly in another plastic container filled with alkaline solution media (pH=9). Another group of the specimens was transported carefully to another container that contains acidic solution (pH=5). The latter group was soaked in plastic container containing domestic sewage water from Zeinein waste water treatment station for the purpose of soaking specimens with the sewage water from the pr-aeration basin. All compacted specimens were soaked in sewage water for 6 months in open container in the summer where the temperature average value were between 37°C-40°C. The sewage water was changed every week.

4.3 Testing Techniques

According to the research program, the strength properties of the cured stabilized soil specimens were determined using the unconfined compression test. Hydration process was stopped immediately after mechanically testing the stabilized specimens in order to conserve the physico-chemical characteristics, until carrying out the tests. The mineralogical composition was determined using X-ray diffraction analysis and differential thermal analyses (DTA). The pH value was also examined.

5. Test Results and Discussion

5.1 The Long-Term Strength (Durability Effect)

The effect of soaking is dependent on the level of strength or pozzolanic reaction achieved prior to the beginning of the period of soaking Little (1998). The strength is an indication of the resistance of soil-cemented additives against: (i) the dilution effect of tap water, (ii) the aggressiveness of alkaline

solution (pH=9), (iii) the aggressiveness of acidic solution (pH =5) and the pollution impact of domestic sewage water. In addition, for long term effect, for 20% OPC, 40% CDD and 10% CKD some considerations were given to: leaching effects and consumption of huge quantities of this dust to reduce their harmful environmental impacts.

This study is divided into two for comparing the effect of soaking media:

First comparison: This comparison is between mixture 1, (91% sand soil + 5% OPC + 4% SSA) and mixture 2, (86 % Sand soil + 10% CKD + 4% SSA).

Second comparison: This comparison is between mixture 3, (71 % sand soil + 20% CDD + 5% OPC + 4% SSA) and mixture 4, (51% sand soil + 40% CDD + 5% OPC + 4% SSA).

In this study, it was observed that the pH values for all soaking media; Tap water (pH =7.3), alkaline media (pH=9), acidic media (pH=5) and domestic sewage water (pH =8.1) are lower than the compacted specimens due to the hydration reaction between the component of the compacted specimens. There are correlations between the UCS and the pH value for the compacted specimens, the behavior of UCS changed from decreasing to increasing trends or reversed depending on pH values.

5.1.1. Impact of Long Term Soaking Media for Mixtures (1 and 2).

It is clear from the results of the UCS for the compacted specimens, for mixtures 1 and 2, soaked in tap water, alkaline and acidic media, have pH values ranging from 9.0 to 11.0. The relation between the UCS and soaking time is shown in Table 5 & Fig.1, Fig.2. The pH values for compacted specimens due to soaking in different media are shown in Table 6.

By soaking mixture 1 in tap water, a sharp decrease occurred in UCS after one month soaking and then a gradual increase up to 6 months. This decrease in the early age is due to the dilution effect of water which dissolves the filler material. This leads to the increase in the pores decrease in the resulting in a UCS. The hydration of OPC with the fine material in soil and SSA takes place with time to form more crystals which fill the pores gradually leading to another increase the UCS. In case of mixture 2, the same behavior occurs when soaking in tap water after one month soaking but the decrease continuous up to 6 months of soaking.

By soaking in alkaline media (pH=9), identical strength behavior of the compacted specimen soil for mixture 1 as that soaked in tap water for one month but after a long time, the UCS increased more than mixture 2 by 188% when soaked up to 6 months.

By soaking in acidic media (pH=5), the behavior of UCS is the same for mixtures 1 and 2 as soaking in tap water and alkaline media. From the results, it appears that mixture 1 possesses higher strength than mixture 2 by 125%, 52%, and 22% when soaked for to 6 months in tap water, alkaline media and acidic media, respectively. The materials which play an important role in the value of UCS for the compacted specimens in mixture (1) are; liberation of lime $\text{Ca}(\text{OH})_2$ due to the hydration of OPC and this reacts with alkaline materials and SiO_2 in SSA and sand soil. The hydration of this component, results in materials filling the pores in the sandy soil leading to an increase in UCS. In the compacted specimens mixture (2), the CKD has the same source of lime ($\text{Ca}(\text{OH})_2$) and its high alkaline value (Na^+ , K^+) leads to higher reaction. The CSH binder converted it to a non-binder material. Aassal A. A., et al. (2004), found that the higher reactivity and the alkalinity of alkali ions K^+ , Na^+ relative to Ca^{2+} ions, according to the electro-chemical series, yet the SiO_2 reacts first with Ca^{2+} ions according to the law of mass action to form CSH binder when cured for 28 days in water to give the maximum amount of binder and hence, maximum strength. When soaked in water for a period of 1-3 months, the alkali ions K^+ and Na^+ react and partially substitute the Ca^{2+} ions of the CSH binder forming non-binder compounds, namely, potassium silicate and sodium silicate, K_2OSiO_2 and Na_2OSiO_2 , respectively. Each of them as hygroscopic material and tends to absorb much water, thus reduce the in strength for the specimens soaked in tap water, alkaline and acidic media. But the increase of UCS after one month soaking in acid media for Mixture 2 due to the natural reaction between the soaking media acid media and the alkalis in CKD reduces the action of alkalis on calcium silicates hydrates phases (binder) so the UCS increase after one month soaking.

Table 5. Effect of Soaking Media on the UCS (kN/m²) for Mixture 1 and Mixture 2

Soaking Media \ Age (days)	Mixture 1				Mixture 2			
	30	60	120	210	30	60	120	210
Tap water	2700	935	1497	1661	1357	1100	912	738
Alkaline		983	2386	2433		1697	1604	842
Acidic		1403	1614	1872		1755	1567	1538
Domestic sewage water		1989	1639	1170		365	468	866

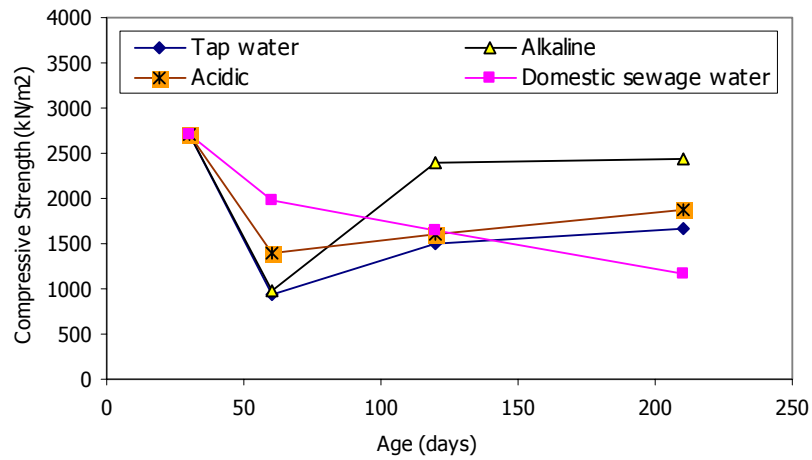
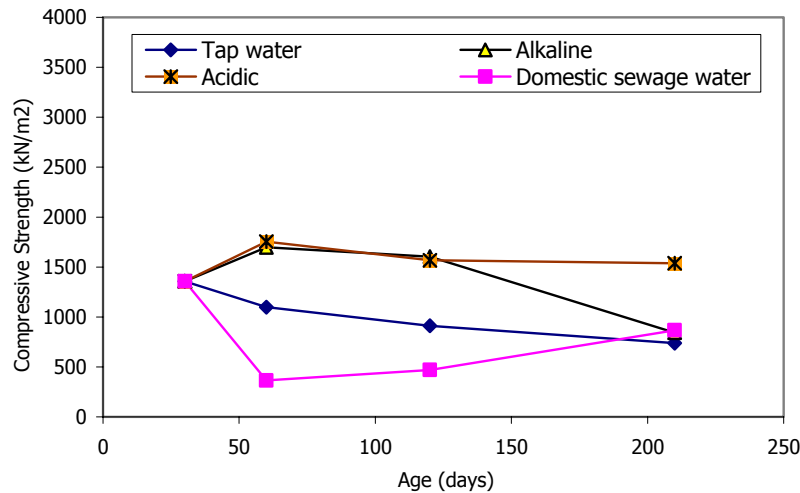
Fig.1 Effect of Soaking Media on the UCS (kN/m²) for Mixture 1Fig. 2 Effect of Soaking Media on the UCS (kN/m²) for Mixture 2

Table 6. pH Value for Mixture (1) and Mixture (2)

Soaking Media \ Age (days)	Mixture 1				Mixture 2			
	30	60	120	210	30	60	120	210
Tap water	10.5	10.1	10.5	10.6	10.8	9.43	9.21	9.01
Alkaline		9.3	10.4	10.6		10.4	9.8	10.3
Acidic		10.6	10.9	11.0		10.5	10.4	10.3
Domestic sewage water		9.5	9.1	8.8		8.53	9.1	9.43

5.1.2 Impact of Long Term Soaking Media for Mixture (3 and 4).

The relation between the UCS and soaking time due to soaking in different media is shown in Table 7 and Fig 3, Fig.4. The pH values for compacted specimens due to soaking in different media are shown in Table 8.

By soaking in tap water, UCS for mixture 3, decrease after 1 and 3 months, than the initial time of curing and after that, the UCS increase by 62.45% for specimen soaked for up to 6 months. The UCS increase for compacted mixture 4 in all soaking times.

By soaking in alkaline media (pH=9), the UCS for mixture 3, increase by 35.3% after 6 Months. The UCS for mixture 4, increase by 29% up 6 months of soaking. From the later results, the gradual increase in the UCS for compacted mixtures 3 and 4, is due to the carbonation reaction and due to the high pH value, the fine material in the soil (alumina, silica), SSA and the active material in OPC. Graves et al. (1987) and Little et al. (1995) demonstrated the benefit of the carbonation reaction over long time of stabilization of calcareous aggregates. When comparing mixtures 3 and 4, it can be noticed that the values of mixture 3 are higher than mixture 4 for 6 months by 12.6% and 18.4 % after soaking in tap water and alkaline media, respectively. This is due to the increase in CDD ratio which leads to the weakness in the strength, Abdel Salam et al. (1997), but still the value of the strength for both mixtures lie around the ASTM 4609D (2002) value.

By soaking in acidic media (pH=5), the UCS for mixtures 3 and 4, decrease gradually up to 6 months soaking. This decrease is due to the decreased pH value for the acidic media which leads to the appearance of effervescence which, in turn causes an increase in the pores of the compacted specimens at the surface of the compacted mixtures. These results in a continuous decrease in the UCS for both of the compacted mixtures.

Table 7. Effect of Soaking Media on the UCS (kN/m²) for Mixture 3 and Mixture 4

Soaking Media \ Age (days)	Mixture 3				Mixture 4			
	30	90	120	210	30	90	120	210
Tap water	2117	1698	1801	3439	1813	1989	2877	3006
Alkaline		1778	2574	2865		2152	2257	2339
Acidic		2055	1988	1674		1800	1542	1069
Domestic sewage water		2597	2319	2082		2536	2153	1920

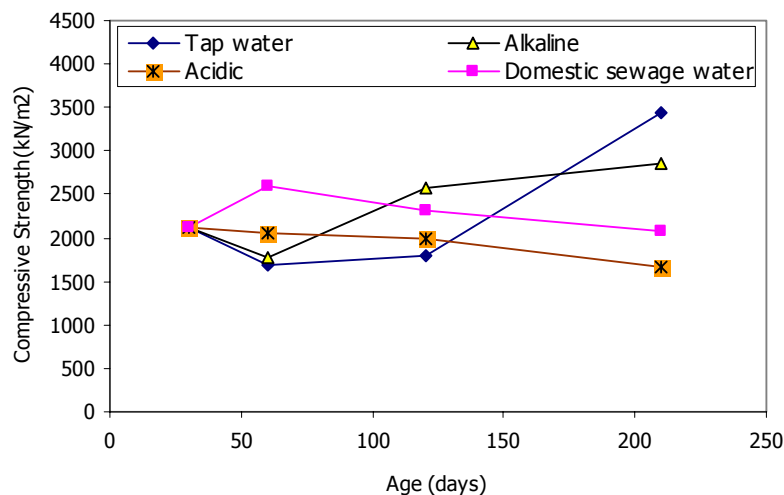


Fig.3 Effect of Soaking Media on the UCS (kN/m²) for Mixture 3

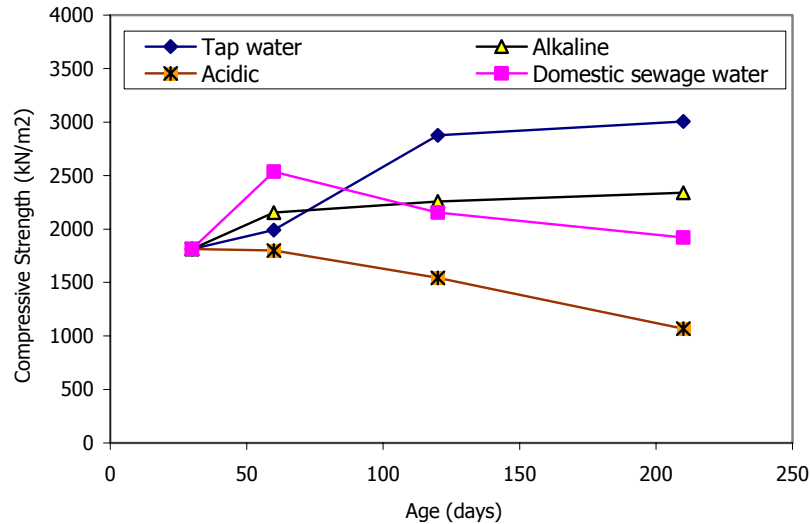


Fig.4 Effect of Soaking Media on the UCS (kN/m²) for Mixture 4

Table 8. pH Value for Mixture 3 and Mixture 4

Soaking Media \ Age (days)	Mixture 3				Mixture 4			
	30	90	120	210	30	90	120	210
Tap water	10.2	9.8	10.0	11.2	10.6	10.6	10.8	11.1
Alkaline		9.9	10.4	10.5		11.0	10.1	11.8
Acidic		9.52	9.43	9.31		10.9	10.8	10.5
Domestic sewage water		10.6	10.3	9.9		8.5	8.23	8.02

5.2 The Durability Effect Due to the Soaking Domestic Sewage Water for All Mixtures

The relation between the UCS and soaking time due to soaking in domestic sewage water media for all mixtures were shown in Table 5, Table 7 and Fig1, Fig.2, Fig.3, Fig.4 and the pH values for compacted specimens due to soaking in domestic sewage water media were shown in Table 6, Table 8.

The UCS for the compacted specimens for mixture 1, was decreased due to the corrosive action of the sulphur bacteria present in the sewage water that produce high H_2S which react with C_3A content in $OPC=7.21\%$ which easily attacked by aggressive sulphate ions. But the UCS for the compacted mixture 2, was sharply decreased due to the aggressive corrosive action of the bacteria after one month soaking but after that, the UCS gradually increased up to 6 months due to the high alkalinity of the CKD and the small ratio of the C_3A which decreased the reaction with the sulphur bacteria which, in turn, decreased the corrosive effect of sulphur bacteria. This helps to form a slim mat of biofilm which causes closing of pores of the specimens preventing the passage of water and oxygen through the specimens which cause an anaerobic reaction at the other sides of the specimens forming a black slim layer at the bottom and the sides of specimens. This black color is due to the presence of sulphur reduction bacteria SRB that acts as an insulating layer that prevents the aggressive bacteria effect, Culimore (2000). The UCS for the mixtures 3 and 4 possess gradually decrease up to 6 months due to the effect of organic matter in the domestic sewage water, Little (1997). Soil-lime reaction and the stabilization process are not only affected by mineralogy but also by the presence of other compounds within the soil including organic matter and salts. High salt concentration may interfere with or affect stabilization. The most important salts are in domestic sewage water (sodium, magnesium or calcium sulphates). This is because high sulphate concentration can lead to deleterious reaction among the dolomitic martial or the lime which produced due to the hydration of OPC. The soil minerals, the sulphate ions and water of concentrations or water within the soil, this deleterious reaction can lead to loss of stability, Little (1997).

6. X-ray Diffraction

In order to detect the form of hydration products, X-ray diffraction analyses were carried out on all the mixtures after one month curing and 6 months soaking in all soaking media. The soaking media mainly leads to the formation of CSH in an ill-crystallized form; the later phases possess a highly hydraulic character which lead to an increase or decrease according to strength values.

7. Phase Composition of the Formed Hydrates

The DTA was made using a thermal analyzer (Model DT-50, Shimadzu Co-Kyoto, and Japan). The data was compared with DTA standard data. The curves for mixtures 1 and 2 in all soaking media, show that the presence of free water at 50.07°C endothermic peak, well crystallized tobermorite gel and quartz ($C_5S_6H_5$) 577.77 °C and calcite (ill cryst.) at 739.95 °C. But in mixture 2, the curves show the decrease in CSH binder which is the binder responsible to the strength, therefore UCS for mixture 1 is higher than that for mixture 2. This agrees with the actual values obtained. The curves for mixtures 3 and mixture 4 show that the presence of free water at 667-671.5 °C endothermic peak, well crystallized tobermorite ($C_5S_6H_5$) at 240-286 °C, quartz (α - β) conversion at 280-286°C endothermic peak and dolomite peak at 800-845 °C endothermic peak. The curves show that mixture 3 contains high value of the well crystallized tobermorite which is the binder responsible to the strength therefore UCS or the mixture 3 is higher than mixture 4 that agrees in table with actual value obtained.

8. Conclusions

The results showed that the modification of sewage slush ash (SSA) proposed in the study could get rid of environmentally harmful materials whilst enhancing soil stabilisation as soil strength increases. This research has proven that modified SSA provides good results when used as construction lining material and stabilisation purposes.

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CONSTITUTING THE USE IN THE MAKING OF LOCAL PUBLIC SPACES

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Abstract

Local public spaces are a major pedestrian street component of Singapore's public new town development. In the post-1990 new towns, public spaces proliferate at the local precincts to connect block to block. Their ubiquity calls to attention the role such spaces play in the residents' living experience, how they contribute to social interactions and ways of life. Through case studies of Singapore's post-1990 precinct public spaces, this paper will explore the dimension of local public space place-making from the perspective of understanding residents' usage of precinct public space. The paper discusses the methodology framework of observation as a way of unpacking the actions and usage residents will attach to public spaces in the residential milieu. How do residents use the precinct public spaces? Do residents use these spaces as planners and designers intend them to? The purpose is to evaluate the 'fit'. To borrow the words of K Lynch in *Good City Form* (1998, p159), "Is there a good fit here between behaviour and form?" which is a fundamental, yet little studied for the consideration of a good city form.

Keywords : Public spaces, Residents, Social interactions, Living experience, Behaviour and form.

1. Introduction

'How can design professionals contribute to better places?' This question has been asked again and again and is becoming one of the most important issues, if not the most important, in urban design today as design professionals are trying to humanize the car-dominated cities. It has led to the '*place-making movement*' in urban design which is spearheaded by pioneers like Jacobs (1961) and Whyte (1980). These theorists advocate that a good neighbourhood is a place where a sense of place and sense of community are created. This place is designed for the residents, with walkable streets, welcoming public spaces, and lively community. From these ideas, the concepts of community approach have been developed. These concepts have tried to divert the design professionals' attention which seems to be more interested in creating aesthetic designs to dealing with everyday life in the public spaces (Lang, 1994).

The community approach to urban design are exemplified by the works of professionals such as Gehl (1987), Hester (1975), Hertzberger (1980), Kroll (1980), Lang (1994). This approach, as its name suggests, relies heavily on subjective analysis and design with the community (i.e., local residents). The fundamental hypothesis of community approach is that no one understands the needs of a community better than those who live there. Therefore design professionals need to listen to the communities and to work with their problems but not the designers' problems. The goal is to develop the physical designs that may invite all kinds of common activities, reflect community's needs and enhance both social opportunities and aesthetic quality of the public realm (Lang, 1994).

Regarding the Singapore's public housing, the need for community approach in the making of local public spaces in Singapore Housing and Development Board's (HDB) precincts has increasingly become evident. The HDB has utilised precinct as the most basic mode for community planning in its public housing since the 1980s. Each precinct has a land area of approximately 4 ha, made up of 6 to 12 blocks of flats of approximately 1,000 dwelling units. A precinct often has well-defined boundaries made up of four streets and a clear precinct centre in the form of a landscape square. Precinct centre often accommodates the public amenities of sufficiently varied types to supply the daily needs of the

residents (e.g., gazebo as a rain shelter and a gathering place, stone fountain, children's play field, bus stop shelter, lighting features, gates, fences and the landscaping of a place). Outdoor public spaces between buildings are no longer 'left-over' but considered in their own right as important as the provision of transport, adequate retail, recreational facilities and other amenities.

Eventhough precinct public spaces have been redesigned and developed over the years, some studies (e.g., Teo and Huang, 1996; Teo, 1996; Hee and Ooi, 2003) have indicated that precinct public spaces are not effectively used and sense of place among the HDB residents are not very positive. These scholars suggest that this may be because the HDB have a low level of involvement with the residents. The HDB structure their priorities within set parameters, while residents have particular needs and concerns. In other words, the HDB seem to be lack of understanding residents' needs and usage of local public spaces.

Given this picture, this paper is to appraise the local public spaces in HDB precincts using community approach, from the perspective of understanding residents' usage of these spaces. The purpose is to evaluate the 'fit' between residents' behaviors and the physical forms of precinct public spaces in an effort to make HDB precincts a better place for living. For such purpose, this study has conducted an observation of residents' activities in the sampled HDB precincts, in which the observers watch the residents, report their behaviours and interaction in a given setting and generate the design solutions from these analysis.

2. Case Study

In this study, two 1990s typically designed precincts in Sengkang new town, one of the latest new towns in Singapore, are selected for investigation. The two sampled precincts were built during the mid-1990s and among the first precincts to be developed and occupied in Sengkang. Accordingly their residents would have moved in and come into contact with the public spaces for some years. These two precincts have the basic characters of a typical precinct. The first sampled precinct (Precinct 1) is surrounded by four roads: Sengkang East Avenue, Punggol Road, Rivervale Walk and Rivervale Drive (refer to Fig.1). It has ten blocks of flats from 16 to 22 storeys accommodating approximately 960 dwelling units and two six-storey car parks. The internal streets divide the precinct into two parts: the periphery blocks and the central blocks. The periphery blocks include five blocks of flat (101, 102, 103, 109, 110) and two multi-storey car parks (102A, 103A). These blocks accommodate four childcare centres and kindergartens at their ground floors. The significance of Precinct 1 is that its three central blocks, numbered 106, 107 and 108, are shaped and arranged in a way that creates a central common space between them. This space is the focal point of activities with badminton court H, children's playground P1, pavilion (Pav1); and plays a role as a precinct centre. Besides this precinct centre, Precinct 1 also has a sub-centre between Block 102, 103, 104 and 105 which accommodates children's playground P2 and pavilion Pav2.

Precinct 2 is surrounded by four roads: Sengkang East Avenue, Sengkang East Road, Compassvale Drive and Sengkang Central (refer to Fig. 2). It has eleven 16-storeys blocks of flats accommodating approximately 1000 dwelling units and two multi-storey car parks. Similar to Precinct 1, the internal streets divide Precinct 2 into two parts: the periphery blocks and the central blocks. The periphery blocks include seven blocks of flat (200A, 200B, 200D, 201D, 201B, 201A, 202) and two multi-storey car parks (200, 201). Precinct 2 is different from Precinct 1 in a sense that the community facilities in Precinct 1 are designed to concentrate in one place while in Precinct 2; they are designed to spread too many places. These places are: (i) children's playground P2, pavilion Pac202D and a large lawn between Block 200C, 200D, 201C, 201D, 202A and 202B; (ii) basketball court H2 between Block 201B, 201 C, 201D; (iii) children's playground P1, badminton court H1 and pavilions Pav1, Pav2 between Block 201A, 202, 202A, and 202B; (iv) pavilion Pav200C between Block 200, 202B and 200C. Besides, in Precinct 1, childcare centre and kindergarten are separated from other facilities while in Precinct 2, childcare centre C1 is accompanied by children's playground P1 and pavilion Pav1. Tree, landscaped garden and lawn of Precinct 1 are at the periphery while in Precinct 2, they are moved into the precinct centre. Precinct 2 is also designed to have a main entrance as a focal point.





Fig.2 Plan of Precinct 2 (source: author)

The distinctive characteristics of the two sampled precincts public spaces can be summarised as follows:

- The precinct has a well-defined territory and a clear boundary.
- The precinct has a discernible center in the form of a square or a green area.
- Most apartment blocks face the precinct center and have direct access to the center.
- Shops, small businesses and hawker centres are in the adjoining precincts.
- There are kindergarten and childcare facilities for the use of precincts' residents.
- There are playgrounds accessible to every dwelling.
- Internal streets of a precinct form a connected network and provide vehicular access to every block.
- The internal streets are paved, humped and relatively narrow. These designs are to slow vehicular traffic entering the precinct and thereby create an environment suitable for pedestrians and bicycles.
- The ground floor of most blocks are left empty for circulation and communal facilities such as nursery school, health centre, children playground, clubs and sites for community meetings, education, and religious or cultural activities.

Once the basic characters of local public spaces in the two sampled precincts had been identified, the observation of residents' activities in these places was carried out.

3. Observation Techniques

The observation was conducted by the author and his wife (who was carefully trained about the observation techniques) over four week days and four weekend days during April and May 2001, from 7:00 a.m. to 9:p.m. These are the months when the weather is not rainy or too hot in Singapore. Each observer was in charge of one half of the precinct to make sure that all activities have been recorded. Residents may feel uncomfortable and have bias reaction if they know that they are being watched. As a result, the observers had to look for a place where they can monitor the observed spaces without being noticed by the local residents.

The field observation is based on Whyte (1980) techniques. The principle of these methods is that outdoor quality has a close relationship with outdoor activities. The design qualities of a public space influence *how many* people use the space, *how long* the individual activities last, and *which* activity types can develop. According to Gehl (1987), the number of people or event does not give a real indication of the activity level in an area because actual activity is equally a question of duration of stays outdoors. It is not the number of people or events, but rather the number of minutes spent outdoors that is important. The more time people spend outdoors, the more frequently they meet and the more they are likely talk. This implies that a high level of activity in a certain area can be stimulated both by ensuring that more people use the public spaces and by encouraging longer individual stays. In this regard, the observation technique is to watch and record the number of people, the amount of time and types of activities they spend in every public space in a designated period of time. In this research, the number of minutes is coded in blocks of 15 minutes.

The observed components are classified into public places, users and time. The observed public spaces are identified based on the observable activities they house including sitting, waiting, chatting, seeing, and playing. The observed spaces consist of void-decks (V), sitting areas in the garden (S), children playgrounds (P), hard courts (H), and pavilions (Pav) (Fig.1 and 2). Another observed component is users' profiles, including age and gender categories. Age category stands as the most important component for observation. It is because the observed public spaces in precincts are primarily designed for different age groups apart from being designed for different types of activities. Children playgrounds, childcare centres and kindergartens are for children. Hard courts are generally used by older children and teenagers. Void-decks, sitting places and pavilions are mostly for the use of adults and the elderly. Resident profiles are identified through their appearances and the following coding is applied:

Age settings

- Small child accompanied by adults (K)
- Young children (C)
- Teenagers (T)
- Young adults (A)
- Middle-aged people (M)
- Elderly (E)

Gender settings

- Male (♂)
- Female (♀)

Patterns of behavior

- Chatting (chat)
- Waiting (wait)
- Playing/Exercising (play)
- Others (write down the activity)

An example of the observation coding is as follows:

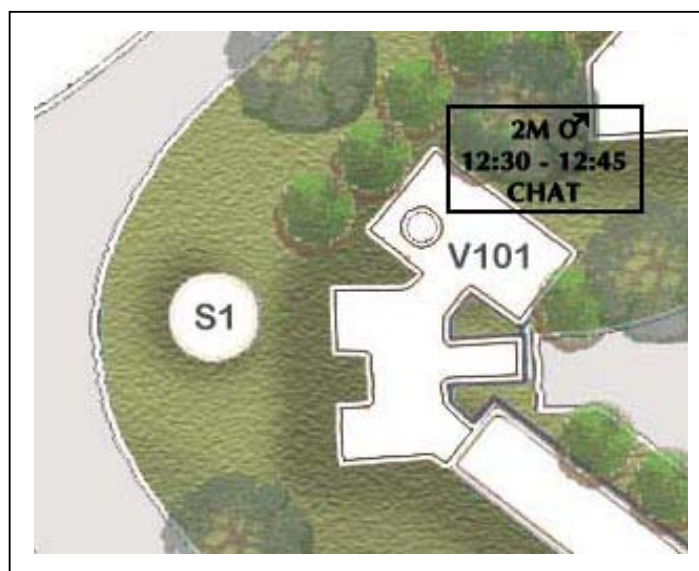


Fig.3 Example of the Observation Coding

This symbol indicates the presence of two middle-aged males who are chatting from 12:30 to 12:45 pm in Void-deck V101 – Precinct 1. This symbol is written on a transparent paper laid on top of the precinct plan. Two transparent papers are used in everyday coding: one in the morning and the other in the afternoon. Everyday, after the observation, the number of users, their use time, their age, gender and patterns of behaviours are recorded in SPSS 10.0. At the end of the observation, the total use time and the total number of users in every public space are integrated and coded into three types of charts.

The first type of charts shows the profiles of users at every observed public space in the form of a bar-chart. The X-axis of these charts indicates the three categories of users' personal profiles: gender, age and activity. Y-axis displays the number of users in each stratum of these three categories (Fig.4 and 5).

The second chart is related to the timeline of the usage in each public space in the form of area-chart. The X-axis indicates the timeline from 7:00 am to 9: pm. The Y-axis shows the number of users in this designated time. From the analysis of these charts, conclusions about the importance of different public spaces in HDB precincts from usage patterns are made.

The third type of chart is a precinct plan, displaying the location of public spaces, number of users and the total amount of time they spent at these spaces. The number of users and their use time are illustrated in the shape of a triangle. The height of the triangle represents the number of people, while its width represents the amount of time spent. This chart gives an overall view of the usage of public spaces in the precinct.

4. Research Findings

In the observation, the number of users of the public spaces in the two sampled precincts was about the same between weekdays and weekend days. The average number of users in the two sampled precincts was approximately 350 per day. Each user spent an average of about 20 minutes in the precinct public spaces. It should be noted that this number does not indicate the exact number of users and the time they spend. Some users were recorded several times because they moved from one space to another. Some other users were present in the public spaces several times per day or several days a week. Over four weekdays and four weekend days of observation, about 2800 users have been recorded. Profiles of the users are presented in Fig.4 and 5.

4.1 Profiles of Users

Fig.4 displays the number of users in terms of their gender. It indicates that the observed females use the public spaces slightly more than males. In both weekdays and weekend days, the number of female users was approximately 54% while the number of male users was only 46%. Many females were found in the playgrounds and void-decks next to the childcare centre. For instance 61% users of the two playgrounds in Precinct 1 were female. Similar finding was also recorded in the playgrounds in Precinct 2. At the same time, 68% users of the void decks next to the childcare centre, such as V101, V103 in Precinct 1 and V201A in Precinct 2 were females. Most of these female users were adults. They have been seen playing with their children or chatting to each others while waiting to pick up their children. These findings indicate that the playgrounds, childcare centre and surrounding spaces are the gathering points of female residents. From a practice dimension, it would appear that more sitting places and community clubs around the playgrounds and childcare centres should be provided for housewife residents. These spaces should be designed in a way that faces the playgrounds and childcare centres.

Males, on the other hand, were seen dominating the hard courts. Some 70% users of hard court H in Precinct 1 were male. This number was 87% in hard court H2 of Precinct 2. Most of these male were children, teenagers or young adults. The observation of male predominance may indicate that play facilities for young female are lacking and should be provided.

Referring to users' ages, all age groups were observed using the precinct public spaces, in which the middle-aged people were found to be slightly less than other age groups (Fig.5). The wide participation of all age groups seems to indicate that the sampled precincts are successfully designed for all age groups. However, the co-location of facilities would be important. In weekdays, small children were the largest group of users, constituting 21% of the total. Most of them were found playing at the playgrounds and the spaces around their childcare centres and kindergartens. On weekend days, when childcare centre and kindergartens were closed, small children became the smallest group, comprising 12% of the total users. These findings indicate that pupils from the childcare centre and kindergartens are very important users of the facilities in the precincts. It supports an ace for co-location of the childcare centres and kindergartens. Paved courts, playing garden and other play facilities for children should be designed with the childcare centre and kindergartens.

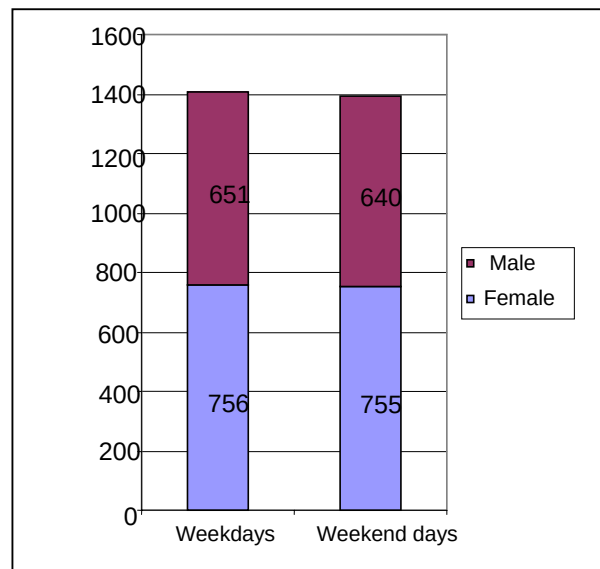


Fig.4 Gender of the users recorded in the observation

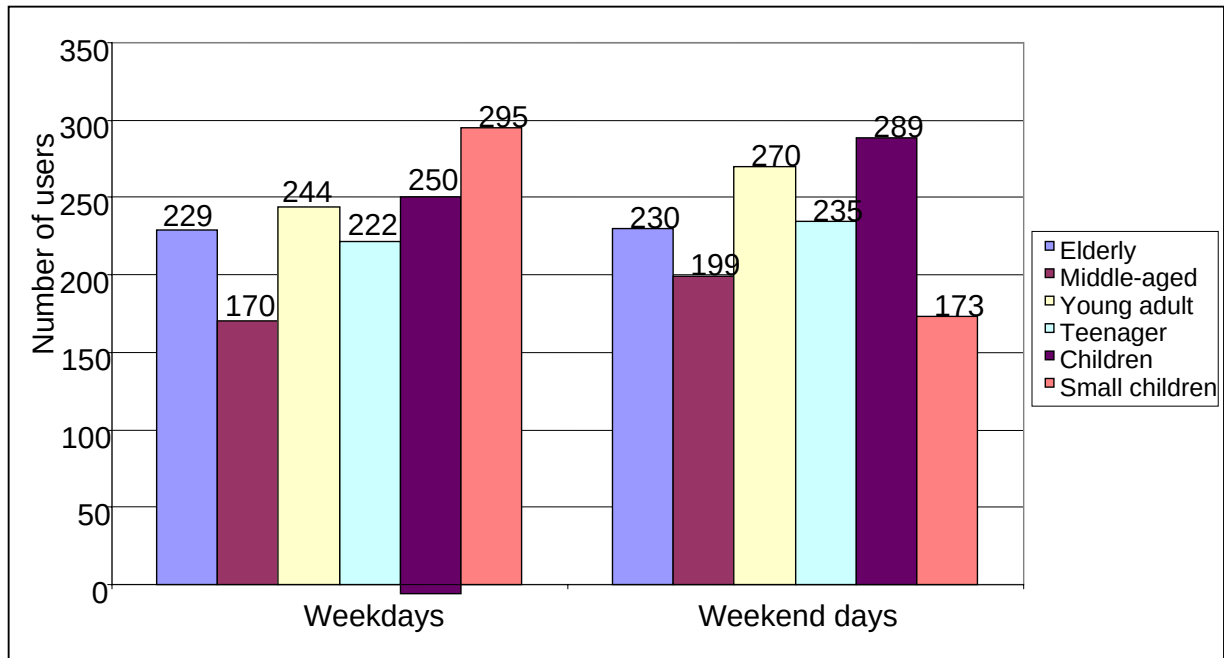


Fig.5 Age of the users recorded in the observation

4.2 Number of Users and Amount of Usage Time

The number of users present in all precinct spaces over the four surveyed weekdays and four weekend days are summarized and presented in Fig.6 and 7. These figures indicate that the number of users is significantly affected by weather conditions. In both weekdays and weekend days, the sampled precinct public spaces were used most in the early morning from 8:00 to 11:00 am and in the late afternoon from 16:00 to 19:00 pm when the weather was breezing and not sunny. These spaces were used least around lunch time from 13:00 to 15:00 when the weather was hot and sunny. This finding confirms the importance of designing for climate, especially in the tropical Singapore.

The observation indicates that designing for climate is concerned with the provision of shelters and building shades. In the two sampled precincts, open-air spaces such as hard courts, playgrounds and sitting places were used most in the early morning from 8:00 to 11:00 and in the late afternoon from 16:00 to 19:00. They were used least in the early afternoon from 13:00 to 15:00. In contrast, sheltered spaces such as void-decks and pavilions were used almost any time in a day. Especially, the pavilions were used most from 11:00 to 15:00 when it is hot and sunny. This finding indicates that shelters are important to the usage of precinct spaces.

The trends of using time also indicate that building shade in the afternoon has an important impact on the usage of open-air spaces. In the afternoon well-shaded Playground P2 (Precinct 1) had double the number of users compared to P1 (Precinct 1) which was exposed to the afternoon sun. Designs for climate were found not to have a relationship with the quality of the landscaping. The observation shows that the void-decks which face breeze and well-landscaped garden (e.g., V104, V105 in precinct 1 or V201D, V200D in Precinct 2) have not been used more than the ordinary ones.

As a result, in order to increase the number of users in precinct spaces throughout a day, it would seem necessary to design for tropical climate. Solutions may include the provision of big trees or shelters to protect the hard courts, playgrounds and sitting places from sunlight. Block heights, blocks and open-air spaces arrangement should be designed in ways that provide building shades to the open spaces.

Besides the impact of climate, the trends over usage time also indicate that the facilities for play must be designed for different days of the week. Even though most public spaces were used similarly between weekdays and weekend days, some facilities for play were used differently. Playground P1 (Precinct 1) was used more in weekend mornings than in weekday mornings. In weekend mornings, this playground

was mostly used by children and their parents on the way to and from shopping. Different from Playground P1 (Precinct 1), in weekdays Playground P1 (Precinct 2) was used more than in weekend days. The users of this space were mostly pupils from the childcare centre. These finding lends strong support to locate children playgrounds on the pathway to shops or next to the childcare centre to increase their usage.

The impact of days in the week is also found in the usage of basketball court H2 (Precinct 2). This space was used more on weekend mornings than weekday mornings. Most users were male teenagers and young adults who were seen playing basketball and soccer at this place. However the number of users of badminton court H (Precinct 1) and H2 (Precinct 2) was comparable in weekdays and weekend days. The finding would seem to indicate that large courts for team games (basketball or street soccer courts) have a larger number of users in weekend mornings compared to small courts (badminton). Support is for large hard courts to be provided instead of small ones in the precincts.

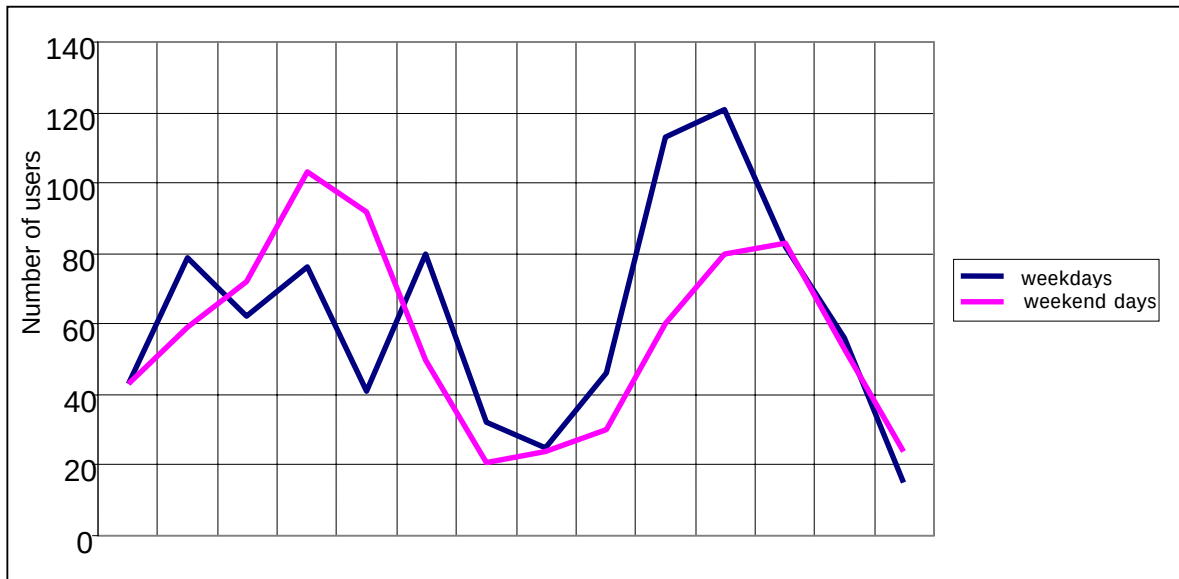


Fig.6 Number of users in precinct 1 from 7:00 to 21:00 in the observation

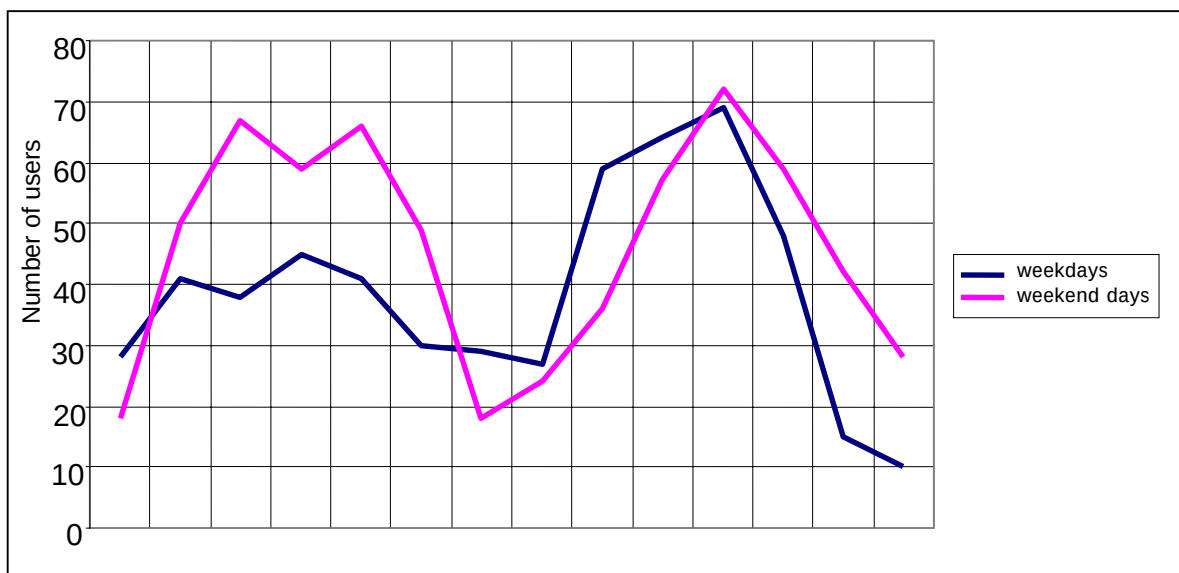


Fig.7 Number of users in precinct 2 from 7:00 to 21:00 in the observation

4.3 Types and Places of Activities

Fig.8 indicates that playing, chatting and seeing/relaxing were the main activities occurring in precinct spaces, in which playing is the most popular activity in the sampled precincts. The number of users participating in play activities was approximately 43% of the total. Chatting and seeing/relaxing were found to be less popular than playing but also featured a large number of users. These findings indicate that play facilities are the most important component of precinct spaces. It lends support to designing the public spaces in precincts based on play activities.

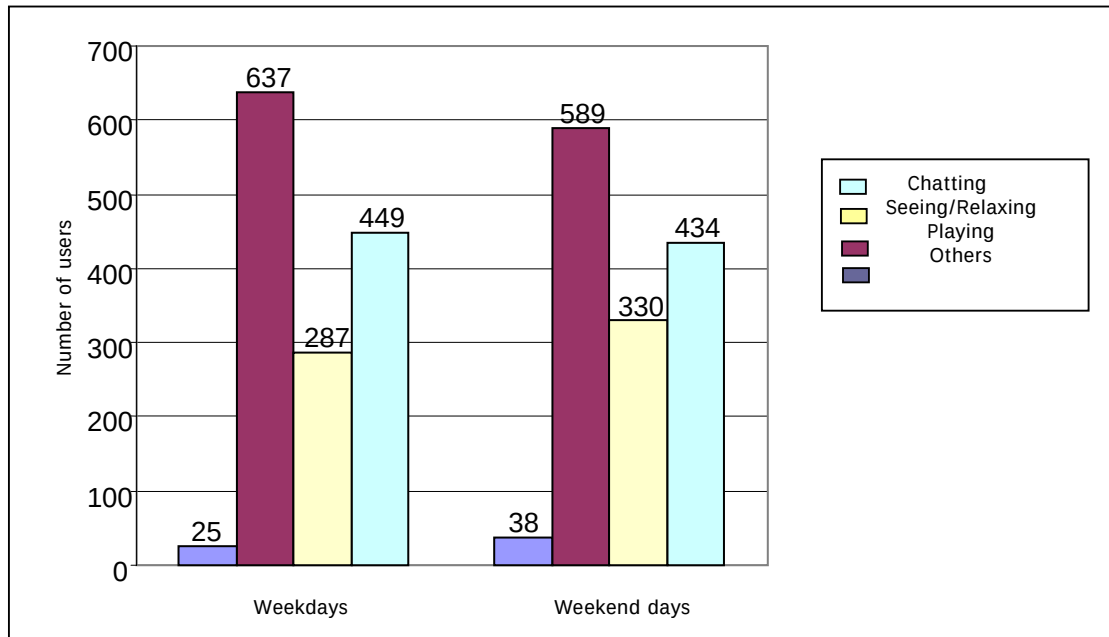


Fig.8 Activities in 4 weekdays and 4 weekend days

The average number of users and their usage time in one week day and one weekend day of the two observed precincts are summarized and presented in Fig.9 to 12. In these diagrams, the height of the triangles present the number of users in a particular place while the width of the same triangle illustrate the time the users spent in such a place. These diagrams indicate that a concentration of activities would increase the number of users. Pavilion Pav, hard court H and playground P1 of Precinct 1 are concentrated in one place and directly face void-decks V106, V107, V108. This layout creates an active precinct centre where a large number of residents and many types of activities occur throughout the days. In contrast, the precinct centre of Precinct 2 has only playground P2 and pavilion Pav202D, but separated from each other. The other playground, pavilion and hard courts of Precinct 2 are located all over the precinct. As a consequence, activities in Precinct 2 are spread around and do not form a centre of activities. This design might have resulted in Precinct 2 having a lower number of users than Precinct 1 (1190 vs 1614 users) while their population and the personalities of their people are similar.



Fig.9 Average number of users and their length of use in Precinct 1 in one weekend day



Fig.10 Average number of users and their length of use in Precinct 1 in one weekday

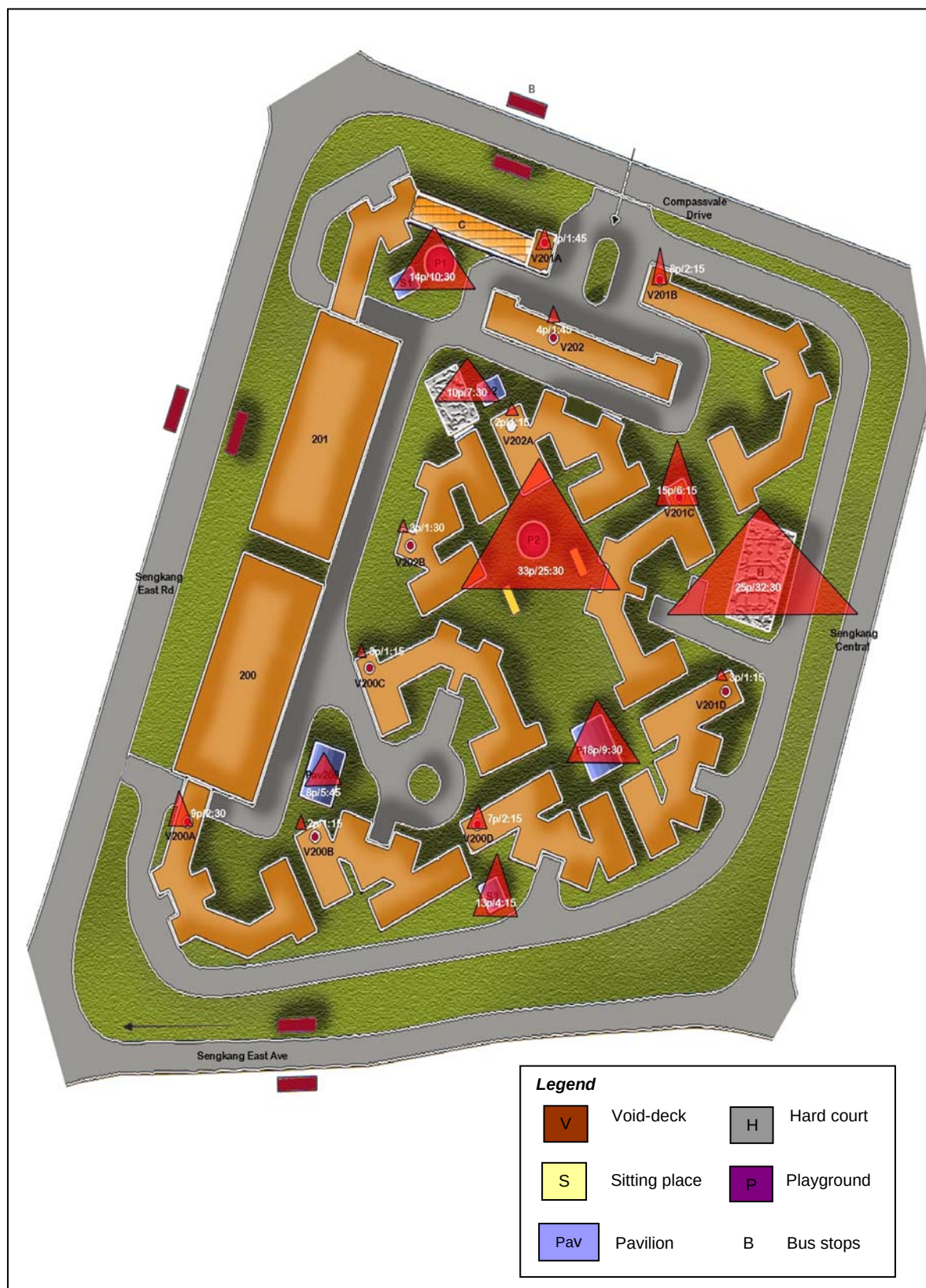


Fig.11 Average number of users and their length of use in Precinct 2 in one weekend day

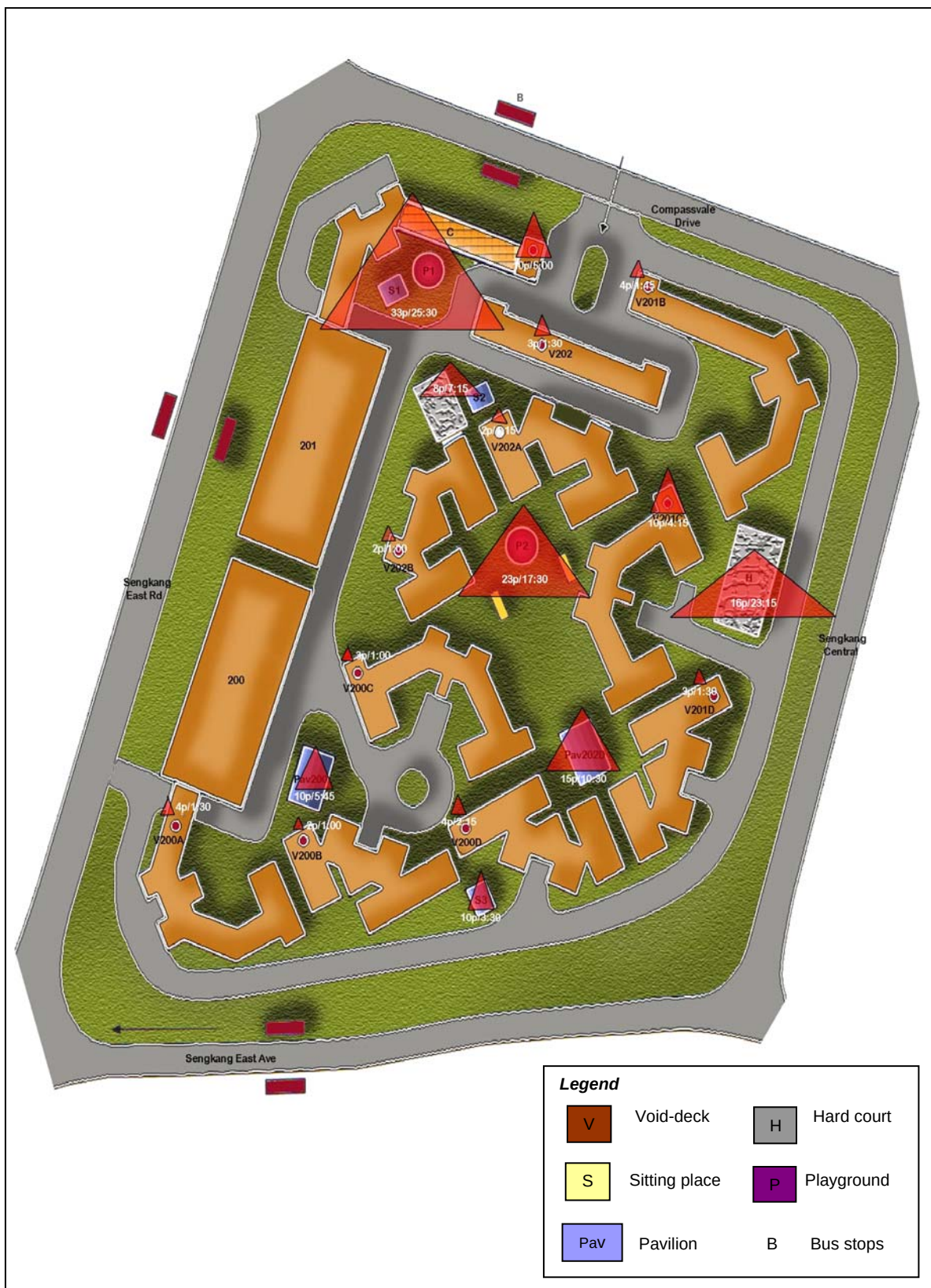


Fig.12 Average number of users and their length of use in Precinct 2 in one weekday

The observation lends evidence to support that the use of a public space is affected by its location. During weekends, the void-decks, sitting places and children playgrounds on the way to the shopping centres (e.g., V110, S5, P1 and P2 in precinct 1, V200A, S3 and P2 in precinct 2) had a higher number of users and usage time compared to other passing through public spaces and also compared to weekdays. In weekends, there were a large number of shoppers passed by these places. They often took a rest and talked to each other in the void-decks and sitting places, while many parents with children stopped at the playgrounds so that their children could play for a while. On weekdays, the void-decks and sitting places next to the childcare centres and kindergartens (e.g., V101, S1, V110, S6, V103, and S3 in Precinct 1 and V201A in Precinct 2) were considerably occupied by parents and maids waiting to pick up their children. As a result, in designing HDB precinct it may be necessary to concentrate the public spaces at the precinct centre, along the ways to shops and bus stops or next to the childcare centres and kindergartens. This pattern of provision would provide visual interest and legibility, promote pedestrian movement and increases the usage of these spaces.

The playgrounds, hard courts and the pavilions are the most used spaces in the sampled precincts. This finding confirms the necessity to provide these facilities in every precinct. While it is necessary to locate the badminton courts, playgrounds and pavilions in the precinct centre, the basketball court can be located at the precinct periphery. The high number of users and usage time of the basketball court (H) in the Precinct 2 lend support to this argument. The explanation may lie in this court being that this court being used for serious games so the users are willing to walk to it despite its long walking distance and separated location. In the present study, the average length of use of this court (approximately 1:30 hour/person) is the highest compared to other places.

To enhance its place-making quality, the void-decks and sitting places should be designed to face 'something', either a playground, bus stop or walkway. The void-decks (V101, V103, V106, V107, V108 of Precinct 1 and V201A, V201C of Precinct 2) and sitting places (S1, S3 of Precinct 1 and S1 of Precinct 2) next to the pavilions, playgrounds, hard courts and childcare centre or have direct views to these places had significantly higher number of users and length of use compared to the void-decks which are alienated. For examples, in weekdays, void deck V101 was used by 20 users while void deck V109 was used by only four people.

5. Conclusions

The findings seem to indicate that in HDB precincts, the playgrounds, childcare centre and surrounding spaces are the gathering points of female residents while hard courts and other sport facilities are dominated by male. From a practice dimension, it would appear that more sitting places and community clubs around the playgrounds and childcare centres should be provided for housewife residents; while appropriate play facilities should be provided for young female. With regard to designing for different age groups, the findings seem to indicate that the sampled precincts are successfully designed for all age groups, from small children, young children, teenagers, young adults, middle-aged people and the elderly.

The findings seem to indicate the importance of tropical climate in the context of Singapore and that the HDB has been quite successful in dealing with this issue. Their efforts in providing pavilions, shelters and covered walkways and leaving the void-decks at the ground floor of every blocks as a sheltered public spaces seem to be rational. Their focus on the landscaping of the open spaces, however, seems to be unnecessary as the well-shaded open spaces would attract more users than the well-landscaped but exposed-to-sunlight ones.

The findings lend strong support to the concentration of activities and public spaces. Children playgrounds should be located on the pathway to shops, bus stops and next to the childcare centre and kindergarten in order to increase their usage. Pavilions, badminton courts, community clubs, void-decks, central gardens, etc should be located in the precinct centre and faced 'something', either a playground, bus stop or

walkway. This layout creates an active precinct centre where a large number of residents and many types of activities occur throughout the days. It would provide visual interest and legibility, promote pedestrian movement and increases the usage of these spaces.

The finding would seem to indicate that precinct public spaces should be designed based on play activities. While most public spaces should be concentrated, large courts for team games for teenagers and adults (basketball or street soccer courts) should be located at the precinct periphery so that noise and ball-related accidents do not disturb the children, elderly and female residents. The findings seem to indicate that this layout does not effect the usage of these courts.

From these findings, we may conclude that the physical forms of precinct public spaces do not fully "fit" the residents' usages. While the HDB have comprehensively dealt with some issues (i.e., designs for tropical climate), they seem to be confused in others. Taking the designs of children playgrounds and childcare centres for example, in some places, children playgrounds are located next to the childcare centres, while in other places, they are not. This is unfortunate as a simple observation such as this study would confirm the concentration of these spaces. A childcare centre often needs a children playground, and in vice versa, the usage of a children playground would significantly increase if it is located next to a childcare centre. As a consequence, we may conclude that community approach which centres around the observation of residents' usages would be a valuable approach in the making of local public spaces, particularly of those in HDB precincts.

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GARDEN AS AN ENVIRONMENTAL INTERVENTION IN THE RESTORATION PROCESS OF HOSPITALIZED CHILDREN

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Abstract

This study investigates the psychological benefits attained by pediatric patients after experiencing a hospital garden during their restoration process. The benefits are measured from patients' increased cognitive performances, improved performance tasks and increased social performances when they play or rest in the garden. Thirty-one patients, aged 6 to 12 years, from the pediatric ward of Batu Pahat Hospital are allowed to experience the garden and their behavioral responses are elicited through field observations by the investigator and caregivers. The responses are measured in two ways: (1) qualitative i.e. preference and satisfaction of patients to the garden properties and attributes by semi-structured interview, and (2) quantitative i.e. movement of patient in play activities by behavioral mapping. It is found that 81% (n=25) patients preferred to be in the garden than the ward. Their preferences are influenced by 11 properties or attributes of the garden including refreshing smell, fresh air, full with light, cheerful environment, pleasant sound, scenic view, open space, free to play, not confined, home feeling, and place for variety of activities. Moreover, 68% (n=21) of patients played actively in the garden with long length of play (mean=52 minutes) and high to moderate number of equipment played (11 to 25 equipment). Such behavioral responses suggest that garden fosters the patients' restorative process by increasing their functioning: cognitive, physical and social. This finding suggests the importance to include garden as an environmental intervention to enhance the health recovery of the pediatric patients in the hospital setting.

Keywords : Pediatric patients, Garden, Restoration, Cognitive performances, Physical functioning, Social functioning.

1.0 Introduction

Research in nursing, healthcare management, health psychology, pediatric psychology and child psychiatry found that hospitalization often erodes the feelings of toddlers and young children that causes stress (Lau 2002). Being in stress leads to reduced cognitive performance, helplessness, restlessness, crying, anxiety, and elevated blood pressure (Lindheim et al. 1972; Oremland and Oremland 1973; Zahr 1998; Hana Haiat et al. 2003). As a result, the pediatric patients react regressively in the hospitals such as excessive fears, anxiety, increased clinging to and dependence on parents, loss of bowel and bladder, intensified thumb-sucking, or low self-esteem (Lindheim et al. 1972; Johnson 1994; Lau 2002). Apart from the medical regimens, the regressive behaviors are also due to the environmental conditions of the hospitals including the wards. The conditions may include confined space, loss of habitual control due to the clinical treatment, alien smells, and staying with strangers, and way-finding difficulties in complex and unfamiliar hospital settings (Lindheim et al. 1972; Copper-Marcus and Barnes 1999; La Greca and Bearman 2000). Hence the children perceive the hospital environment as an unfamiliar and strange setting with conditions that inflicts pain and segregation from their families and favorite places (Lindheim et al. 1972). In such environment the children have no control on their bodies and behaviors (Lindheim et al. 1972; La Greca and Bearman 2000).

Such regressive behaviors are pertinent in pediatric wards of 114 government hospitals in Malaysia, including 12 nucleus hospitals (Ismail et al. 2002). In year 2002, the Ministry of Health (MOH) healthcare service has administered 330151 children, ranging from neonate to 12 years old (MOH Malaysia 2004). The nucleus hospitals administered more than 22000 acutely and chronic ill children whose length of stay ranging from 2 to 14 days (Ismail et al. 2002). Restorative activities especially physiological and pharmacotherapy are done indoor where patients are restricted to their beds, and limited space to play and socialize with peers and caregivers except in the ward's playroom. The

nurturing potentials of garden as playspace to stimulate the patients' senses, to generate feedbacks and to allow affordances are very limited hospital rehabilitative program (Ismail et al. 2002).

These unfamiliar and strange settings are common in hospitals because design of most late twentieth century hospitals concentrate on biomedical approach rather than holistic approach to treat patients (Dilani, 2000; Nagasawa 2000). The biomedical approach considers the pathogenic treatment that focuses on the physical needs of the treated body part. Thus emotion and belief of patients towards the illness are not considered. Therefore, interaction with environmental elements such as vegetation and climatic factors and scenic views are not part of the treatment. Moreover, transaction with other people only happening in the indoor, not at the outdoor landscape of the hospital setting. Inasmuch, the opportunity to interact with the landscape is limited because many hospital designs left the outdoor spaces such as gardens as peripheral landscape which not intended for the restorative process of the patients (Copper-Marcus and Barnes 1999).

On the other hand, holistic approach is salutogenic treatment that considers the physical, mental and social health of the patient (Dilani, 2000; Lercher, 2003). In this approach, while being administered with the medical treatment in the ward, the patients are encouraged to interact with the landscape elements and climatic factors. The interaction stimulates the senses and allows them to have their own movement and control. In addition, the landscape such as garden affords them to socialize with relatives, siblings, peers and caregivers that generate social communication and affection (Moore 1999). Studies in environmental psychology and ecological perceptual psychology found that such interactions foster psychological harmony or well-being to the patients (Korpela and Hartig 1996; Korpela et al. 2001; Korpela 2002).

The aim of this study is to determine the restorative impact of a pediatric-ward garden on the cognitive, physical and social functioning of 6-12-year old patients. The endpoint of the environmental restorative process is to foster the patients' recovery process. Recovery means the condition that patients reach their homeostatis level to equilibrium state (Schor 1998). This means the health of the patients is a state of complete physical, mental and social well-being as stipulated by 1948's World Health Organization.

2.0 Theories of Environmental Restoration

Two theories have a direct bearing on the notion of restorative impact of experiencing with garden on hospitalized children. They are Stress Coping Restoration Theory (Ulrich, 1999) and Attention Restorative Theory (Kaplan & Kaplan, 1989). Both theories largely focus on psychophysiological stress recovery that experiencing with garden renews diminished functional resources and capabilities of a patient (Hartig & Staats, 2003). In perspectives of pediatric psychology, nursing, environmental psychology, horticulture therapy, and landscape architecture, the recovery to increase the functioning of patients in three ways: physical, cognitive, and social (Rubin et al. 1998; Ulrich 1999; Hartig and Staats 2003). In healthcare perspective, increment in these functioning is restorative effect which would later generate to several clinical outcomes. Rubin et al. (1998) suggested seven outcomes including: (1) decreased medication intake, (2) decreased stress, (3) increased recovery rate, (4) decreased length of stay, (5) reduced pain, (6) decreased recovery time, and (7) increased psychological and physical peacefulness and increased psychological adjustment. Increased in physical functioning means improvement in performance tasks (Hartig and Staats 2003). For example, a pediatric patient is experiencing stress and reacting regressively by being passive and stay on his bed. Allowing him to play in a garden, as an environmental intervention, stimulates and encourages him to move and play in the garden. According to Kytta (2003) children's mobility (motion) reveals a lot of significant information about the garden. Inasmuch, motion allows the patient to assume different body posture, create his own boundaries, have access to diverse territories, manifest power, have control, and explore his abilities (Olds, 1989).

Increased in cognitive functioning means positive shift in cognitive performances. For example, playing in the garden generates sense of affection (Kellert 2002) to play equipment and perhaps, sense of attachment or affiliation to similar features that he used to play (Chawla 1992). The play may also generate assimilation and accommodation as childhood behavioral development (McDevitt and Ormrod 2002). Other increased cognitive functioning include self-regulation (Korpela et al. 2002), memory,

attentiveness, information processing, intuition, skill and many others (Yates 2002). Participating in outdoor play reduces the stress of pediatric patients leading to decrease in anxiety, satisfaction and other positive psychological adjustments (Rubin 2003).

Increased in social functioning means improvement in social play. For example, a child would communicate, negotiate and conduct turn-taking with other patients or siblings during the garden activities. Subsequently, the positive behavioral changes lead to progressive development in peer relationships including acceptance, competence and acquaintance (Ladd & Coleman, 1993; Ladd, 1999).

The concept of garden for children's restoration (healing) has evolved for more than fifty years in North America and Europe (Moore, 1999). The garden include adventure playground in residential neighborhood (Wolff 1979) to therapeutic garden and courtyard in children hospitals designed by landscape architects (Copper-Marcus & Barnes, 1999). Despite the long establishment, there is lack of empirical studies on the effects or impacts of garden on healthcare outcomes of hospitalized children (Rubin et al. 1998; Whitehouse et al. 2001; Irvine and Warber 2003). Question on what are the properties and attributes of the garden that generate restorative effect remains without empirical proof (Whitehouse et al. 2001). Relating question is what are the patients' behavioral changes to be elicited to prove they gain recovery from experiencing the garden. Therefore, this study aims to fill the gap in determining the environmental qualities of pediatric-ward garden that foster the restorative process of young children in a hospital setting. Hence, this study is an application of salutogenic treatment

3.0 Method

3.1 Subject

An experiment was conducted on 31 pediatric patients experiencing a pediatric-ward garden of Batu Pahat Hospital for three months, from January to March 2004. During this period the hospital administered 259 children between the ages of 6 to 12 years old. The children were inpatients administered in the ward for an average of length of stay for 3.7 days. They were recuperating from acute to some chronic diseases, congenital problems and injuries. The patients were allowed to participate in the garden activities from 9:00 to 11:30 am and 4:30 to 6:00 pm. In the ward as well as in the garden the patients were accompanied by their caregivers, mostly by mothers. Most of them were able to walk to the garden. However, a few patients suffering from ankle injury or nephritic syndrome were pushed on wheelchairs into the garden.

3.2 Garden

The 878.8m² garden was design and built by the first author (researcher). Its design was based on healing garden design guidelines proposed by Robin C. Moore (1999) and design philosophy described by (Barnes and Copper Marcus 1999) (See Figure 1.0—Master Plan of Children's Garden at Batu Pahat Hospital). It is located beside the ward, thus patients are able to view it from their beds through glass-louvered windows. It is easily accessible through two ward's doors via the bathrooms and toilets. The garden is composed of eight play areas including (1) an alphabetical walk, (2) two multipurpose lawn areas with play equipment, (3) two sand play areas with spring-riders and rope play equipment, (4) a short, lawn bowling pitch, (5) a fishpond with deck, and (6) a patio. There are 25 play equipment laid on lawn or sand and frame with a variety of tropical trees, palms, shrubs and groundcovers. The play equipment are a set of swing and timber ladder, a balancing bar, eight treasurer chests, two rope play structures, an overturned urn for lawn bowling, four spring-riders, a shovel and a trolley, a chatter box, a spiral slide, two bucket swings, a hop-scotch, a frog and a snake sculpture. A ward wall painted with a mural also frames the garden. The mural consisted of large cartooned figures including dinosaurs and other animals, toys, and trees, which are drawn based on 22 children's books. For rest and shelter the garden is also equipped with two timber pavilions and seven timber benches distributed throughout the garden.

The garden offers 30 to 50m² of play space for each patient per period of play. This is much more than the ward space, only 8 to 10m² per child. Thus the patient affords to move freely away and having his own control and choice playing in the garden. The available play space in the garden is much larger

than suggested by some playspace standards, for example, Greenham (1988 cited in Strinsite and Moore 1989) proposed about 9 m² per child and Frost (1985 cited in Hartle and Johnson 1993) recommended 8 to 9 m² per child. The choice of play equipment in the garden including the play equipment and vegetation is 5 to 6 choices per child when 5 children occupied the garden per time. This is more or less with the number recommended by Prescott (1987) which is 4 to 5 choices per child.

3.3 Measures

To elicit the perceptual responses of the patients to the garden the study used a research study design called observational study with paired data (Rubin et al. 1998). Direct observation was conducted in the ward and the garden on the patients' behavioral responses. Two instruments were used simultaneously to elicit the patients' responses, observational behavioral mapping and semi-structured interviews. Behavioral mapping measures the overt behaviors of the patients experiencing with the features and activities in the ward and the garden. In other words, it illustrates the operational value of how the garden is utilized by the patients (Moore 1978; Hart 1979). The behaviors include play or rest performed by a patient alone or with peers. Play means movement or locomotion of the patient in the ward space or garden play areas. It also means the movement of patient from a play equipment or garden structure to another. The researcher began the mapping by observing the patients in the garden and then into the ward. Location of a patient playing in the garden was represented by a bold dot in an A-size garden plan with a scale of 1:250. Thus the dot denoted the overt choice of playing with a particular equipment or plant in a particular play area of the garden. Moore and Young (1978) called this behavior as operational value which means how the garden is actually used by the patient. In addition, a star represented location of his/her caregiver. Date of observation and length of play in minutes were also noted on the garden plan. This plan was called individual play behavior plan.

The semi-structured interview elicits patients' cognitive and social capabilities interacting with the garden features and transacting with their peers in the garden and the ward. Words from the patients were elicited by asking the patients on their perceptual judgments toward the conditions of the garden and the ward. The positive perceptual judgments toward the garden may include preference, fascination and satisfaction, attachment, affiliation, affection, feeling relax and calm, being cheerful, and forgetting worries (Korpela et al. 2001; Kellert 2002; Korpela 2002; Yates 2002). Before the interview, the researcher developed rapport with the patients, first doing garden maintenance works, and later assisting the patients in their play. The interview was conducted at one of the pavilions or any play spots following the tempo and mood of the patient. The conversation was tape-recorded and each patient was let to hold the recorder. Questions were poised in tactful manner so that the patient would tell what things to ask rather than what to ask (Graue and Walsh 1995). One or two short breaks were taken during each interview to relax the patient from boredom and lose interest to the conversation. The breaks included letting the patient to hear his recorded voice, playing with equipment or even getting back to the ward for drink and later resume the interview.

3.0 Data Analysis

Locations of the play for each patient were transferred onto a composite behavioral plan in a similar scale as the individual play behavior plan. Therefore, the composite plan illustrated the distribution of play location of play locations for the 31 patients. The distribution of play can be either clustering or scattering. This analytical method was similar to the behavioral mapping technique conducted by Moore and Young (1978) in their study of children behavior at Washington Environmental yard (p. 290). From the composite plan, clustering or scattering of the dots indicated the play behavior of the patient. Clustering of dots means the patients' preference to the garden features (equipment or plant) and play areas. In contrast, scattering of dots means there is no pattern of preference. Moreover, the clustering illustrated the movement pattern of the patients in the garden. Information from the composite behavioral plan was later triangulated with the data from the interview. More information of the patients' play behaviors and responses were summarized in Table 1.

Table 1. Data of patients' behaviors participating in the garden

<i>Observational Mapping Data for 31 patients</i>	<i>Rate</i>
Mean length of participation (LOP)	52 minutes
Maximum LOP	106 minutes
Minimum LOP	24 minutes
Patient having LOP greater than the mean	39% (n=12)
Patient having LOP less than the mean	61% (n=23)
Mean garden area visited (GAV)	505m ² (57%)
Maximum GAV	844m ² (96%)
Minimum GAV	207m ² (52%)
Patient having GAV greater than the mean	48% (n=15)
Patient having GAV less than the mean	52% (n=16)
Mean time spent to play with an equipment	4 minutes
Longest time a patient spent to play with an equipment	7 minutes
Least time a patient spent to play with an equipment	2 minutes
Mean number of equipment or features visited (EFV)	14 units
Maximum EFV	25 units
Minimum EFV	6 units
Play area most visited and percentage of patient visiting	D; 84%
Percentage of patient played in a group	68% (n=21)
Percentage grouped play without introduction	35% (n=11)

Data from the interview were words from the patients on their behavioral responses to the garden and the ward. The words were either positive feeling or negative feeling to the two settings. The data were analyzed by content analysis to elucidate the patients' behavioral patterns or regularities (Patton 2002). Therefore, the analysis was an interpretive process to determine the perceptual judgments of the patients toward the garden. The process included bracketing or categorizing the behavioral responses into essential elements, and constructing the behavioral phenomenon, and finally contextualizing the phenomenon back to the garden-ward context (Denzin 2001).

The words of the patients on the garden suggesting their positive feelings were best, comfort, happy, fun, beautiful, inviting, refreshing, not bored, open, a playground, and a place with flowers, play equipment and fishpond. They noted that the presence of plenty playing equipment, lush and varied vegetations, and some animals were the major physical features that generated those feelings. Additionally, the presence of wind, sunlight and openness of the garden as an outdoor space also triggered the feelings. Hence, 81% (n=25) of patients mentioned those words indicating their preferences, bonding, memories, fascinations and satisfaction toward the garden. Nineteenth percent (n=6) of them gave no negative comments to the garden. From the 25 respondents, 14 of them mentioned the word 'best' towards the garden. Additionally, 74% (n=23) mentioned they played with manipulating equipment, namely shovel, swing, bucket swing, chatterbox and rope play structure.

On the other hand, 48% (n=15) of the patients having negative feelings toward the conditions of the ward by mentioning words including hate, bored, worry, not free to move, restless, noisy, and crowded. Moreover, the negative feelings toward the ward were also due to medical regimens that the patients mentioned they afraid or hated the injection, pain and medicine. However, 42% (n=13) of them mentioned positive words to the ward such as not afraid, enjoy being alone on bed, like to be in ward, nurses are nice and helpful, having many friends in the ward, happy, comfort, ward has a playground, and ward is a cool place. Furthermore, there were only 6% (n=2) of patients preferred both of the settings suggesting feeling of ambivalence toward the garden and the ward.

5.0 Discussions

Most patients (81%) felt positive towards the garden and only 19% of them towards the ward. On average, they visited 57% of the garden. Some have visited 96% of the garden suggesting their perceptual preferences and mobility to participate in the garden activities. They have participated as long as 106 minutes while others as short as 24 minutes; an average of 52 minutes of length of

participation (LOP). Sixty-one percent (n=23) of them participated less than mean LOP. These behaviors suggest that the patients are more active and mobile in the garden than the ward suggesting increase in their cognitive and physical functioning.

As can be seen from the composite behavioral plan, the clustering of dots were most seen at manipulating play equipment and none at plants. Play area D with the most number of play equipment (nine types) and a pavilion is the most frequent visited by the patient. The clustering signifies the patients focus their attention to manipulables which are shovel, swing, bucket swing, chatterbox and rope play structure. In other words, the patients are fascinated more on these equipment than non-manipulables (e.g. slide) and plants. Playing with these equipment enable them to manifest power and explore abilities allowing them to assume different body postures (Olds 1989). For example, the shovel affords a patient to grasp, to move the equipment's arms, to scoop sand, and to dump sand into a timber trolley. Thus the shovel stimulates at least three senses: touch, hear, and sight. Another equipment, the Mars rope play equipment affords the patients to grasp, climb, look-out-from, stand-on, and balance. The equipment is a flexible climbing structure in which a child has to establish at least three-point contact rather than two-point contact on rigid structure (BerlinerSeilfabrik 2004). Thus, the rope play structure affords more tactile contacts (grasps) to a child in order for him to balance himself on the structure. Therefore, the manipulables not only stimulate the patients but also generates feedback and sense of affordances (Wohlwill and Heft 1987; Heft 1999). The patients begin to perceive the affordances of the equipment or play area from their beds looking through the ward's windows. When the patients approach the play area and its equipment, they perceived more affordances through utilization, for examples, grasping arms of shovel, climbing rope play structure, swinging in a bucket swing, riding on a spring-rider. The affordances of the manipulables are generated through direct action with them. Gibson and Spelke (1983 cited in Kytta 2003) posit "the child learns what things are manipulable and how they can be manipulated." It seems clear that direct action and contact with the garden features and its spatial composition generate cognitive and physical functioning.

Little feedback and affordances are generated to the patients by the elements of the ward. The reason is obvious since the ward is equipped with biomedical equipment and accessories to facilitate the recovery of the patients' health. Moreover, the ward affords 4 to 5 times less space than the garden. Limited space means less opportunity for movement leading to little chance for the patients to manifest their power and to have control (Olds 1989). Therefore, perception and movement in the garden increases the patients' sense of cognitive performances as well as performance tasks. This finding is in accord with the view of ecological perceptual psychology that perception is an active experience, in which one finds information through mobility (Kytta 2003). "We must perceive to be able to move around, and we must move around to be able to perceive" (Gibson 1979 cited in Kytta 2003).

There are differences in movement between individual patients which are generally influenced by their health status. Some patients played in rapid pace as high as 2 minutes per equipment whilst others move slowly and played as slow as 7 minutes per equipment. For example, an asthmatic 10-year-old boy played for 50 minutes (2 minutes per equipment) with all the equipment covering 85% of the garden area. His mobility is high but participated less time than the mean LOP. On the other hand, two nephritic boys aged 11 and 10, spent 78 minutes and 88 minutes (more or less 4 minutes per equipment) in the garden, respectively. They played together on 21 equipment covering 96% of the garden. In comparison to the asthmatic boy, they are less mobile due to their illness and frequently used wheelchair to access to the garden. This difference suggests that the agile and passive children perceived the garden with high fascination. Being in the garden with man-made elements, plants, animals and climatic forces permits such cognitive functioning and Kaplan et al. (1998) called it as quiet fascination. It is an effortless attention that is without mental fatigue that permits reflection to the children (Kaplan et al. 1998). This is the very reason why the children able to reflect positive feelings to the garden--best, comfort, happy, fun, beautiful, inviting, refreshing, not bored. It seems clear that playing with equipment, observing plants and animals, and interacting with the microclimatic factors of the garden generate the positive feelings.

As can be seen from Table 1, 68% (n=21) of the patients played in group either other patients (n=17) or siblings (n=4) that they had met in the ward. Eleven of them joined in the social play without introduction. And as illustrated in the composite behavioral plan, their pattern of social play happened in play area D and A with manipulating and non-manipulating equipment. With the manipulables including shovel and timber trolley, swing, chatterbox and rope play structure the patients play in a

small group, generally two to five individuals. They practiced cooperative, associative, and parallel plays that generated several social skills such as communicating, sharing, cooperating, and turn-taking (Hartle and Johnson 1993). Playing with the shovel with timber trolley is the high cooperative play because the play required plenty of communications and turn-takings to scoop the sand with the shovel and to dump it into the trolley. For example, two asthmatic boys, both nine years old, played for 83 minutes in the garden in particular playing with the shovel. One of them scooped the sand while the other pushed or pulled the trolley. Lots of commands were given by the boy on the shovel asking his counterpart to place the trolley with the reach of the shovel.

Apart from the cooperative play, increased in social functioning also happened at bucket swings and spring-riders where they practiced parallel and mutual play. In this play one patient assimilates the action of another. For example, a six-year-old girl, followed the move of a 10-year-old girl to play with the pair of bucket swings at the ward's patio. Both were suffering from abdominal pain. They played for a very long duration, 96 minutes, participating in two parallel plays, two mutual plays, two associative plays, and one cooperative observation. They are among the eleven patients that played without introducing themselves. Their social transactions generate affection to each other as well as attachment and affiliation to the garden features. In comparison to the behavior in the ward, most patients stay in their beds accompanied by their caregivers, generally mothers. The limited space, 8 to 10 m² of the ward per patient, does not afford them to socialize.

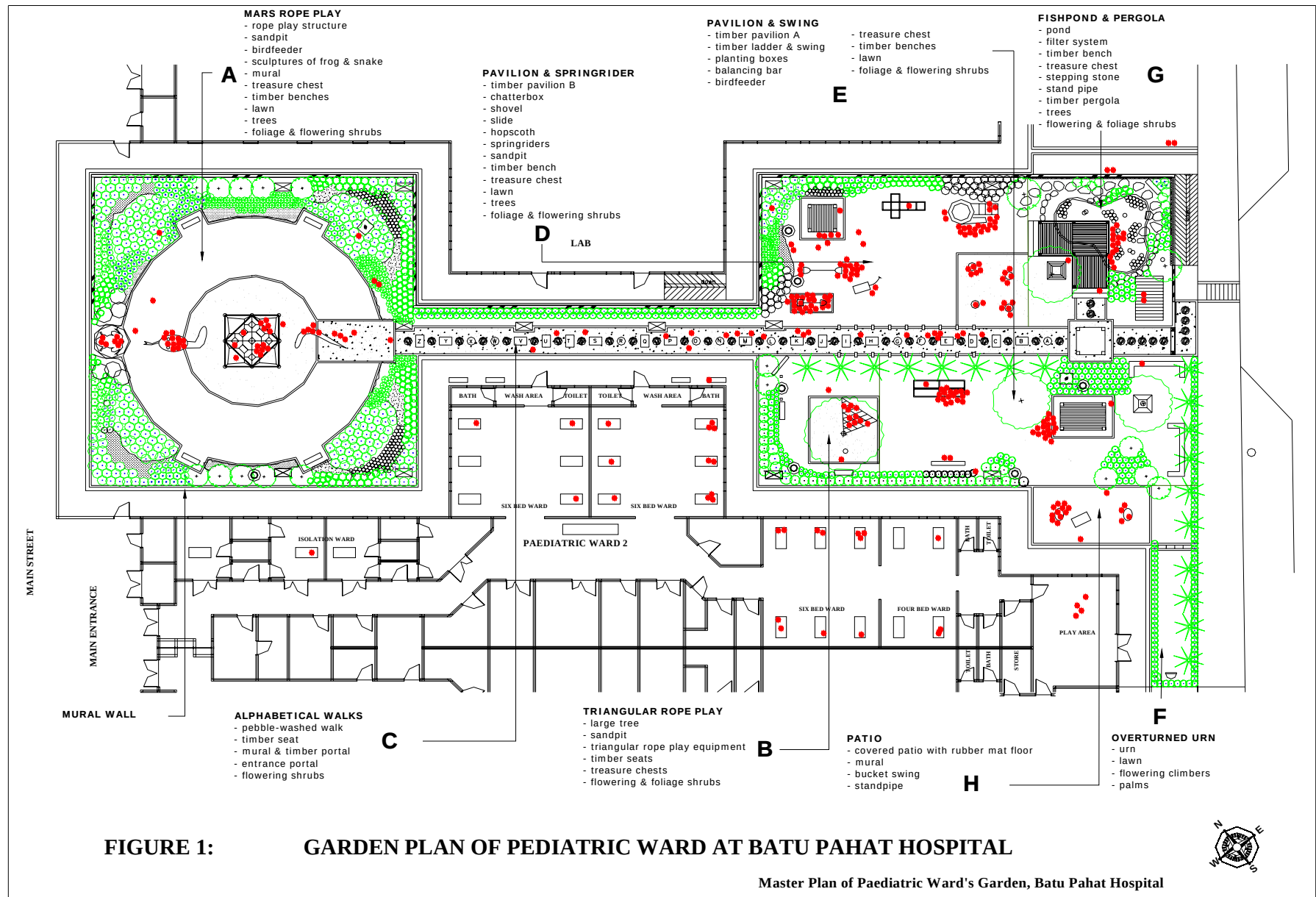
In summary, it seems clear that when pediatric patients move out from the ward and play in the garden they experienced positive shifts in cognitive, physical and social performances. The presence of a variety of play equipment (manipulables and non-manipulables) strongly affects the fascination of the patients more than the presence of the vegetations. The play equipment and the open space of the garden afford them plenty of functions which the ward physical conditions afford much less. In addition, the affordances of the manipulables are greater than non-manipulables. In general the patients played in a group with peers (patients or siblings) covering almost the whole garden area and almost all play equipment. The fascination towards to play together with the garden features is high that some played without introducing themselves. The findings of the study suggest that garden can foster the restorative process of hospitalized children by increasing their cognitive, physical and social functioning through play participation.

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MANAGING ETHNIC SPACE FOR A SUSTAINABLE CITY; THE CASE STUDY OF MADURESE MOSQUE IN SAMPIT, CENTRAL KALIMANTAN, INDONESIA

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Abstract

Whenever an ethnic group decides having and using a space, they will do a process for defining it, so other ethnic groups will understand that the space is theirs. That process will change shared space into divided space. It will change the space condition too, from friendly into conflict or the opposite. Architecture is one of understandable languages for communicating those goals. Then, the ethnic group will create some architectural forms for attributing their spaces.

For Madurese, mosque is not only for strengthening their religious life, but also defining their ethnic space. So, here, the mosque is a space's attribute for Madurese space, especially at the city where they migrated. One of Madurese migrant city is Sampit, at Central Kalimantan, Indonesia.

By observing the recent condition of Sampit, it could be concluded that the mosque, as an ethnic space's attribute, would define the sustainability of both ethnic space relationship and friendly condition. An understanding of the role of ethnic space's attribute, the mosque could be designed through the holistic approach for sustainability especially in migrant and plural city.

Keywords : Ethnic space's attribute, Friendly city, Migrant, Plural city.

1. Introduction

Markus and Cameron (2002) observed that *there are no 'power-free' spaces*. From this, one could understand two things, which influenced our everyday life. Firstly is the space, which is presented in various pattern and order. According to Lawson (2001), this space is organised and structured by its architecture. The relationship of space and architecture is not as simple while the presence is inevitable. Secondly is the space quality, which is no "power-free" and refers to human relationship as both the owner and the user of space. The nature of human is always in a group. Things, people, objects or ideas are distinguished from each other and then grouped according to differences and similarities. The group of community then, tends to make a cluster both in physic and perception. And again as Markus – Cameron (2002) said, that clustering process therefore seemed to have something to do with power. Clustering marks similarity and defines differences in the same time. This can be seen clearly in the form of urban enclave. Urban enclaves, then, define the quality of heterogeneous community of the city.

The human relationship in heterogeneous community presents a plural community. For Cohen and Middleton (Grillo, 1998), pluralism could refer to ethnically heterogeneous directly. Thus, the discussion of plural community would refer to certain ethnic groups relationship. When an ethnic group has decided to acquire a space, they would do undertake a process in order to make others understand about their existence and presence. Here, architecture has an important role to play (Lawson, 2001). As far as the outcome is concerned, such ethnic groups would create architecture as both their space and power signifier, then, this architectural form is called as space's attribute. And the space created here, which influenced by its ethnicity factor, is termed ethnic space.

The formation of ethnic spaces in urban area, which have plural community, will have an inevitable outcome. It arrives at certain quality of space relationship, when a community is crossing other space boundary and occupying it. Here, the architecture of space's attribute is a tool for measuring the quality

of that relationship, which has an impact on ethnic conflict. From this, the relation between ethnic conflict and ethnic space's attribute can be observed. Accordingly, one needs to understand the role of ethnic space's attribute for predicting the impact of both its existence and presence. Furthermore, could it be directed to the sustainable concept of non-conflict ethnic space, especially in plural city, for creating friendly city?

Space is both structured and organised by its architecture (Lawson, 2001), thus architecture is used as a tool for understanding the role of ethnic space's attribute in ethnic conflict. Within this framework, an architectural research is needed in order to understand the relation between ethnic conflict and ethnic space's attribute. One of the research benefits would be to contribute towards the urban development planning and design, especially in plural city, which is ethnically heterogenic, as well as to extend the architecture theory of ethnic space.

2. Theoretical Consideration

2.1 Plural Community

Richard Jenkins (1997) said that the notion of plural community is a response to different collective problem. He also referred to M.G Smith (1974), who distinguishes three types of pluralism. And from those three, the type of cultural pluralism is the easiest type for observing ethnic group without interfered by its external condition. And then, it has been known that the basic problem was "identity" problem.

There are some concepts of plural community. The first is Furnivall's (Grillo, 1998), who called the plural community as medley of peoples, where blended but still not combined. So, he called this community as mixed populations with particularistic tendencies. In that condition, each community will have their space's concept and their architecture. The less simple of plural community concept had been made by Cohen and Middleton (1970), who called the plural community as ethnically heterogeneous. From here, it can conclude that the ethnic differentiation is a primary aggregation for plural community formation. So, the plural community discussion will simple refer to the discussion about community group that based on ethnicity.

2.2 Ethnicity Factor

The word of 'ethnicity' comes from the ancient Greek *ethnos*, which seemed to have referred to a range of situations in which a collective of human lived and acted together, and which is typically translated today as 'people' or 'nation'. Chapman, McDonald, and Torkin (Grillo, 1998) claimed that ethnicity is an abstract noun, derived by non-vernacular morphological processes from a substantive that does not exist. Instead, they proposed to use identity, glossing that as 'a notion only existing in a context of oppositions and relativities'. Abner Cohen (1969) considered that ethnicity related to 'interest'. An ethnic group is an interest group, and the group's integration is needed for communication between one and another. To protect their interest, then an ethnic group tends to produce an exclusive space for themselves. Cohen also supposed that ethnicity related to power and symbol. The term ethnic group is generally understood in anthropological literature to designate a population, which has a membership that identifies itself, and is identified by others, as constituting a category distinguishable from other categories of the same order. Then Everett Hughes (1948) said that the word of 'ethnic group' described an ethnic relationship, which involved some different and non-united groups. So, it would need an identity for giving the clear sign, which inside the group or out side the group.

Jenkins (1997:63) also mentioned a category, which differed between one ethnic group and another based on the formality and informality of their social life. It is also referred to ethnicity factor and this is described in Fig.1.

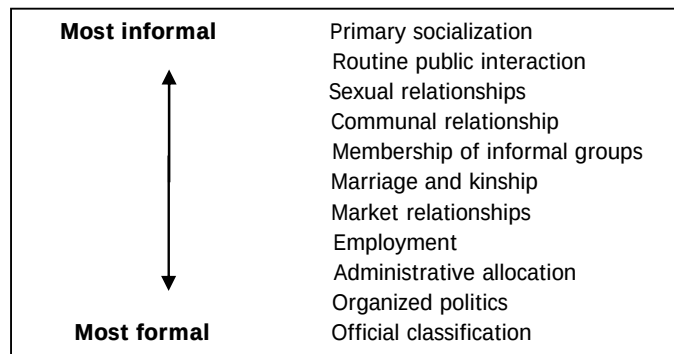


Fig.1 Jenkins's Contexts of ethnic categorization

The contrast between the formal and the informal is not a sharp distinction. It is rather, a continuum of emphasis as highlighted by Jenkins (1998).

2.3 Ethnic Space, Ethnic Space's Attribute

For Kim Dovey (1999), 'Space' is not an abstract set of relations (nor an 'ether') within which the life world is structured. Then he borrowed the space syntax diagrams from Hillier (1984) for focusing his discussion. Hillier itself has an obvious space definition, which then borrowed here for observation phase. According to Hillier (1984), space itself is arranged by building, boundaries, paths, markers, zone, etc, so that the physical milieu of that society also takes on definite pattern. The element of space, then, is adopted here, which are buildings, boundaries, paths (or streets), markers, and zone. Focusing in plural community, especially who lived in plural city, there is another space element which important for managing their relationship. The space element is non-path (or streets) open space, such as private garden, outdoor plaza, city garden, community garden, field, grave yard, etc. Then, the space element is completed by added the non-path (or streets) open space.

While the society here, refers to an ethnic group. For Barth (1998) the word 'ethnic' is used to refer to groups of people who are considered to have a shared identity, a common history, and a traditional cultural heritage. While Cohen (1969), defined an ethnic group as an interest group. Then, it is improved for having proper operational definition of ethnic space. So, the character of ethnic space, here, are:

- Arranged by elements of space, which are buildings, boundaries, paths, non-path (or streets) open space, markers, and zone
- Forming specific pattern arrangement, which represent both interest and identity of certain ethnic group, physically.

In conclusion it can be defined that the ethnic space here, is space, which represented certain ethnic group, architecturally.

In reality, element of space in our mind is certain place and every element is represented by more than one place or object, architecturally. An every architectural representation, both place and object, of every space element, is named as space's attribute. So, Space attribute is the result of decomposition of space element, architecturally. While Ethnic space's attribute refers to both place and object as the result of decomposition of ethnic space, architecturally. The place, here, is detected from the activity, which represent ethnicity factor, so does the object.

On social psychology, Breakwell (1998) noticed that structure of geography and architectural of the space are sub factors from some interaction factors, which can be the trigger for an aggressive behaviour. The other factors are location; time and event; number of people, which attend; and interaction quality between the people. Beside of that, the built environment can also be the target of the aggressive behaviour while the destroyed of the target is the goal. Nan Ellin (1997) and Kim Dovey (1999) had proved that architecturally, both direct and indirect, the building and their environment could be both the caused and the target of the riot in a conflict.

From the study of the formation process of exclusive space, which based on ethnicity factor, Hastijanti (2004) had found that there are several roles of the architecture in riots, which are:

- target of the aggressive behaviour.
- trigger of the aggressive behaviour.
- guide of the aggressive behaviour.
- container of the aggressive behaviour.

So, ethnic space's attribute, as one of architectural formation, can have certain role above in the riots of ethnic conflict.

3. Methodology

This research has been conducted in qualitative method. And for reaching better result, a case study will be conducted. The case study is Sampit conflict ethnic, between Dayak and Madurese. The primary sources of the data are the local government; non-Madurese people of Sampit; and refugee of Madurese-Sampit, in Surabaya. The secondary sources of the data are Dayak's red books (2 Volume); both local and abroad newspaper and online information; Sampit's planning documents (include the Sampit map). The field data had been documented on tape, video and photograph.

The data analysis had been conducted in several ways. From the oral history and media analysis the result was the chronology of the conflict and ethnic space's attribute, while from the map analysis, it can be found the conflict diasporas. By tracing physical evidence, it will be understood the role of mosque, as one of Madurese space's attributes, in Sampit Ethnic Conflict. And by observing the recent condition of Sampit, three years aftermath, it could be concluded that the mosque as ethnic space's attribute would define the sustainability of both ethnic space relationship and friendly condition of Sampit. And by understanding the role of ethnic space's attribute, it could be designed the holistic approach of sustainable concept, especially in migrant city.

4. The Case Study : Sampit Ethnic Conflict

Kotawaringin Timur Regency is the largest Central Kalimantan Regency. While Sampit itself is the capitol of this regency. Sampit city local authority, in 2001, is divided into two (2) districts of Mentawa Baru Ketapang (MB Ketapang) district (722 km²), and Baamang district (774km²). Each has 6 (six) sub-districts, which makes a total of 12 sub-districts in Sampit city. The Mentaya River is one of big rivers of Central Kalimantan, which divided the city in two parts. The demography stated that the total inhabitants of MB Ketapang district, in 2001, are 63.341 while Baamang district are 38.999. From the demography it can be seen that the pluralism of Sampit is not only the heterogeneity of the ethnic from Indonesia, but also the stranger from other country. The 2001 statistics shows that there are 474 people from other country, especially from China (the most), Malaysia and South Korea. Most of them live at MB Ketapang district (327). While the most ethnic group from Indonesia that live here are Dayak, Madurese, Javanese, Banjar, Minang and Bugis. The other aspect of the pluralism in Sampit is the inhabitant religion. The major people of Sampit are Moslem (91.091), Christian-protestant (3.779), Catholic (1.684), Hindu (1.272) and finally Buddha (771). This made the total mosque and *langgar* (small mosque or private/family mosque) is higher than other. And the 2001 statistic stated that there are 73 mosques; 136 *langgar* (small mosque or private/family mosque); 8 Christian Churches; 1 Catholic Church, and 5 Temples.

For recent decade, Sampit is one of destiny town of the migration from all Indonesian area for reaching the welfare. And this has proved by many observers. Those migrants, always comes with their own cultural identities. The condition makes possible for calling Sampit as a plural city. Basically, Sampit is a Dayak town for a long ago, before the migrant coming. Then in 1920s the VOC government opened local office of coconut plantation and sawmill along the Mentaya River side. The assimilation, which had worked for long time, more than 80 years, could not prevent the ethnic conflict. The community disparity has developed deeper than it thought. The distance of the community groups had been wider, and the build of the migrant new settlement had made the acquisition of other people (origin people) land. Based on the late condition before the conflict, there was an unpredictable development at the

Madurese *kampung*, which spread at all of city part. They tend to bring their family in big number to live in Sampit. So, the settlement became more crowded than before.



Fig.1 The Map Of Kalimantan Island (From: www.4x44u.com)

5. Discussions

The character of Madurese space in Sampit is interfered by labelling process, which emerged in Sampit plural community. This labelling process results in the named of some locations related to Madurese, or *Kampung Madura*.

From *Kampung Madura*, elements of Madurese Space can be defined and then divided into Madurese Space's Attribute, which are:

- Buildings: house, market, mosque, *langgar* (small/private mosque), *pesantren*
- Boundaries: fence
- Paths: *gang*, neighbourhood street, main road
- Non-path open spaces: house yard
- Markers: *langgar* (small/private Mosque)
- Zones: Housing zone, Trading zone

Private mosque (*langgar*), here, has double role which are both as 'building' and as 'marker'. The crucial role of *langgar* makes it has complex role in the riots of ethnic conflict. The correlation of ethnic category, as non-physic element, and *langgar*, as physic element of space, can be seen obviously in the riots time.

The *langgar* is an important element in Madurese traditional settlement that is called *tanean lanjeng*. In *tanean*, there are some family houses that clustered surround a long yard. The *langgar* is located at one of the long yard point. The functions are for male living room as well as for pray room. There is a traditional architecture form of the *langgar*. While in Sampit, the Madurese did not build *tanean lanjeng*. But they still built the *langgar* for marking their family zones as well as in Madura Island, their original island. The architecture form is more urbanised than traditional ones. The functional space is developed from family needs to community needs. Non-Madurese Moslem who lived surround the *langgar*, is permitted to use it for praying.

The connection between the *langgar* and ethnic category, is also clearly indicated here. As mentioned before, *Langgar* is used for marking the Madurese family housing cluster, where the socialisation takes place. The function, reflects the context of routine public interaction and communal relationship. While the original task of the *langgar* itself is still going on which is as the male living room in the Madurese family housing cluster. The function as pray room for Madurese family housing cluster reflects the context of membership of informal groups. Almost 80% Madurese live from trading in the urban market at every scale. So, here, in the *langgar*, they also speak about the market and their jobs in general. Hence, it reflects the context of market relationship and employment. The context of employment, here

can also both extend and refer to the context of administrative allocation and organized politics. Because the *langgar*, then, acts as the character landmark of the Madurese housing cluster, so the area surround it is known as Madurese area, even though there are some people, who is not Madurese is living here.

The recent condition of *langgar* in Sampit, has shown that it can be the negotiation tool for the sustainability of the Madurese and Dayak relationship. They cooperate for financial gathering and renovation by themselves. The local government also contributes some financial support for community programs. But then, the *langgar* does not belong to the Madurese again. It, then, belongs to the community surround. And now, it doesn't become as Madurese Space's attribute, because many of the Madurese housing surround the *langgar* is bought by non-Madurese people for living in. So, now, there aren't any *kampongs Madurese*.

6. Conclusions

From the discussion above, it can be concluded that:

- The role of the ethnic space's attribute is very complex but still can observe. In the development of ethnic space, especially in migrant city, it has an important role both in labelling process and marking identity process. So, the existence and the presence of the ethnic space's attribute are important for the sustainability of the ethnic space in plural city.
- The impact of the existence and the presence of ethnic space's attribute are both conflict and non-conflict ethnic. It depends on the management of the development of the ethnic space. It can be the non-conflict impact, when the ethnic space' attribute is used not only by its ethnic group, but also other ethnic groups that live surround it, properly.
- The right management for developing and controlling the ethnic space' attribute can impact on the sustainability of friendly condition in plural city.

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HOW TO ACHIEVE SUSTAINABILITY – REGULATORY CHALLENGES

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Abstract

The importance of designing sustainable buildings is gaining greater acceptance worldwide. Evidence of this is how regulators are incorporating sustainable design principles into building regulations and requirements. The aim being to increase the number of sustainable buildings and move from a traditional voluntary compliance to one that is mandatory. However, developing regulations that actually achieve these aims can be a difficult exercise.

Several countries in South East Asia, such as Singapore and Malaysia, have performance based building regulations that are supplemented by prescriptive measures for achieving the desired performance. Australia too has similar building regulations and has had energy efficiency regulations within the Building Code of Australia for over a decade. This paper explores some of the difficulties and problems that Australian regulators have experienced with the performance-based method and the prescriptive or “deemed-to-comply” method and measures that have been taken to try and overcome these problems. These experiences act as a useful guide to all regulators considering the incorporation of sustainable design measures into their countries building regulations.

The paper also speculates on future environmental requirements being incorporated into regulations, including the possibility of non-residential buildings being required to meet minimum energy efficiency requirements, and the possible systems that would need to be in place before such requirements were included.

Finally, the paper looks at a possible way forward using direct assessment from electronic designs and introduces several software tools that are currently being developed that move towards achieving this goal.

Keywords : Sustainable buildings, Performance-based, Regulations, Energy efficiency, Assessment tools.

1. Introduction

The importance of designing sustainable buildings is gaining greater acceptance worldwide. Evidence of this is how regulators are incorporating sustainable design principles into building regulations and requirements. The aim being to increase the number of sustainable buildings and move from a traditional voluntary compliance to one that is mandatory. However, developing regulations that actually achieve these aims can be a difficult exercise.

Many countries are now moving towards performance based building regulations, including many in South East Asia such as Singapore and Malaysia. One of the main reasons behind the use of such regulations is to allow greater flexibility within the construction industry and help drive innovation in the way buildings are designed and built. However, how to achieve the required performance level has not always been clear and consequently these building regulations are usually supplemented by a series of prescriptive measures for achieving the desired performance. These prescriptive measures have been seen as essential for small building projects where the resources are not often available to undertake testing and analysis of design solutions that may be required to achieve the performance based requirements.

Australia also has performance based building regulations and has had sustainable design principles, in the form of energy efficiency regulations, within the Building Code of Australia for over a decade,

although they have generally been State based rather than national regulations. However, national energy efficiency standards have now been adopted for house construction and focus on a minimum energy efficiency requirement for housing with the aim of bringing about reductions in energy use and consequently a reduction in greenhouse gas emissions. Methods for determining whether a house design meets these requirements has been mainly through prescriptive based or “deemed-to-comply” provisions by providing designers with basic insulation levels for ceilings, floors and walls. A performance-based option is also available by using an accredited assessor and simulation software to obtain a performance rating for their design. Both these methods continue to be the two options within the new energy efficiency section, although some States have now moved to the performance-based method as the only allowable method for new residential construction. However, future trends in environmental requirements and the possibility of including commercial buildings within energy efficient and environmental requirements may see that the deemed-to-comply options become increasingly difficult to structure and undertake.

2. Need for Energy Efficient Regulations

Buildings are one of the leading consumers of energy. In highly urbanised countries such as Singapore, it has been estimated that more than half the electricity generated is consumed by buildings (Building Energy and Information Centre, 2004).

In Australia, the use of energy in the home is the largest source of greenhouse gas emissions from households. The average Australian household's energy use is responsible for about eight tonnes of carbon dioxide (CO₂), the main greenhouse gas, per year (Reardon, 2001). Consequently, the need for regulations that cover the energy efficiency of dwellings constructed within Australia is clearly warranted. Voluntary schemes such as the Australian Housing Industry Association's GreenSmart program have proven to be very successful where implemented and show a desire by the housing industry to educate and promote energy efficient principals to their members and the general public. However, the take up by the general public of such homes has been very small and there continues to be a lack of understanding by many builders of the principles of energy efficient design. Energy efficient requirements by local government through their building permits system has allowed for localised improvement in house energy efficiency, but has also lead to a rather disjointed and inconsistent methodology for implementing energy efficient principles at the state and national level.

Within Australia a star based rating system is used to assess the relative energy efficiency of residential construction. The number of stars achieved is determined through a computer based thermal modelling program that determines average annual energy usage required to maintain a house within a particular thermal comfort range, over a set time period and in a particular climate zone. The resulting energy total, in MJ/m²/annum, determines which star band a house falls into. A recent study into energy efficiency of new homes in Queensland, where until recently no energy efficiency regulations existed, showed most homes performed very poorly in terms of energy efficiency (Tucker, et. al., 2002). The study of 100 typical homes built in South East Queensland over the last three years showed that 91% achieved only a 1 star rating or worse. Fig.1 shows the distribution of star ratings achieved by the homes rated. The temperate climatic conditions in this part of Australia should allow homes to easily achieve a good result, yet they do not. A lack of regulations and poor community and industry understanding of energy efficiency issues was considered the main cause for the poor result and it is reasonable to assume that similar results would be likely in other parts of the world where specific mandatory regulations do not exist.

The study also looked at the types of improvements that would be needed to bring those poor performing homes up to the new required standard of 3.5 stars and the additional cost involved in doing so and found that in 45% of cases the additional improvements cost under \$AU2000 extra, averaging at \$AU1669. Only 10% of homes required additional improvements in excess of \$AU5000 while the overall average for all the homes considered was only \$AU3015, which is less than 3% of the cost of building any of these homes. The relative minimal cost involved highlights why mandatory national energy efficiency regulations have been adopted and appear to be the only viable method for achieving universal improvement in Australia's housing stock.

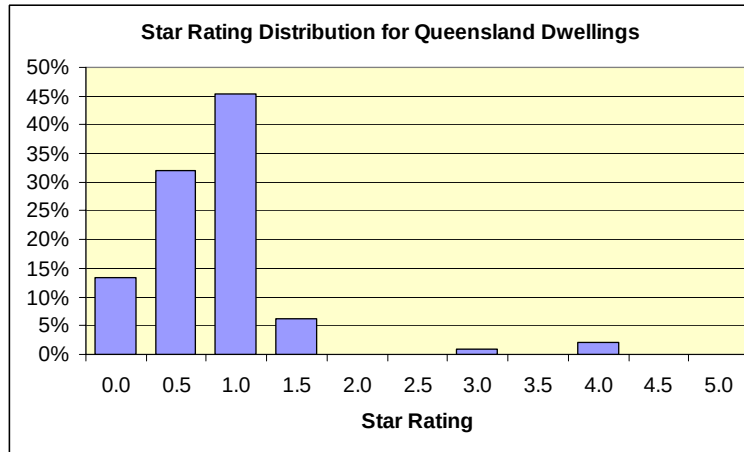


Fig.1 Star rating distribution for sample Queensland dwellings

3. Prescriptive Based Regulations

Although performance based regulations have been in place in Australia for over a decade, the prescriptive measures or deemed-to-comply method has traditionally been used for meeting the energy efficiency requirements. A study into building practice in Victoria showed that the deemed-to-comply method was used in almost every building approval (Australian Greenhouse Office, 2000). The study into the Victorian experience with minimum energy performance requirements also revealed that although the original intention of the deemed-to-comply provisions was to try and equate to a 3 star rated home (the performance based requirement), in reality 80% of homes failed to meet 3 stars with some only achieving 1 star. On average, homes were achieving 2.2 stars. Fig.2 shows the distribution of star ratings for the sample group of homes that were rated for the study.

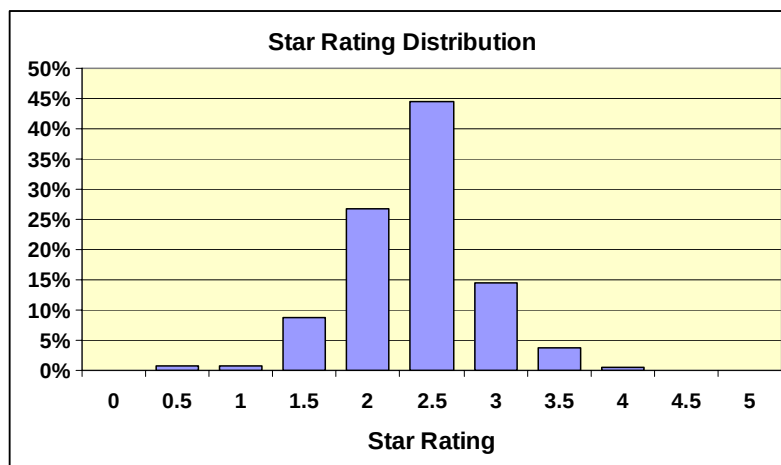


Fig.2 Star rating distribution for sample Victorian housing

The main reason cited for the significant under performance of the deemed-to-comply option was the almost non-existent take up of passive solar design principles in the homes built. Sadly, the researchers concluded that they saw *"no significant improvement in the thermal efficiency of new buildings since the introduction of regulations in 1991."* Increasing insulation levels set by the deemed-to-comply option was seen to offer little hope of improving the performance of homes and that the greatest improvement would have been achieved through a mandatory minimum energy performance standard such as a minimum star rating. The fundamental failing of the prescriptive based regulations was due to the fact that they contained a series of simple measures that failed to take into account the interaction of design and materials in achieving good performance. The prescriptive measures focused solely on materials which when combined with poor design resulted in poor performance.

However, the poor performance levels achieved by prescriptive methods appear to be reversed when the performance level is significantly increased. Recently, the Victorian State Government with the desire to significantly improve the performance of new dwellings increased the performance requirement to 5 stars, resulting in Victoria having the toughest regulations in Australia for energy efficiency. Studies carried out to assess how best to achieve this performance level and avoid the problems encountered with the previous regulatory arrangements found that with the increased prescriptive measures required to meet the new standards many dwellings well exceeded the performance based target (Energy Efficient Strategies, 2002). This resulted in the prescriptive based method delivering higher performing dwellings, but at a greater cost. A cost benefit analysis carried out found that the increased benefits associated with the prescriptive based approach were consistently outweighed by the associated increase in costs. Conversely, it was estimated that Victorian builders using performance based methods would save between 40 to 50 million Australian dollars in investment costs per annum, with even greater savings possible with the likely reduction in costs associated with undertaking energy efficiency simulations. Consequently, the prescriptive based option has been removed for dwellings in Victoria with all new dwellings having to undertake a performance-based simulation.

4. Performance Based Regulations

Despite the problems that have been found with prescriptive methods, the overwhelming popularity of the method suggests that builders and designers hold serious reservations with the performance-based method. Certainly, the relatively simple prescriptive nature of the deemed-to-comply option is attractive but probably the overwhelming factor is the need to use a qualified assessor to rate a design if using the performance-based method. This results in additional cost and delays in getting the building compliant with energy efficiency requirements. Builders who have used assessors have cited that when their designs fail, no feedback is given as to why they have failed and it is only through trial and error that they develop a design that meets the requirements. It is this uncertainty and the cost involved that seem to be a significant barrier to the uptake of the performance-based provisions.

However, as has been discussed earlier, as performance requirements increase, the associated costs with achieving this through prescriptive methods increases dramatically and thus the benefits of performance based methods are likely to be adopted. The ability of performance simulations to model design solutions, such as orientation, window positioning, etc which can often be achieved with no additional cost, rather than prescriptive methods which usually rely on additional materials, is where significant cost savings can be achieved. Indeed, some builders who have adopted performance-based assessment have reported that they have reduced improvement costs by up to 50% over using the simplified prescriptive method (Energy Efficient Strategies, 2002). Such significant savings dwarf the additional cost of simulations.

Nevertheless, many builders have expressed a need for a simple approximation method which would give them guidance and greater certainty that the formal assessment would succeed.

5. Future Regulations

A countries building regulations are not a static document. As situations change regulations are modified and amended to reflect these changes. The drivers for this change may be political, social, technical, physical or a combination of these and they can have an effect on any aspect of countries building regulations. As has been seen in Australia and many other countries, sustainability issues are growing in importance and the role that the built environment has on sustainability is being reflected in changes to building regulations. Energy regulations are an excellent example of this evolutionary process and often represent the first step in the delivery of increasingly stringent sustainability requirements for buildings. Additional regulations could deal with water consumption, greenhouse gas emissions, indoor air quality, resource use, solid waste and a range of other environmental measures. It is likely too that such environmental regulation would not be restricted to housing but extend to all building types. Programs such as GreenStar in Australia, LEED in the United States, BREEAM in the United Kingdom and HK-BEAM in Hong Kong all have a significant focus on commercial buildings and although largely voluntary, many new government buildings are required to meet the various

requirements of each program as part of their tender documents. It would seem likely that many countries in the near future will incorporate at least some aspects of these programs within their building regulations for commercial buildings.

6. Way Forward

Although the need for greater sustainability from our built assets has been well recognised for many years, the great difficulty has been how to implement it. Voluntary programs are good initial steps and provide opportunities to explore the different ways that schemes can be developed and implemented and their relative success can be assessed without the complexities of a mandatory requirement. However, as has been shown, voluntary schemes have little overall impact and for sustainability measures to have any significant benefit to the environment, legislated mandatory regulations appear to be the only practical solution. However, a significant problem is that as these regulations become more encompassing and demanding, the ability to assess the compliance with the regulations becomes increasingly difficult. For example, the 5 star energy rating requirement for Victorian homes was considered too difficult to achieve through prescriptive methods as fundamental design issues are essential for compliance. Thus the performance-based method was adopted as the only way to rate dwellings.

The implementation of wider ranging and tougher regulations will lead to a need for different ways in which these regulations may be assessed and complied with. Present rating tools are one method of undertaking these assessments, but like energy simulation software, are often considered time consuming and costly. Future systems need to be quicker and more cost effective if wide acceptance is sought.

7. Automatic Assessment

With the movement towards more electronic means of design and documentation, such as computer aided design (CAD) systems, an opportunity exists to utilise this vast amount of design information to undertake automatic checking of building regulation compliance. Energy efficiency compliance is an ideal area to investigate the effectiveness of such systems. One system that is presently being developed utilises CAD information to undertake environmental assessments on residential buildings, including energy efficiency ratings. The Life-Cycle Housing Energy Estimator system (LICHEE) is able to take elemental and dimensional information direct from a CAD based building design and performs a series of sophisticated environmental assessments on the design. One of these assessments utilises the energy rating software NatHERS, which is used in Australia for complying with the performance based energy efficiency regulations. In addition to the NatHERS assessment and rating, LICHEE also assesses the embodied energy and CO₂ emissions of a dwelling design for a given lifecycle. However, it is LICHEE's ability to automatically perform NatHERS ratings that has generated the most interest and which has the most immediate benefit for designers.

LICHEE utilises the power of the next generation of CAD systems. Presently, most CAD systems produce drawings with little 'intelligent' information, that is, the drawings are simply lines with no inherent information as to what the lines represent. The software cannot determine whether the line represents a wall or a toilet. However, object-oriented, three-dimensional CAD systems are leading the way for the future of the CAD industry. One such system is ArchiCAD and this has been utilised by the LICHEE developers to demonstrate the power of the LICHEE system. Fig.3 shows a typical example of an ArchiCAD drawing.

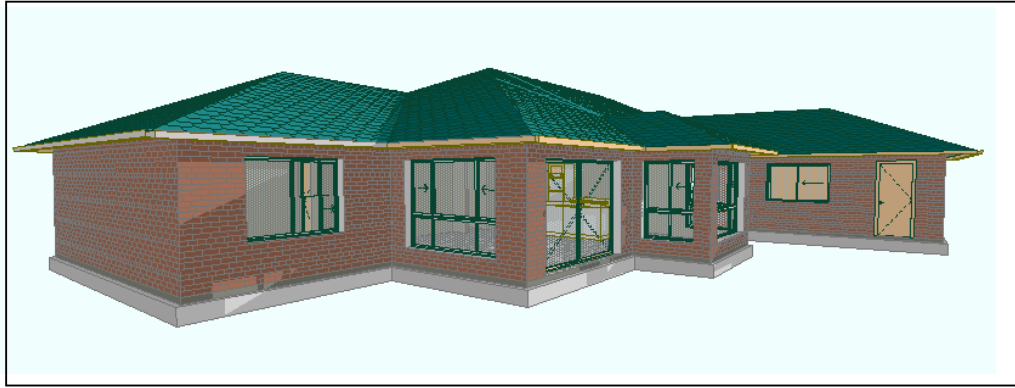


Fig.3 Typical 3D CAD image generated by ArchiCAD

Of course, it has been recognised that it is imperative that a tool such as LICHEE not be restricted to a single CAD platform and as such LICHEE employs Industry Foundation Classes or IFC's as its input file standard. The IFC's have been developed as the international standard for defining architectural and constructional CAD graphic data as 3D real-world objects and are being implemented into CAD systems, such as ArchiCAD, as the vendor neutral file sharing system. The IFC standard has been embraced by the Singapore government as part of its CORENT (Construction and Real Estate Network) program, a major IT initiative aimed at reengineering the business process of the construction industry (Graphisoft, 2002).

From the IFC file, LICHEE is able to interpret what the various building elements are (walls, windows, roofs, etc), the product type (brick wall, concrete wall, plaster wall, etc), their dimensional information (area, length, width, height and volume) and their orientation. Coupled with climate zone information, LICHEE is able to pass the data automatically to the NatHERS program for an energy efficiency rating. The results are then passed back to LICHEE for display. Graphical displays are also available detailing the progressive and cumulative life cycle energy and details on energy and CO₂ emissions based on building elements and building products.

The LICHEE system has been developed for residential buildings. However, the basic principles behind its design can be applied to commercial buildings as well. Prototype software has been developed designed to perform environmental life cycle analysis of commercial buildings from their CAD drawings. The tool is called LCADesign and provides designers with the ability to perform detailed analysis of their designs and deal with possible future environmental regulations with relative ease. As with LICHEE, LCADesign utilises 3D CAD information via an IFC file and performs a wide ranging environmental life cycle analysis on the proposed design, which is then able to be compared with alternative design variations. Fig.4 shows a typical example of a resulting analysis.

Tools such as LICHEE and LCADesign will greatly benefit designers, enabling them to quickly assess designs against both voluntary and regulatory environmental requirements. This will also enable performance based building regulations to be widely adopted and used which will thus deliver buildings that meet the true intent of such regulations.

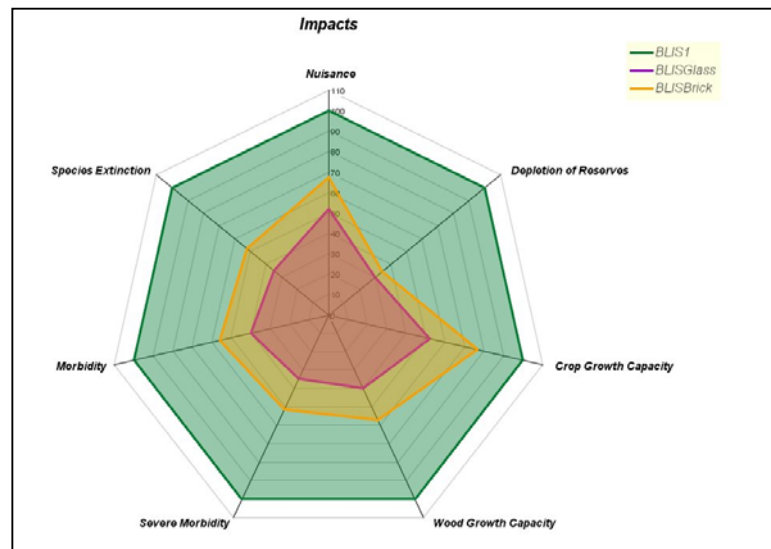


Fig.4 Example design comparison graph from LCADesign

8. Conclusions

Energy efficiency and other environmental regulations are becoming an increasingly important aspect of many countries building regulations. Such regulations not only help reduce our impact on the environment such as reducing greenhouse gas emissions, but also deliver buildings that are more comfortable and healthy to live and work in. However, such regulations need to be implemented in a way that enables the designers and builders to assess their designs and ensure compliance with relative ease. Performance based regulations have generally been backed up by prescriptive options and this balance has worked relatively well for most aspects of the regulations. However, in Australia energy efficiency has proved to be a difficult area to ensure that the deemed-to-comply provisions achieve the intention of the performance based regulation. As energy efficiency regulations have expanded and enhanced the use of deemed-to-comply provisions have been found to be increasingly difficult to effectively implement and have consequently been abandoned. Other sustainability related regulations are likely to suffer the same problems with the prescriptive methods and as such performance based is likely to be the only option.

Reliance on the performance regulations alone requires a system that does not disadvantage or discouraged designers from achieving compliance. Tools such as LICHEE and LCADesign provide an example of the type of systems that designers could utilise to aid their design process, meet energy and environmental regulations and provide the public with buildings that are more comfortable to live and work in while reducing their impact on the world. The tools also enable the regulatory bodies to look forward into the future and develop codes that build on the existing codes to strengthen their environmental emphasis, knowing that effective methods exist for helping ensure compliance.

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GREEN BUILDING POLICIES IN TAIWAN

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Abstract

This paper introduces the current development and implementation of Green Building policies in Taiwan. Today's building industry of Taiwan is confronted with several environmental problems and sustainability issues, for example, overcrowded urban population, shortage of green spaces, high impermeability of the living environment, inefficient building design for energy consumption, and the immense market of reinforced concrete buildings. In order to solve these problems and mitigate the environmental impacts of urban development and building construction, the Architecture and Building Research Institute, Ministry of the Interior of Taiwan (ABRI, MOI), proposed a two-stage "Green Building and Living Environmental Technology Plan" (1997-2006) and "Green Building Promotion Program (effective since March 2001, first revised in May 2003). These policies aim to forge a comprehensive mechanism providing resources, research, guidance, training, and education to support the development of green building in Taiwan. The major tasks focus on site ecological environment technology, construction waste reduction, building energy conservation, natural resource usage, indoor environmental quality control, and green building demonstrative projects. Based on years of research, the ABRI developed a Green Building Evaluation and Labeling System accommodating the climate in tropical and subtropical regions. In addition, an evaluation and labeling system for green building materials was launched in July 2004. According to Taiwan's Green Building Promotion Program, green building design is required as mandatory for all new public-owned buildings prior to the issuance of building license. Several tens of green building remodeling projects for existing public buildings and schools are currently in progress, as well. All these efforts are expected to efficiently transform the built environment in Taiwan.

Keywords : Green Building, Policy, Evaluation System

1. Introduction

Since the international community raised awareness of the importance of global environmental protection at the Earth Summit 1992, pursuing sustainable development has become the wave of the future worldwide. Taiwan, experiencing severe disasters caused by hillside community landslides, sea sand house damages, mudslides and flood during the past decade, was confronted with several crucial environmental problems and sustainability issues. Therefore, the people of Taiwan realized that the sustainability should be one of the most urgent issues for our living environment. Following such a pulse of public concerns, the concept of Green Building was initiated in Taiwan and become one of government's emphases.

The major environmental problems in Taiwan can be reviewed in the following aspects. First of all, recent studies showed that the climate in the urban areas of Taiwan was getting warmer and warmer. Overcrowded urban population, shortage of green spaces, impermeability of the living environment, and inefficient building design for energy conservation have all caused the climatic problem. The high temperature of the urban environment significantly aggravates cooling energy consumption and carbon dioxide emissions, and accelerates the green house effect in the city. According to the past survey results, the temperature differences between downtown and the suburbs in most of metropolitan areas in Taiwan are 3 to 4°C during peak summer months. In general, air conditioning electricity consumption increases about 6% when the outdoor air temperature increases 1°C in Taiwan. It indicates that the energy consumption of cooling is about one fourth higher in downtown than that in the suburban areas in summer. High energy consumption life style is not affordable for Taiwan. As a matter of fact, Taiwan

is highly dependent on imported energy, which percentage is over 97. The building industry accounts for 28.3 percent of nation's total energy consumption (including building material production 9.77%, construction transportation 0.53%, housing energy 12%, commercial energy 6%) in Taiwan (ABRI, 2001). Therefore, the Green Building evaluation system and policy of Taiwan needs to be incorporated with proper building energy saving techniques and regulations.

Second, Taiwan can be actually viewed as a water-lacking country with abundant rainfalls. The average annual precipitation of Taiwan is more than 2,500 mm, however, the amount of water per capita only reaches one sixth of the world's average. According to the United Nation's records, Taiwan is typically one of the areas facing the severe problem of water shortage. From water resources perspectives, the Green Building policy and its related strategies in Taiwan should be focused on water conservation and its effective reuse.

Third, more than 90 percent of buildings and construction work in Taiwan is reinforced concrete made. Such an immense market of reinforced concrete building is one of the biggest environmental killers in Taiwan. Reinforced concrete construction is typically considered as a high-polluted, high-GHG-emission building method for its enormous energy and natural resource uses. Despite the aggregate market of 110 million tons per year in Taiwan, legal aggregate excavation can only supply 42% (46 million tons) of the actual demand. It implies that 58 percent aggregate is obtained from illegally excavated sources. Even worse, 80 percent of the alleged illegal aggregate is reported excavated from rivers. The fact not only makes Taiwan the second highest rank of cement consumption in the world, but also indirectly brings on many disasters, such as flooding, landslides, and bridge collapses (Fig.1). The large amount of cement uses also results in the generation of 11 million tons of construction wastes per year. Therefore, the issue of waste reduction, including GHG emission reduction, should be involved in the extent of the entire Green Building development in Taiwan.

For resolving the environmental problems mentioned above and establishing the mechanism for Green Building development, a variety of environmental assessment methods for Green Building Evaluation have been proposed and integrated over the past few years. The compatibility of these methods with Subtropical/tropical climate was the major focus. The evaluation system for green buildings in Taiwan was developed simplified, quantified, and localized, in order to accommodate with the climatic characteristics (high humidity and high temperature), and correspond to Taiwan's local environmental issues. In addition, the comprehensive Green Building Policy needs to be evolved as well. The Green Building Evaluation System and policies will be discussed in next sections.



Fig.1 Illegal Aggregate Excavation is detrimental to bridge safety

2. Green Building Evaluation System

While the term “Green” has been used as a symbol of environmental protection in Taiwan, the Architecture and Building Research Institute (ABRI) of the Ministry of Interior (MOI) decided to use “Green Building” as a specific term for environment-friendly and sustainable buildings. The definition of the Green Building in Taiwan is “a healthy and comfortable building that is capable of efficiently reducing the consumption and natural resources, and the pollution caused by wastes during the life cycle of the building.”(Chen et al., 2004) In this way, Green Building does not only mean to put plants around buildings, but also reveal an overall and sustainable development concept.

Generally speaking, the earliest research on building energy conservation was triggered by the Oil Crisis traced back in 1973. Through many years of research, the ABRI proposed ENVLOAD (Building Envelope Thermal Load) as the standard for building shell energy saving design in 1990 that was officially involved into Taiwan's Building Code afterwards in 1995. In order to comprehensively and efficiently examine the environmental performance of the building, an appropriate evaluation system capable of accommodating with the subtropical/tropical climate in Taiwan was thus developed. The ABRI came up with an evaluation system for Green Buildings that was first announced in 1998 and comprised of seven evaluation categories, green, soil water content, energy saving, water conservation, CO₂ emission reduction, construction waste reduction, and sewage and garbage improvement. Five years later, the ABRI modified the evaluation system in 2003 via introducing two new indicators in addition to the original ones, Biodiversity and Indoor Environment, to continuously meet the interest and concerns of international community. The system has performed a relatively effective implementation since it was launched. An evaluation system, integrated with nine categories, was revealed in 2003, as listed in Table 1. These indicators can be divided into four categories, Ecology, Energy Conservation, Waste Reduction, and Health (known as EEWH system). Quantitative indicators and the corresponding criteria for each category have been well formulated.

The ABRI also developed a Green Building Labelling system for green building certification. The Green Building Labelling System consists of two parts: Green Building Label for completed buildings, and Green Building Candidate Certificate for building projects. The minimum requirement for Green Building certification is to pass two prerequisites (energy conservation and water conservation), and two optional indicators from among the other seven. Until December 2004, 29 buildings have been certified as Green Buildings, and 505 projects have received Candidate Certificates. Total building floor areas reached 7.07 million m², electricity saving 199 million degrees, water saving 5.26 million tons, and monetary saving 16.3 million US dollars per year. The Green Building Label of Taiwan and Green Building examples are shown in Fig.2.

Table 1. Indicators for Green Building Evaluation in Taiwan

Climate	Water	Soil	Energy	Materials	Indicators	Evaluation Items (unit)
					1.Biodiversity	Ecological net, biological habitat, plant diversity
					2.Green	CO ₂ absorption (kg-CO ₂ /(m ² .40yr))
					3.Soil water content	Water contentment of the site (-)
					4.Energy conservation	ENVLOAD、Req、PACS、energy saving techniques
					5.CO ₂ emission Reduction	CO ₂ emission of building material (kg-CO ₂ /m ²)
					6.Construction waste reduction	Waste of soil, construction, destruction(-), recycling material(-)
					7.Indoor Environment Quality	Acoustics, Light and Ventilation, Building Materials
					8.Water conservation	Water usage (L/person), hygienic instrument with water saving (-)
	*			*	9.Sewage and garbage	Sewer plumbing, sanitary condition for garbage gathering

Source: Chen et al, 2004



Fig.2 Green Building Label and Green Buildings of Taiwan (ABRI, 2003)

3. Green Building Promotion Program

In order to solve the environmental problems and mitigate the impact of urban development and building construction, the ABRI has proposed a two-stage "Green Building and Living Environmental Technology Plan" (1997-2006) and "Green Building Promotion Program (effective since March 2001, first revised in May 2003). These policies essentially forge a comprehensive mechanism providing resources, research, guidance, training, and education to support the adoption of green building in Taiwan. The major work emphasizes on site ecological environment technology, construction waste reduction, building energy conservation, natural resource usage, indoor environmental quality control, and green building demonstrative projects. The contents of the Green Building Promotion Program in Taiwan are summarized as follows.

3.1 Mandatory Green Building Design for New Governmental Buildings

For strengthening the development of Green Building, the government of Taiwan realized that powerful policies played an absolutely important role. Therefore, the ABRI proposed the "Green Building Promotion Program," which was ratified by the Executive Yuan (2003). The ratification affirmatively granted the Program power to implement and enforce Green Building policies all over the country. The Green Building Labeling process has thus been raised as the National system since the Program started. Both the label and certificate are conferred by the Ministry of the Interior. One of the major promotional strategies in this program, which also runs first in the world, is to initiate mandatory green building design for governmental buildings. The purpose of the strategy is to initiate green building design with public buildings and to encourage private sectors to adopt the green building concept, so as to gradually evolve a mechanism for the entire building industry. Mandatory green building design for new buildings of central government was required in 2002, and for local government buildings in 2003. Any governmental building project which construction cost is more than 1.5 million US dollars would be issued with the building license once it received the Green Building Candidate Certificate. The process is illustrated in Fig.3. The ABRI established the Commission on Green Building that includes three committees and forty members to ensure the effective evaluation for Green Building. The commission will also provide technical consultation during the design process.

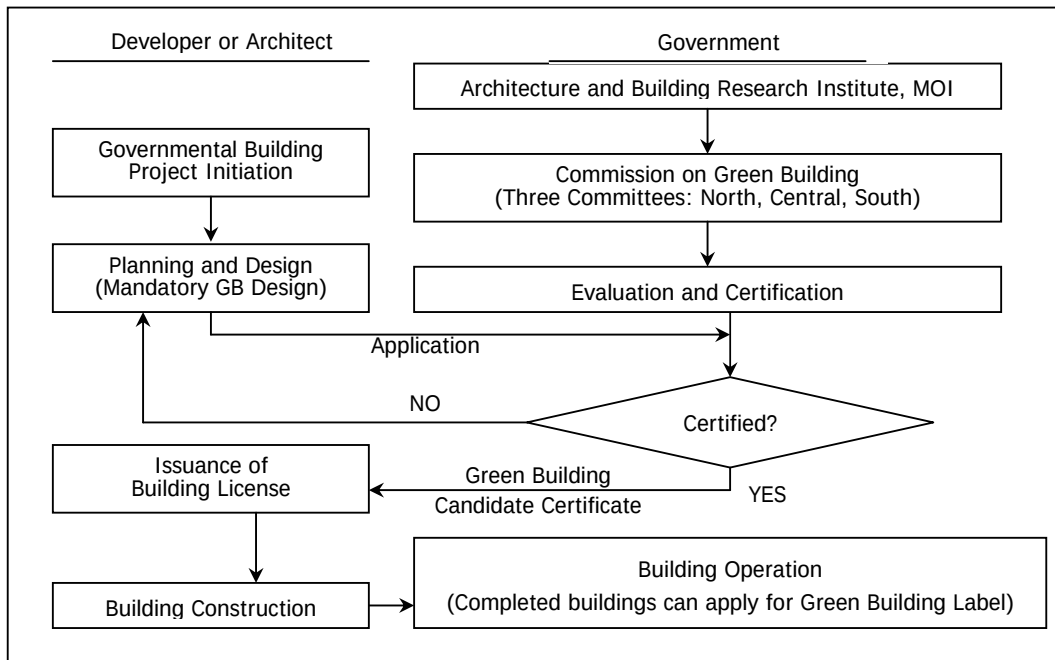


Fig.3 The Framework of Green Building Certification for Governmental Buildings in Taiwan

3.2 Subsidy on Green Building Improvement Projects for Existing Buildings

The ABRI also subsidized green remodeling projects for existing buildings. From 2002 to 2004, twenty-eight green remodeling projects were completed for official buildings and public schools, which total budget was 9.85 million US dollars. In 2003, twenty-four green remodeling projects have been undertaken for official buildings and public schools. The green remodeling projects include (1) the increase of permeability and on-site infiltration, (2) the insulation improvement work, such as the installation of sun shading devices, (3) the ecological protection work, such as the constructed wetlands combined with the function of wastewater treatment and reuse, and so forth. Fig.4 presents one of the green remodeling projects for governmental buildings in a before-and-after context. The left picture shows that the original courtyard area, and the right one the utilization open-grid pavement systems for parking lots. This is one of the strategies to increase the permeability of the building site. Fig.5 shows a successful remodeling project of the constructed wetland integrated with wastewater treatment. The other major program of the Green Building Policy is the HVAC improvement project which total budget was 9.44 million US dollars in 2003 and 2004. The ABRI selected twenty-eight buildings with air-conditioning improvement potentials in 2003. Its procedure is, first, to measure the performance of existing systems. The second step is to analyse the air-conditioning load and its type. The optimal capacity for efficient operations can thus be estimated. Total energy saving was estimated to reach 40 percent. In addition to green remodelling and HVAC improvement projects, three pilot projects for IEQ and energy saving have been completed as well.



Fig.4 Green Remodelling Project – open-grid pavement systems (ABRI, 2003)



Fig.5 Green Remodeling Project – constructed wetland (ABRI, 2004)

3.3 Technology Development, Promotion, and Commercialisation for Recycling Building Materials

The ABRI established the testing and processing laboratories for recycling building materials and initiated with plans for product promotion and commercialisation. The laboratories are built within the laboratory group described in section (3.7). A variety of recycling building materials have been developed under the support of this program, including compressed concrete paving units, recycled grid bricks, wood-like building materials, fire resistance boards, etc. The program will focus on the mechanism for technology transfer and mass production of recycled building materials in the next stage.

3.4 Establishment of Green Building Material Evaluation and Labelling System

The Green Building Material Evaluation and Labelling System was launched in July 2004. Its logo, selected from a design competition, is shown in Fig.6. Four types of materials can be considered as green building materials, which are able to agree with ecological, healthy, recycled, and high-performance (for example, heat and noise insulation) concepts. Supported by this system, the indoor environment quality of buildings can be gradually enhanced through the increasing adoption of green building materials. The further promotional strategies are currently being drafted by the ABRI.



Fig.6 Green Building Material Label of Taiwan (Chen et al., 2004)

3.5 Promotion of Green Building Concepts to Architects, Professionals, and the Public

The ABRI actively promotes the green building concept and conducts a series of promotional activities, including seminars, training courses, conferences, technical tours, and the Green Building Expo. Among these promotion activities, seminars, training courses, conferences, and technical tours are prepared for architects, engineers, and professionals in Green Building related fields. Besides, the Green Building Expo in Taiwan was held from January to March in 2004. More than 100 thousand people visited the Expo and the Green Building concept was first extensively promoted to the public. All of these incentive efforts were expected to efficiently stimulate the Green Building market in Taiwan.

3.6 Excellent Green Building Award

The ABRI encourages excellent Green Building Design through a national competition. The competition recognized the architects and their excellent work, in order to improve the design quality of Green Building and increase the motivation of Green Building design. Fig.7 shows Excellent Green Building Award winners in 2003. All these outstanding designs are well coordinated with the subtropical/tropical climate or local aboriginal culture.

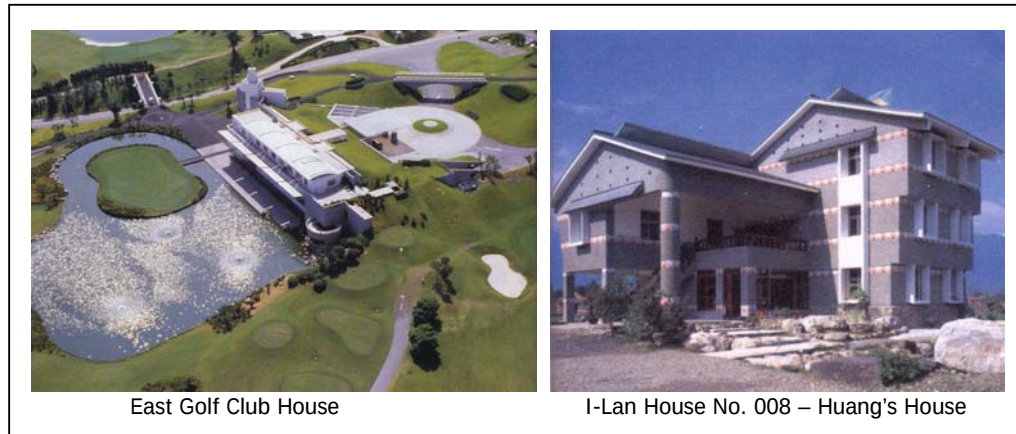


Fig.7 Excellent Green Building Award of Taiwan (Source: Author)

3.7 Establishment of National Laboratory for Building Environmental Performance

This task is part of the “Green Building and Living Environment Technology Plan.” For ensuring the assessment methods of Green Building in Taiwan with a sound quantitative basis, experimental facilities are necessary to be established. The Building Performance Laboratory Group (Fig.8) includes five laboratories, Building Performance, Building Environment, Acoustics, Wind and Rain, and Wind Tunnel. The laboratory was officially launched in November 2004. The laboratory group will be capable of providing more certification work in many Green Building and Building Environmental Performance related fields.



Fig.8 National Laboratory Facilities for Green Building Performance (Source: Author)

4. Conclusions

Seriously looking back on the progress in recent environmental protection around the world, its related actions might need further consolidation through more public sector involvement. To date, the government of Taiwan has initiated several relevant programs, and undoubtedly will continue enhancing and accelerating the environmental protection work based on our hard-won achievements of Green Building development. Furthermore, the Green Building concept will be involved into Taiwan's

Building Code in 2005. In conclusions, today a standard manual for Green Building evaluation in Taiwan was established and distributed widely to building designers, teachers, architects and contractors trained in Green Building design. Meanwhile, all of new governmental buildings are required with mandatory green building design and private sectors encouraged pursuing the Green Building Label or Candidate Certificate. According to these promotion programs, many green remodeling and improvement projects for existing public buildings and schools are currently in progress. Significant savings on electricity and water resources have been achieved. Cooperating with the government, the builders, architects, and even building material manufacturers in Taiwan are working together on a practical endeavour to reach a better living environment. The Green Building policy is, undoubtedly, a milestone on the road to upgrading the traditional building industry in Taiwan. The experiences of Taiwan described in this paper can be provided as a reference for other countries in the policy-making of Green Building Development for public sector.

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A STUDY ON THE GREEN BUILDING MATERIAL LABEL SYSTEM IN TAIWAN

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Abstract

The study on the building interior environment in Taiwan shows that the carcinogenic effect of formaldehyde estimated by lifetime cancer probability (LCP) is about 2.06×10^{-4} to 1.75×10^{-3} . The risks are 100 to 1000 times of the acceptable carcinogenic level.

Dealing with the waste material poses serious problems in Taiwan especially after a catastrophic earthquake on 21st September 1999, where construction waste materials were discarded without any planning. Until now, there are no rules in Taiwan restraining the quality of building materials used in buildings. Hence promoting the labeling system for low emission material in order to protect consumers from exposure to excessive emissions as well as helping the industry to develop environmental-friendly materials is important and urgent and deserves greater efforts. The green building material labeling system in Taiwan examines the combined performance of materials with respect to cost, wastes, pollution and health issues.

Keywords : Green building material label, Standard of Green building material, Verification of Green building material Label.

1. Introduction

Rapid industrialization and urbanization in the 20th century has caused disruptions of environments, increase in global population, and large-scale constructions everywhere for economic developing have all impacted our world. The global and unusual climate, results in energy crisis, which in order to overcome uses a lot of natural resources and hence the environmental impacts. Taiwan uses a large amount of furnishing materials in the process of building construction that consume energy and resource, and therefore influence the natural environment of the earth directly or indirectly. The emission of the volatile compounds affects the indoor air quality. Further more, no system has been established yet, to cater for disposing materials at the end of the construction process. At present the sustainability of construction materials in Taiwan is an urgent issue to be addressed.

In order to find out which building materials are acceptable and beneficial to the environment, a study is undertaken to define and evaluate all factors influencing the environmental impacts of building materials including its life cycle. The study is intended for setting up measurement procedures to assess the material performance and establishing an institution for assessing these effects. To establish a framework for operation rules, principal target, and identified criterion of Green building material, feedbacks and opinion were obtained from industry, public, academic and research departments. The outcome will be a local standard, which is aimed at improving the residential environment and the built environment.

2. Environmental Studies in Taiwan

Generally in Taiwan, the interior of buildings are overly furnished with paint coating, adhesives and timber which emit large amount of formaldehyde and volatile compounds. The study investigates the

building interior environment and discovers that the carcinogenic effect of formaldehyde estimate by lifetime cancer probability (LCP) is about 2.06×10^{-4} to 1.75×10^{-3} ; i.e. 100-1000 times of the acceptable carcinogenic risk. The measurement was measured by continuous photoacoustic Multi-Gas monitor Type 1320 (Brüel & Kjær). Formaldehyde is one of the most widely used chemicals, and extensively found in equipments and materials used in daily environments and activities. Experimental results show that the amount of formaldehyde contained in decorative spaces is proportional to the decorative area (Fig.1). The lack of the efforts restraining the quality and quantity of building materials used in construction and the lack of information on indoor environment resulting from building materials, has made people unaware of the importance of these factors to the health of buildings and its occupant.

In 1999, as a result of 921 earthquake, there were more than 50000 buildings and countless public facilities seriously damaged and leaning with a large number of building wastes in the disaster areas. According to Environment Protection Administration (EPA) report, the building offal (waste) retrieve ratio by weight accounts for 98% and 90% by volume. The general relies mainly on timber. The large number of construction offal is due to the awkward situation of piling and classifying. The waste because of the huge amount being produced. For sand and stones, they are more easily disposed near mountain valley, rivers and creeks however these cause unsightly effects and environmental pollutions, which have become governments' and authorities concerned in recent years. As more construction waste are disposed and landfill becomes saturated, obtaining a new landfill site becomes a problem and hence an urgent problem to be addressed. The consequence of population concentration and urbanisation and the increased of construction activities and transportation infrastructures, has added to these problems. With the progress of mega projects and the demand for domestic grits resources and consequential effects on the environmental problem is in questioned. Sources of grits form main rivers and creeks have been prohibited therefore limiting domestic grits. The demand for grit of the project in Taiwan has caused the price of grit to skyrocket. The used of construction waste as recycled materials to replace grit allows construction in Taiwan to progress.

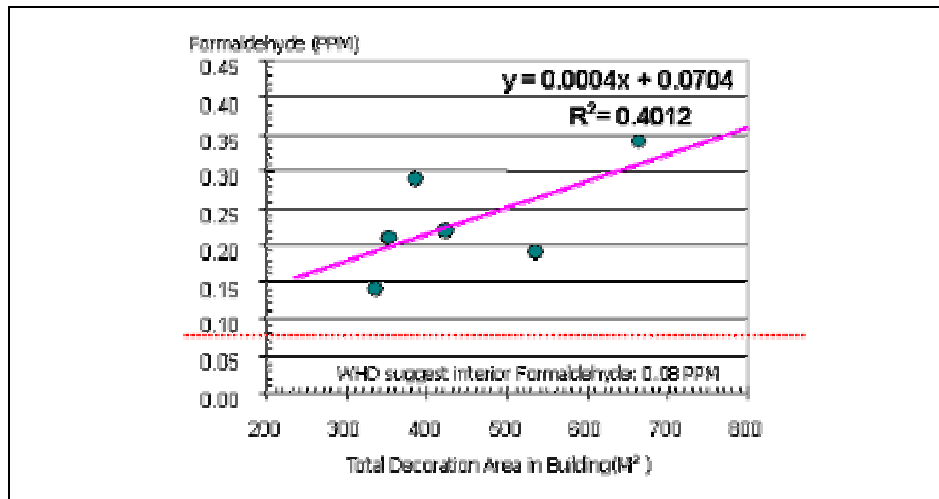


Fig.1 the relation between total decoration area and interior formaldehyde consistency

By integrating all factors mentioned above, for healthy and regeneration of building materials, the authorities of Taiwan will take the controlling step for producing "healthy green material" and "recycled green material". "Healthy Green material" includes wooden plates and paints and "recycled green material" composed of eight regenerated building materials.

3. The Evaluation of the Green Material Label

According to international general definition of green materials, it means "In the circulation of adopting raw materials, manufacturing, applying, and post-applying regeneration, that material would due to the minimum of the environmental load, and most healthy and harmless to the mankind." The chapter of

green building materials label in Taiwan refers to the international regulations, local weather and industrial conditions and stipulated standard values.

In Taiwan, “the green building materials label” is a priority for healthy and recycled projects. It highlights the main categories for the life cycle of the building materials, which includes ecological, healthy, high performance, and recycling green building material. With the exception of individual evaluations, the green building materials need to satisfy the general requirements specified by the labeling system. The chapter for the green building materials specifies four categories as below and as shown in Fig.2.

- (i) ecological green building material: using resources during fabrication stage.
- (ii) healthy green building material.
- (iii) high performance green building material: high-quality and efficiency of material.
- (iv) recycling green building material: recycled efficiency of regeneration stage

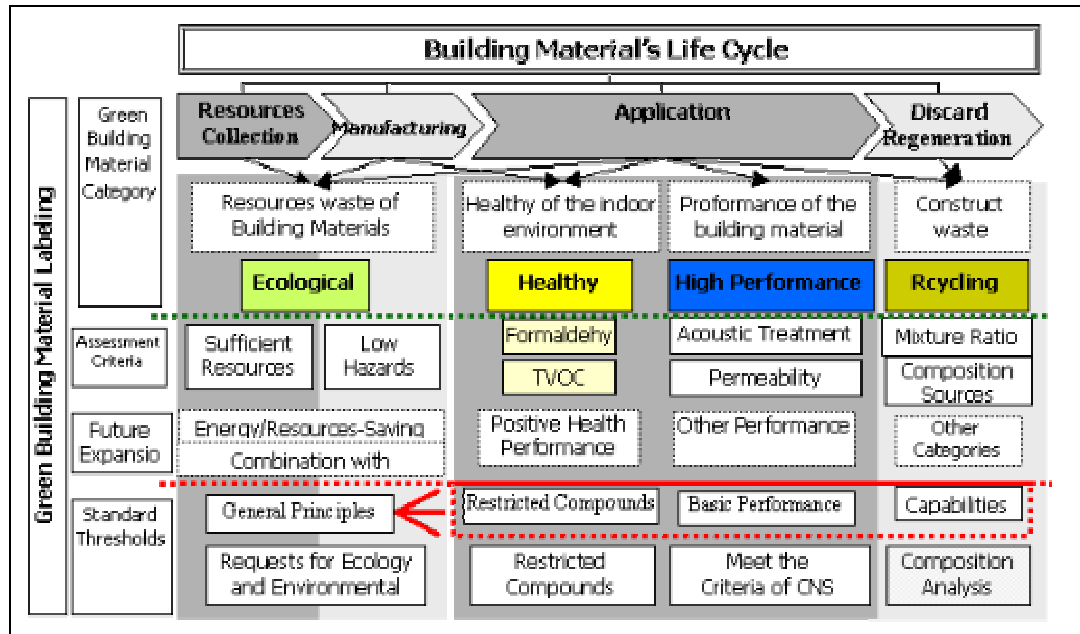


Fig.2 The system intention of the chapter for the green building materials.

3.1 Evaluation of Healthy Green Building Material

Being in a subtropical region, Taiwan experiences high temperature and relative high humidity year-round. A high density of occupancy and over decorative interior of spaces is very common. The level of formaldehyde emitted from building materials can be affected by climatic conditions such as temperature and relative humidity. Chamber test and studies have suggested that increasing the temperature and relative humidity could increase the emission rate of formaldehyde and high concentrations (Andersen et al., 1975; Wolkoff, 1998).

For high-temperatures and high-humidity environment, the total amount of formaldehyde emission certainly will be higher than temperate zones in the north. After some studies, the interior conditions of Taiwan is based on temperature 25°C, humidity 50% and aeration ratio 0.5 ACH. (Table 1)

Table 1. The evaluation of healthy green material

	Evaluated item	Evaluated item standards (emission ratio)	Conditions	Testing method
1	carpets PVC bricks plywood paints	formaldehyde 0.08mg / m ² .hr	1.Environmental Protection Administration: interiors standard for health HCHO-0.1ppm 2.definition of interior condition of Taiwan temperature 25°C, humidity 50%, aeration ratio 0.5ACH 3.Loading Factor:0.4 m ² /m ³ , Evaluating formaldehyde emission ratio by single room mass balance model	ASTM D 5116-97
2	carpets PVC bricks plywood paints	volatility organic compounds 0.19mg / m ² .hr	1. WHO standards of interior for health: TVOC-300µg/m ³ 2. Definition of interior condition of Taiwan temperature 25°C, humidity 50%, aeration ratio 0.5 ACH 3. Loading Factor:0.4 m ² /m ³ , Evaluating volatility organic compounds emission ratio by single room mass balance model	ASTM D 5116-97

3.2 Evaluation of Recycle Green Building Material

For solving the problem of building wastes, through concepts such as waste reduction, resources reuse, and eco-engineering methods, there are three purposes of waste reduction of buildings construction and to develop the green recycled building materials: (i)Solve the building offal and handling problems to avoid secondary pollution; (ii)make the products to be recycled again; (iii)reduction of energy consumption and carbon dioxide production to reduce environmental impacts.

The evaluation of the recycled green building materials was done in accordance to international relevant standards, and environmental protection system of Taiwan and domestic CNS standard.

The committee will check the data of the offal retrieved, the material source, and evaluate the fraction of recycled material used in the composition. This way the material could be evaluated to: (i)promote waste to be recycled which helps to reduce the consumption of resources; (ii)guarantee that these materials can be used safely, without harming the environment; (iii)for solving problem of transporting the building construction waste.

Amongst others the items to be evaluated includes Particle Boards, Medium density Fiberboards(CNS2215), Wooden Furniture(CNS9909), Fiber Cement Boards(CNS2837, 2838,2840), Compressed Concrete Paving Units(CNS3802,13777), Concrete Hollow Bricks(CNS13295), Aggregates(CNS1240,6298), and Ceramic Tile(CNS9737,97439744,3299).

4. Green Building Material Regulations

In the past, there are many controlling measures on commodities, but not available in the building industry in Taiwan. These make the quality of building materials inconsistent. In order to enhance the quality of living in Taiwan, comfortable and healthy interior living environment is sought after. Assistance is required to transform local building material industries, as well as promotion by architects, medical, ecological and manufactures to popularize labeling.

The Ministry of Interior has legislated additional chapters of green building (effective from 2006), which specify that interior decorated materials should used more than 5% green building materials. Issues on the agenda include health risk, standard functions, ecological concern and material regeneration. Through green labeling, materials are more ecological, and can be regenerated for improving health and performance. Besides for purpose of occupants health and sustainable environments, labeling enables the materials to be classified as one suitable to subtropical climate and local condition

Table.2 Description of the Green Building Material Regulations

Indicator name	Definition	Applicable scope	Assessment standard	Effective date
Green building material	To reduce energy and resources consumption and to maintain health of indoor environments and sustainable development of ecological environments, this index stipulates that materials recognized by the MOI as ecological, recyclable, environment-friendly, healthy, and high-performance, be adopted.	Green materials provided for public-use buildings as well as non-public-use buildings recognized by the central institution governing building as necessary.	The green materials rate (Rg) must be higher than the standard (Rgc = 5%) stipulated in Clause 321 in the design and construction part of the construction Code.	Set otherwise

5. Conclusions

This study mainly establish a set of “Green building materials label system”, for governments and building materials industries and consumers ,a system to evaluate Green Building materials for human health and sustainable environment. A green building material label suitable for the subtropical climate and local conditions will improve a healthy indoor environment and protecting the environment. The achievement of “GREEN BUILDING MATERIAL LABEL SYSTEM IN TAIWAN” includes:

The framework for the system on the Green building material. To establish local system of the Green building materials, standard, and examination process to evaluate, the quality of building materials, and enhancing the green concepts. The labeling system will also gradually reduce the negative impacts of building materials on the environment in Taiwan. The system also strategies for label identification

Provide for labeling materials provides a framework of operation and measures of evaluation. These were devised through the opinions of the industry, public and research.

The promotions of Green Building Material Label are for public, industry, and government organizations to get better knowledge about the Green Building Materials through a series of reports detailing the concepts, system, and certification categories of the Label system. Public awareness on these concepts, procedures, documentation and criteria is important for designs to be conformed to the green building materials requirements.



Fig 3 Label of Green Building Material (provided by CABC)

Acknowledgements

The authors wish to thank for the project support of Ministry of the Interior()supported this study. The content of this paper is part of the project. Archilife Research foundation also supplies the some equipment of the experiment.

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A QUANTITATIVE EVALUATION METHOD FOR RAINWATER USE : GUIDELINES TO BUILDING CODES IN TAIWAN

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Abstract

Sustainable strategy is one of the most critical policies in Taiwan's authority. Taiwan's National Building Code review committee recognized this imperative and conducted a series of researches for introducing a new guideline for rainwater use systems for architectural design and planning. Many metropolitan areas in Taiwan have experienced water shortages in recent years, due partly to droughts, economic development and rapid urbanization. Rainwater use as a supplement to the potable water supply in Taiwan has been demonstrated a practical and promising alternative where traditional groundwater or surface water is limited. This new rainwater use guideline offers an easy approach to the evaluation of water conservation and a rainwater use system for architectural planning. The proposed system involves a quantitative methodology to evaluate and improve the rainwater use systems in buildings. This paper introduces the methodology of this new guideline and the practicable evaluation system that fulfills application cases and proposes a new water conservation method linked to the National Building Code in Taiwan.

Keywords : Rainwater use, Water conservation, Guideline, Building code, Evaluation system.

1. Introduction

The growing pressures of fresh water shortages and pollution are becoming one of the most critical global problems. Water conservation is an inherent pre-requisite to sustainable utility service provision in building design today. Taiwan's National Building Code review committee recognized this as imperative and conducted a series of researches for introducing a new guideline for rainwater use systems for architectural design and planning. Taiwan is located in the Asian monsoon area and has an abundant supply of rainwater with annual precipitation that averages around 2,500 mm. However, water shortages are a critical problem during the dry season.

Many metropolitan areas in Taiwan have experienced water shortages in recent years, due partly to droughts, economic development and rapid urbanization. These water shortages have resulted in an anxious public consciousness to existing water supplies and created an economic barrier to development. Consequently, it is clear that alternative water resources must be investigated to alleviate the water shortage problem in urban areas. Rainwater use as a supplement to the potable water supply in Taiwan has been demonstrated a practical and promising alternative where traditional groundwater or surface water is limited. To implement rooftop rainwater harvesting systems for domestic water-use, the Water Resources Bureau, Ministry of Economic Affairs, has published the "Rainfall Catchments and Dual Water Supply System-Handbook" to provide a reference for engineers in preliminary building design. This report will introduce a simplified evaluation program for rainwater harvesting systems for domestic water-use linked to the national building code as a new guideline. The importance of utility performance will be stressed and a method that allows reliable verification for general building categories will be presented.

2. Green Building Evaluation System

Taiwan government departments are endeavoring to publicly spread the concept of water conservation. While industry and commerce have made excellent progress in water conservation, progress among the public for toilet or building water has been extremely slow. Due to the global trend, the Architecture & Building Research Institute, Ministry of Interior in Taiwan, proposed the "Green Building Label" award

system and introduced a comprehensive evaluation method in 1998. To save water resources through building equipment design, this system prioritized water conservation as one of its seven categories. After four years' performance, the assessment indexes for the evaluation system were refined from seven categories into nine in 2003. Water conservation has remained the most critical item. The purpose of this program is to save water resources and reduce the environmental impact on the Earth.

A Green Building is called Environmental Co-Habitual Architecture in Japan, an Ecological Building or Sustainable Building in Europe. Many fashionable terms such as Green consumption, Green living, and Green illumination have been broadly used in Taiwan. "Green" has been used as a symbol of environmental protection in this country. The Construction Research Department, Ministry of the Interior of the Executive Yuan, has decided to adopt the term "Green Building" to signify ecological and environmental protection architecture in Taiwan (ABRI, 1999).

An evaluation system with seven Green Building indices was promoted well in Taiwan until 2002. The evaluation theory mechanism is based on a life cycle assessment of a buildings' impact on the environment with an "Earth Resource Input" and "Environmental Waste Output" interaction evaluation. Fig.1 illustrates the concept behind this general idea. Practically, the Green Building definition in Taiwan can be described as "buildings that consume the least Earth resources and create the least construction waste". Theoretically, each country has an individual method of environment assessment, thus Taiwan created a unique evaluation system for Green Buildings in subtropical areas. The new evaluation system version with nine green building indices implies the basic evaluation for "Low environment impact" and higher-level issues such as biological diversity, health and comfort and community consciousness. This system provides a basic, practical and controllable environmental protection tool for inclusion in the government's urgent environment protection construction policy. The "Green Building Label" is the Green Building design award used to encourage the government and private sector to pay attention to sustainable development.

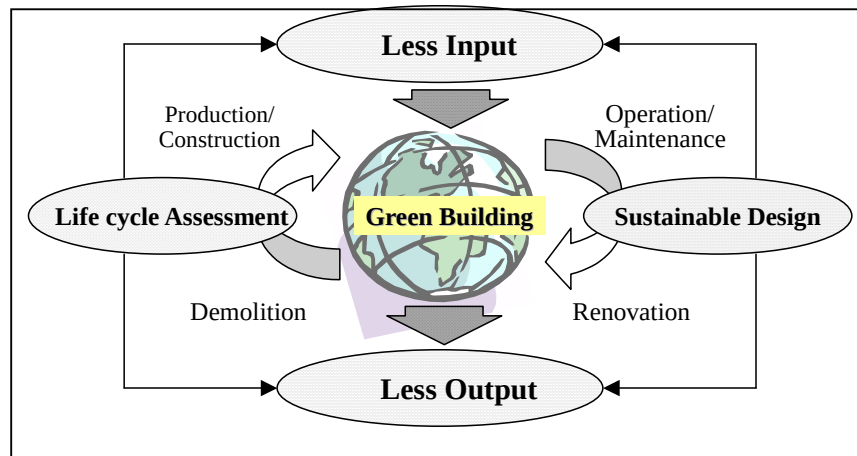


Fig.1 Green Building Concept

To solve the water shortage problems, we are developing a new system and movement. As mentioned above, the evaluation categories for our green building label were refined in 2003. The authorities linked new water conservation guideline into the National Building Code. In architectural design, architects and engineers rely heavily on the Building Code. For long-term sustainable development, building design for water conservation performance is an important step in creating a saving water society. The content of this new guideline also involves water recycling for toilets and building landscape soil water content.

3. New Provision for Building Code

Implementing water conservation is difficult if it relies solely upon achieving changes in public attitudes. However, all buildings must comply with the governing building codes to receive building permits. Although the building code has been criticized in that actual building practice does not always conform to the code, building permits are still the method employed by public authorities to protect public safety and

health. Therefore, building codes must specify the minimum standards to pass permit checks. The building code plays a role as a planning and design information provider and dictates architectural design. Because of the growing pressure from fresh water shortages, public authorities have included the water conservation into the national building codes.

Currently, a new provision named green building chapter is added into National Building Code and would be performed from January 1 of 2005. Among the new regulation, rainwater use system for building is necessary under specified condition. It declares that architectural projects with total floor area exceeding 20,000 m² or with a site plan exceeding one hectare must include a rainwater harvesting system with a tap water substitution rate R_c of at least 4%. The R_c (tap water substitution rate) calculation must comply with the rainwater use guideline evaluation system. As a primary stage, this new provision is not strict for practice. However, according to this new provision, a rainwater use evaluation system is the governing guideline linked to the building code is a prerequisite for obtaining building permits. Rainfall data must be determined from the local precipitation records and transferred into the basic rainfall parameters calculated using statistic methods.

4. Rainfall Data

According to the annual rainfall sequence records from the Central Weather Bureau of Taiwan, 6 measurement stations that have a sequence of rainfall records for over 100 years were adopted for long-term precipitation observation and analysis. The long-term variation from 1901 to 2000 is shown in Fig.2. The Taiwan rainfall sequence records imply a regular variation pattern and plenty-dry cycle of about 10-20 years. The overall review in this long-term observation reveals a variation tendency that is neither decreasing nor increasing. The total rainfall situation in Taiwan is nearly unchanged over this period of 100 years. This result does not reflect the public consciousness and anxiety over water resource shortages in recent years. Hence, a series of researches into individual measurement station variations were conducted from the initial sequence observation. We found that some areas, mostly in the northern and eastern part of Taiwan, exhibited an increasing water resource tendency and some areas, mostly in the western and southern part of Taiwan, with more metropolitan areas and comparable high population density, exhibited a decreasing water resource tendency. Consequently, the public perception of the water resources in these individual areas dominates the public consciousness. These results also closely meet the conclusion from previous researches in Taiwan and public documents. Furthermore, the growing demand for domestic water in urban areas and the difficulties in building new reservoirs are also critical factors.

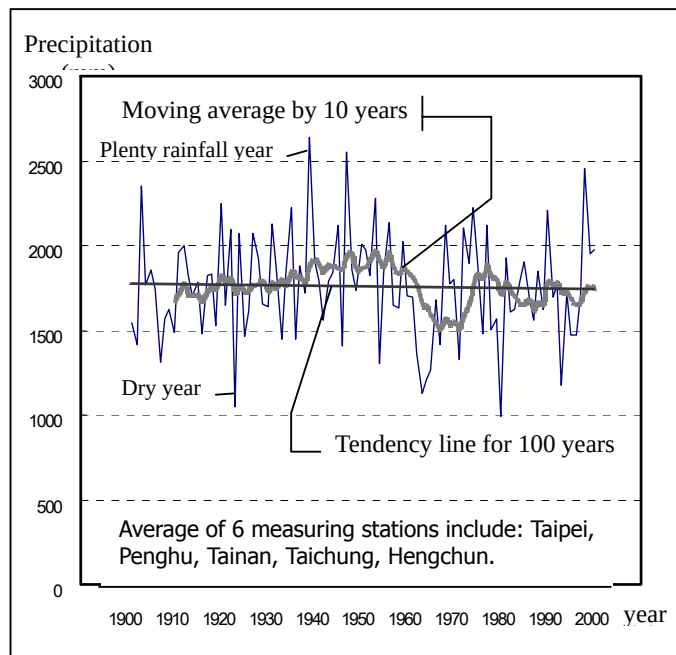


Fig.2 Long-term precipitation observation (1941-2000)

4.1 Zoning for Regulation

Today, hundreds of rainfall measurement stations cover Taiwan for many purposes. According to the annual rainfall records published by the Water Resources Bureau, Ministry of Economic Affairs in 2000, the average annual rainfall for Taiwan is about 2,512 mm. In order to conduct a practicable evaluation system, more detail understanding to each district is needed. The average annual rainfall for the northern part of Taiwan is about 2,934 mm, with about 62% in the wet season (between May to October). The central part of Taiwan has about 2,081 mm with about 78% in the wet season. The southern part has 2,501 mm with 90% in the wet season. The eastern part has 2,715 mm with 78% in the wet season. The northern parts of Taiwan are subject to the seasonal influence of a northeasterly wind and are usually dry in summer and wet in winter. The majority of the rainfall is concentrated in June to August in the southern part of Taiwan due to typhoons. Winter is usually dry and lacks rainfall. The spatial and temporal rainfall variations are larger in the southern part of Taiwan.

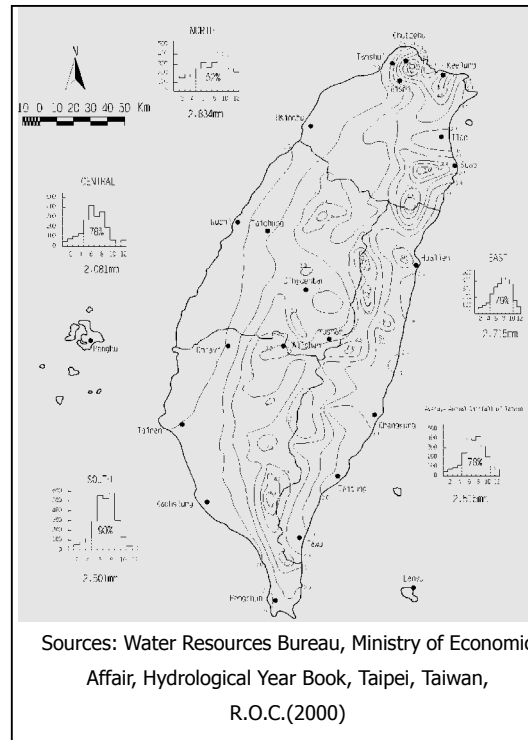


Fig.3 Average annual rainfall isohyets map of Taiwan

The precipitation zones in Taiwan are schematically arranged based on the average annual rainfall isohyets map as shown in Fig.3. As a governing tool, the zoning arrangement is according to districts for water regulation. Therefore, the major precipitation zones are roughly divided into three levels - A, B and C. The A zone is a high precipitation area with recorded rainfall above 3,000 mm. The B zone is the middle precipitation area with recorded rainfall of 2,001 - 3,000 mm. The C zone is a low precipitation area with recorded rainfall below 2,000 mm. Each zoning area has a corresponding measurement station and can offer reference data for rainwater system evaluation.

5. Assessment System

In the past, the rainwater use system was primarily an empirical technology used by building designers or engineers. The application equipment includes collection facilities, piping and treatment and storage devices. The rainwater quality is adaptable for many water uses besides drinking. To encourage people to adopt a more deliberate system, an evaluation method and guideline for rainwater use in building construction is necessary. The tap water substitution rate is described as an acceptable category for evaluating rainwater use system efficiency. Herein, the tap water substitution rate R_c can be defined in

terms of the substitution volume and water demand, i.e. R_c equals W_s divided by W_t . Hence we offer a convenient evaluation method for practical application.

5.1 Calculation Method

List of symbols and definitions used in Formula (1)~(5) and Table 3			
A_r	rainwater collection area (m^2)	V_s	volume of rainwater storage tank(m^3)
N_f	the numbers of dwelling families	W_d	daily rainwater use volume (l/day)
N_s	multiple number of daily rainwater use volume due to empirical function	W_f	water demand for individual building category (l/ m^3 /day)
P_d	probability rate of raining (-)	W_r	daily rainwater collection volume (l/day)
R_c	Tap water substitution rate (-)	W_s	tap water substitution volume (l/day)
R_d	daily precipitation of site(mm/day)	W_t	daily total water demand of the application building (l/day)
UR_i	rainwater use volume dependent on the design requirement or confirmed purpose with due devices (l/day)		

Because "daily water utilization" is adopted as a reference for public consciousness, the rainwater use index should be set as a daily reference for public understanding. First, the tap water substitution volume must be confirmed from the planning process. The tap water substitution volume (W_s) is determined using two conditions. The first is the daily rainwater use volume (W_d), which is flexible results up to the design requirement and is expressed using the following equation.

$$W_d = \sum UR_i \quad \text{Eq. 1}$$

The second condition is the daily rainwater collection volume (W_r), which is limited by local precipitation and the determined collection area is expressed as a function of the following parameters:

$$W_r = (R_d \times P_d \times A_r) \quad \text{Eq. 2}$$

where parameters R_d and P_d are determined by local precipitation, A_r is determined by the design requirement. The local precipitation parameters R_d and P_d are pre-arranged in Table 1 for application.

Table 1. Prescriptive database from authorized rainfall measurement stations (1991-2000)

Zoning category		Measure station							
A: High precipitation	Statistic items	A1	A2	A3	A4	A5	A6		
	R_d (mm/day)	10.16	7.84	12.96	7.57	9.83	8.45		
	P_d (-)	0.534	0.541	0.475	0.355	0.440	0.499		
	N_s	5.62	5.55	6.32	8.44	6.82	6.02		
B: Middle precipitation	Statistic items	B1	B2	B3	B4	B5	B6	B7	B8
	R_d (mm/day)	11.20	5.53	6.59	6.15	5.53	6.27	5.84	5.86
	P_d (-)	0.450	0.339	0.463	0.427	0.296	0.299	0.331	0.400
	N_s	6.66	8.84	6.48	7.02	10.12	10.02	9.06	7.49
C: Low precipitation	Statistic items	C1	C2	C3	C4	C5	C6	C7	C8
	R_d (mm/day)	4.37	3.39	4.45	4.68	4.67	5.06	4.95	2.42
	P_d (-)	0.315	0.198	0.312	0.273	0.233	0.251	0.330	0.235
	N_s	9.53	15.15	9.63	10.97	12.87	11.94	9.10	12.78

Source: the Central Weather Bureau of Taiwan

The parameters are arranged using the free precipitation database cited from the Central Weather Bureau of Taiwan with 10 years sequential data from 1991 to 2000. The tap water substitution volume (W_s) is a ratio derived from the daily rainwater use volume (W_d) and collection volume (W_r). That is

$$\text{if } W_r \leq W_d \text{ then } W_s = W_r$$

$$\text{or } W_r > W_d \text{ then } W_s = W_d$$

where parameter W_d may be determined by the design requirement and W_r may be calculated from the local precipitation as shown in Tables 1 and 2. For a simplified evaluation index, the tap water substitution rate (R_c) may be expressed using the following equation.

$$R_c = W_s \div W_t \quad \text{Eq. 3}$$

where parameter W_t is the total water demand for the building application. Technically, the total water demand for a building is dependent upon the building category and scale. For an evaluation method to be used as a guideline standard it must be postulated that calculation is in a prescribed database. A prescribed calculation database progresses from the initial empirical studies to the previous researches and reviews, hence this data are shown in Table 2.

Table 2. The prescriptive reference of water demand for due building category

Category	Type/scale	W_r *2 (l/m ² □day)	W_t (l/day)
Office*1	Reserved typical use	7	$W_t = W_r \times A_r$ (m ²) Where A_r would not include the non- dwelling area for parking, machine, storage, lobby, stair, ...etc..
	Composite use	9	
Commercial building	With restaurant	20	
	Without restaurant	10	
Hotel	Business hotel	15	
	Typical hotel	20	
	Resort hotel	25	
Hospital	Dispensary/Sanatorium	15	
	General hospital	21	
	Teaching hospital	24	
School	Administration/Teaching	10	
	Others	Same as others category	
Dormitory	----	10	
House	$W_t = 250(\text{l/person/day}) \times 4(\text{person/family}) \times N_r$, where N_r is parameter of assumed typical family with 4 person.		
Others	Evaluation is dependent upon the practical water demand.		

*1. Office is one kind of commercial building and which of composite use type is with coffee shop, restaurant or other commercial function.
 *2. Parameter of water demand for per floor area per day W_r is empirical data from existed document and investigation.

Table 3. Dwelling water demand estimation for each purpose (l/day/person)

Purposes /demand	Irreplaceable rate 68%				Replaceable rate 32%			Total
	Shower	Wash	Basin	Kitchen	W.C	Cleaning	Others	
Daily average	50	60	20	40	60	10	10	250

5.2 Minimum Provision for Storage Tank

The tap water substitution rate evaluation mechanism for the rainwater reuse system is now clarified. However, as a practical provision in the building design process, the minimal volume for a rainwater storage tank must be regulated. Therefore, a rational multiple number of the daily rainwater use volume

(N_s) is developed as the determined parameter that endows the minimal volume for rainwater storage tank to reflect the local precipitation in this evaluation system. The minimal rainwater storage tank volume (V_s) is expressed using the following function.

$$V_s = N_s \times W_s \quad \text{Eq. 4}$$

$$N_s = 3.0 \div P_d \quad \text{Eq. 5}$$

The practicable values of N_s and P_d are also arranged in Table 1. Table 3 shows the average daily household water consumption for each Taiwanese person, from which a standardized daily total water-consumption of 250 liters per person per day is estimated and set as the calculation base. We can see the water consumption proportion for toilet, cleaning and others is approximately 32%. Water consumption for these purposes can be replaced using gray water or rainwater.

5.3 Evaluation Procedure

The rainwater use evaluation calculation procedure for building design is now well understood and could be adopted in building regulations. Figure 5 illustrates the flow chart for the evaluation procedure using four steps.

First, the basic data and documents must be arranged for the evaluation process including site location, building scope, total floor area, rainwater collection area, weather data, etc. A series of calculations and conditions must to be set from the initial design concept through comprehensive decision-making, step by step, as shown in Fig. 4. As a practicable tool for architectural planning, this evaluation method avoids the complicated process and complex mathematical function. Nonetheless, the proposed system involves a quantitative methodology that derives from a series of empirical and substantive research.

6. Conclusions

The fresh water shortage problem is becoming a critical issue all over the world. Taiwan needs a more active and powerful decision process to deal with this crisis. Owing to an abundant supply of annual rainfall like Taiwan, an efficient rainwater use system in buildings is needed. This new rainwater use guideline offers an easy approach to the evaluation of water conservation and a rainwater use system for architectural planning. The proposed system involves a quantitative methodology to evaluate and improve the rainwater use systems in buildings. This report introduces the methodology of this new guideline and the practicable evaluation system. At present, a new water conservation method associated with the National Building Code in Taiwan is proposed. Additionally, a new regulation for green building chapter will be implemented from 1st January, 2005 as one of practicable and sustainable strategies in Taiwan.

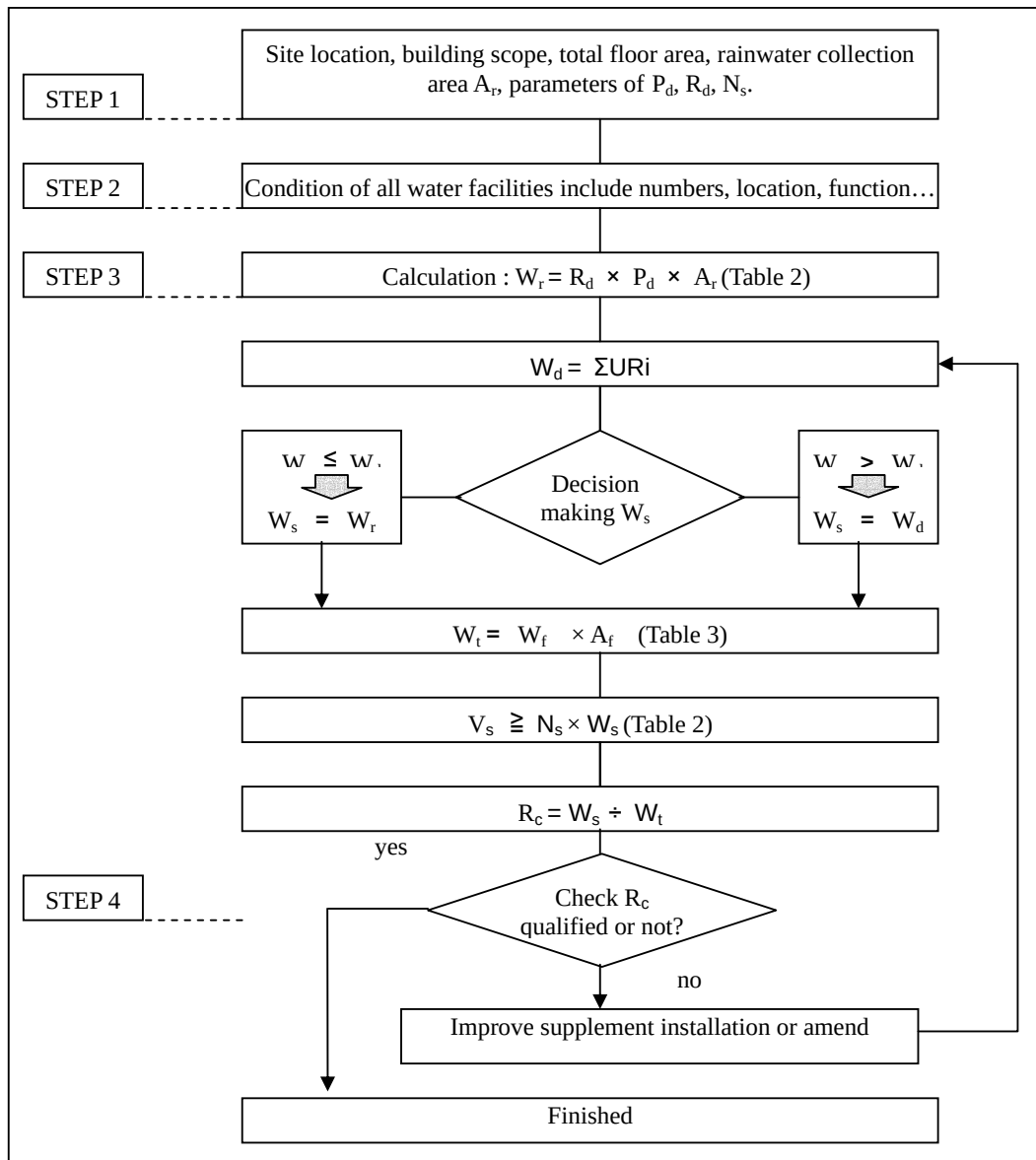


Fig.4 Evaluation procedure and flow chart

Acknowledgements

The author would like to thank the Architecture & Building Research Institute of the Ministry of the Interior of Taiwan (ABRI) and the National Science Council of the Republic of China for financially supporting this research.

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POTENTIAL DEVELOPMENT IN ENVIRONMENTAL DESIGN AND SUSTAINABLE HIGH RISE BUILDINGS IN MALAYSIA

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Abstract

The aim of this paper is to examine the potential future development of high rise buildings in Malaysia which can contribute to the sustainable design of the built environment. The paper addresses sustainable high rise buildings from two aspects. Firstly, it reviews recent developments in façade engineering in Europe for solar control, use of daylight, and thermal insulation. Then it reviews innovations in building services which includes a mix of air and surface cooling to provide greater comfort, improved air quality, lower services space requirements and lower energy use. The paper refers to case studies carried out in Europe and Asia and provides guidelines for applying these developments to hot humid climates such as Malaysia for high rise high density developments.

Keywords : Environmental Design, High rise, Facades.

1. Introduction

High density urban built environments can offer a sustainable solution for future city development. They are often associated with increased use of public transport and reduced car use. A high density built environment has the potential to be operated in a more energy and resource efficient way. It generally means a greater proportion of high rise buildings. In the past high rise buildings have not been associated with sustainability, although there are notable exceptions, for example, the work of the Malaysian practice T.R.Hamzah and Yeang [1].

Generally high rise buildings have been associated with intense air conditioned environments and high energy use, and the environmental design and energy efficiency aspects have generally been ignored. They are also associated with heat island, pollution hot spots and lack of opportunities for renewable energy applications. Recent developments in facades and mechanical services have provided opportunities for improving the environmental performance of high rise buildings, for both commercial and residential use [2]. In Europe environmental control of skins and innovative cooling systems has resulted in a new breed of energy efficient often highly glazed buildings [3].

2. Thermal Design of Facades

The aim of the thermal design of facades is to control heat gain and heat loss. The solar heat gain can be from direct and diffuse solar radiation. In hot weather, there will also be some transmission heat gains from high external temperatures. Controlling solar gains can be more difficult for west and east facades where the sun angle is lower. In Malaysia it is advisable to reduce unprotected glazing in the west and east facades as much as possible. Alternatively, PV cells may be integrated in the shading elements of these facades to take advantage of the potential solar heat gains.

The problem of controlling solar gains can be addressed through innovative shading, often of a dynamic nature, moving into position only when the sun is incident on the façade. A typical requirement, from European experience, would be that the internal air temperature does not exceed 26°C in summer and the internal glass surface temperature should be within 5°C of the space air temperature. Glazing g-values (that is, a coefficient that describes the total solar transmission through a façade) should be less than 0.15. The g-value includes the direct solar gains through the glazing plus the indirect convective and radiant heat gains from the inside surface of the glazing system (Fig.1).

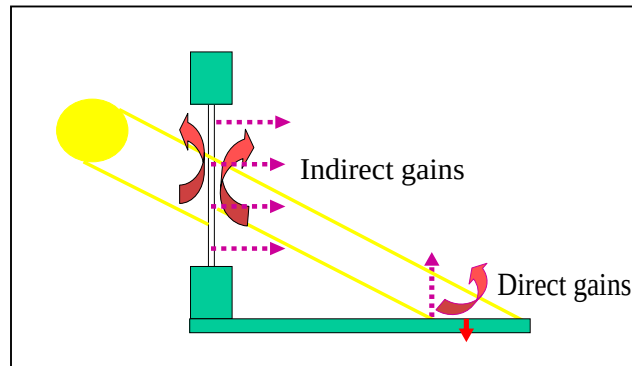


Fig.1 The g-value includes the direct and indirect solar gains.

The façade has to be carefully designed to minimise solar heat gains, not only to the space but also to the glazing system and avoiding high glass temperatures. There have been problems associated with excessive heat gains to the glazing system resulting in high internal glass surface temperatures (greater than 40°C), making the internal glazing effectively a 'low temperature' radiator. This is an area of concern that has often been overlooked by air-conditioning engineers as well as architects in Malaysia.

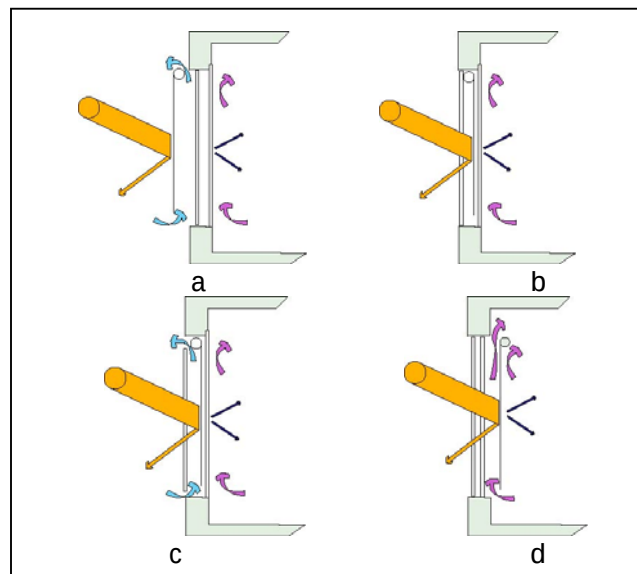


Fig.2 Illustration of different glazing shading strategies indicating convective and radiant heat exchange for, a) external shading, b) middle sealed shading, c) middle ventilated shading, and d) internal shading.

Fig.2 summarises some of the main façades used, with shading located at various positions within the construction, as follows:

- On the external façade (Fig.2a): sometimes moving into position only when the sun is on the façade. This is usually considered the best approach, as the solar heat gains are kept external to the space and glazing system.

- In the middle: within the glazing system. If the system is sealed (Fig.2b) then the solar heat gains can be trapped within the glazing system and can result in high internal glass temperatures. If the glazing system is ventilated (Fig.2c) then the heat gains can be exhausted to outside, but still the glazing system is subject to some gains which can give high temperatures, especially if the ventilated glazing extends for a number of floors. In some cases the cavity containing the shading device may be part of the ventilation exhaust system, allowing the internal stale air to be extracted through the cavity exhausting the solar heat gains.
- On the inside (Fig.2d): This is the worst case to control as the heat gains are allowed to enter the space. Although some are reflected back and absorbed by the shading system most of the heat will be contained in the space either as convective gains or long wave radiant gains.

In some cases the mechanical extract, takes air out of the space through the double skin, at the same time extracting the solar gains captured by the blind system. This is particularly appropriate for high rise buildings where a continuous external skin is required (Fig.3).

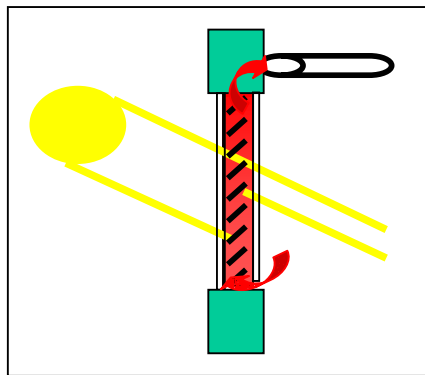


Fig.3 Mechanical air extract through the double skin facade

3. Chilled surface cooling

Ventilation can often be reduced to the minimum for occupation and where necessary, other means of cooling applied. This should be accompanied by measures to reduce internally generated heat gains from lights and small power. The reduction in solar load and the use of daylight to reduce electric lighting through 'smart' facades reduces the space cooling load. Using chilled surfaces by exposing thermal mass and night time cooling or using active chilled mass or surfaces reduces the need for air cooling and mechanical air supply is just used for 100% fresh air ventilation. This air can also be cooled or heated if required. A consequence of this approach is that the internal environments will have different requirements to achieve thermal comfort compared to a more traditional air conditioning approach, where the criteria for thermal comfort is mainly achieved through control of the internal air temperature and relative humidity (4). Thermal comfort is achieved through a balance of air and radiant temperatures and in some cases where there are high solar gains the air temperature is reduced to counter the high radiant heat, either from direct gains or from high internal surface temperatures, for example, at internal glazing and mullions.

In spaces which have a greater emphasis on chilled surface cooling the air temperature will need to be higher than is normally the case with 'all air' environmental control systems. However the reduced surface temperatures will result in lower radiant temperatures and what should be a more comfortable environmental condition for the occupants.

Reports from occupants working in chilled surface or passive cooled environments indicate that they enjoy greater comfort conditions. This is understandable, as people exchange heat more by radiant exchange with the surroundings than convective exchange with the surrounding air. So even though air temperatures are higher the comfort conditions may be improved due to the lower radiant temperatures.

One benefit of this approach is that the ventilation air supply is reduced and so the air can be 100% fresh (outside) and ductwork and air handling equipment are all reduced in size. Internal patterns of air movement are therefore more controllable than with the traditional mixing approach. It should be possible to reduce cross contamination in large office spaces by using a more displacement means of indoor air distribution.

In Europe there has been an increase in using chilled surfaces to provide the cooling requirement for commercial buildings. This has a number of advantages over all-air systems, namely:

- i) the air supply to the space is reduced to that for the purpose of ventilation, so typically it can be reduced to 1 to 2ac/h for typical office densities (say 1 person per 10m²). This also means that space for air distribution equipment and ductwork is reduced.
- ii) the mean radiant temperature of the space is reduced and this could improve comfort conditions.
- iii) there is less space required for air handling equipment and distribution ductwork.
- iv) cooling systems are more energy efficient with higher COP's of cooling equipment resulting from higher temperature cooling medium.

There are a range of chilled surface cooling methods, depending on the heat load of the space. They are indicated in Fig.4, with typical cooling capacities. The cooling capacities are related to the rate at which heat can be extracted. Figure 4a is referred to as passive cooling and depends on night cooling to extract the build-up of heat from the slab. Figures 4b and 4c use active methods of extracting heat from the slab and surface respectively.

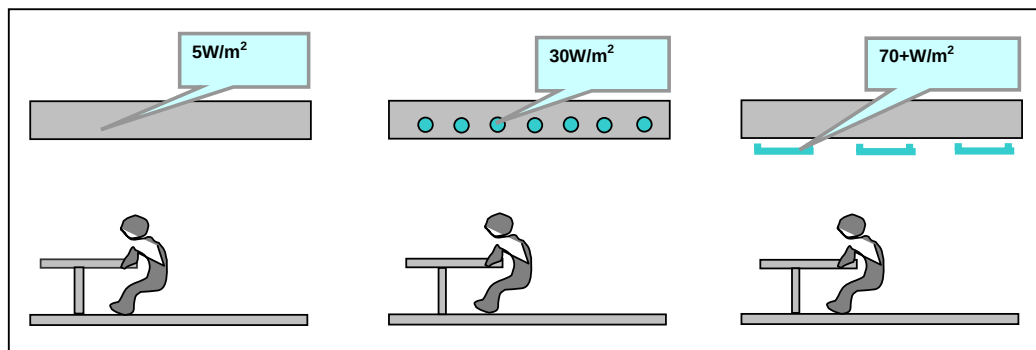


Fig.4 Chilled surface cooling systems.

4. Integrated façade, ventilation chilled surface cooling

An integrated approach to environmental design using smart facades, low volume ventilation and chilled surface cooling is described in Fig.5. This approach should be applicable to most locations, provided the façade is airtight so that moisture cannot infiltrate to the space from outside through air leakage.

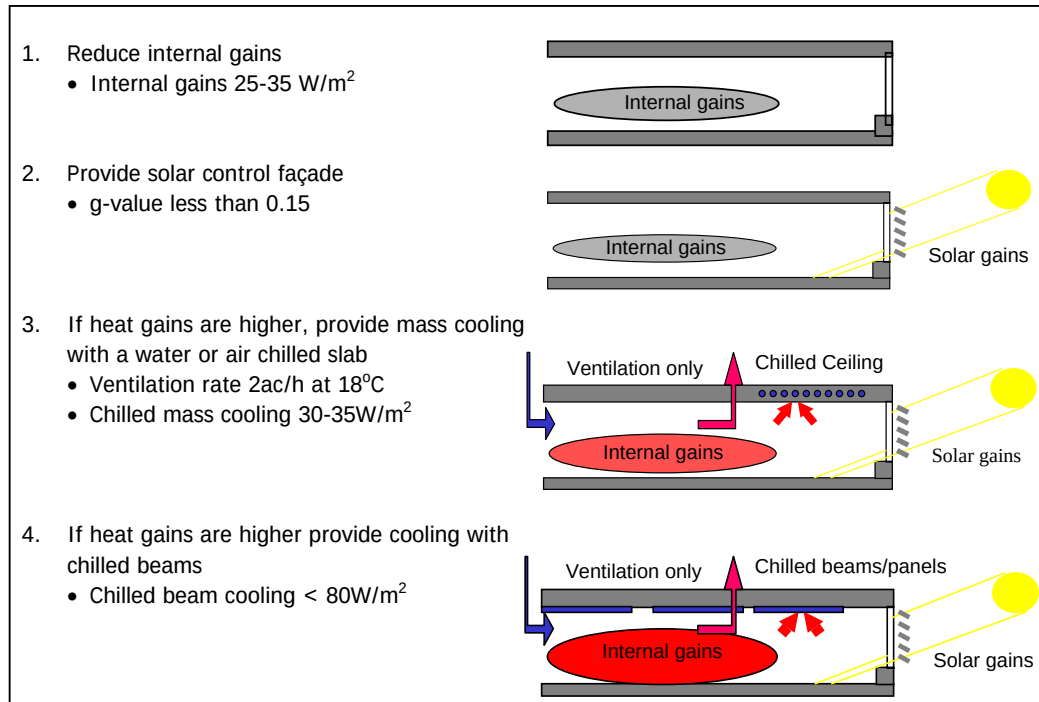


Fig.5 Integrated design approach

5. Conclusions

The focus on smart facades and radiant cooling is a relatively new approach in hot humid climates. In this case chilled cooling systems have a good potential for improving comfort and reducing energy in offices, especially when combined with glazed facades that provide good solar control. This should be applicable to hot humid climates such as Malaysia as well as European cases, provided the external façade is reasonably airtight. The ventilation supply air will need to be de-humidified as usual.

Environmental temperatures are reduced by 2 to 3°C compared to the more traditional all-air systems, and external blinds reduce the internal glazing/blind surface temperatures.

The reduced ventilation loads will result in lower space requirements for air handling equipment and ductwork, and therefore this should produce capital cost savings.

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A SIMPLIFIED COMPUTER THERMAL SIMULATION TOOL FOR SUSTAINABLE HOUSING DESIGN

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Abstract

The technology of sustainable building design is well established by now in South Africa. However, sufficient implementation of the technology is not taking place, particularly in the housing delivery sector.

Computer-aided thermal design and simulation tools have been developed to assist designers and other housing stakeholders with the implementation of sustainable building design technology. However, some of the computer programs are unduly complicated and comprehensive for non-specialist users. Most of the required data input for these programs is fairly straightforward, such as building orientation and dimensions. However, other additional and more complex technical information often needs to be entered, such as hourly data for air infiltration, natural ventilation rates and convective, radiative and latent heat loads generated internally by lights, appliances and occupants. Furthermore, users are required to develop the databases of these programs for which extensive information regarding the thermo-physical properties of local building materials and appropriate climatic design data are needed.

This study presents a simplified computer thermal simulation tool, TERMO, which has been validated locally. The program is specifically intended for the thermal design of sustainable housing in the various climatic regions of South Africa. It is aimed essentially at non-expert users such as architects, local housing authorities, homebuilders and building discipline students. The program is especially useful in demonstrating the influence of alternative design interventions on the thermal performance of a house. Raw data input is limited to building locality, dimensions and material specification. All further required information is sourced from a database of local climatic data and properties of building materials. The need for entering additional technical data is obviated by incorporating essential parameters, based on certain rational design assumptions applicable to housing, directly into the program's algorithm. The analytical basis of TERMO is explained and illustrated.

Keywords : Housing, Sustainable building, Computer-aided thermal design, Thermal performance.

1. Introduction

Sufficient implementation of sustainable building design is not taking place in South Africa, particularly in the housing delivery sector, despite the availability of a well-established technology database.

Computer-aided thermal design and simulation tools have been developed to assist designers and other housing stakeholders with sustainable building design. However, some of the computer programs are unduly complicated and comprehensive for non-specialist users. Most of the required data input for these programs is fairly straightforward, such as building orientation and dimensions. However, additional more complex technical information often needs to be entered, such as hourly data for air infiltration, natural ventilation rates and convective, radiative and latent heat loads generated internally by lights, appliances and occupants. Furthermore, users are required to develop the databases of these programs for which extensive information regarding the thermo-physical properties of local building materials and appropriate climatic design data are needed.

TERMO is a simplified computer thermal simulation tool developed specifically for the thermal design of housing. The program has been validated locally for the various climatic regions of South Africa. It is aimed essentially at non-expert users such as architects, local housing authorities, homebuilders and building discipline students. TERMO is especially useful in demonstrating the influence of alternative design interventions on the thermal performance of a house and to test innovative building methods against the known performance of conventional building.

Raw data input is limited to building locality, dimensions and material specification. All further required information is sourced from a database of local climatic data and properties of building materials. The need for entering additional technical data is obviated by incorporating essential parameters, based on certain rational design assumptions applicable to housing, directly into the program's algorithm.

The program has many limitations and is not ideally suited for research purposes or able to compete with powerful building energy and thermal simulation computer programs. However, TERMO provides a satisfactory degree of precision for housing when its results are compared with that of other building thermal design tools.

2. Thermal analytical procedure

The thermal analytical procedure of TERMO is empirically derived from thermal measurements of many different types of buildings, under both summer and winter conditions, in various climatic regions of South Africa (Wentzel et.al., 1981). Reasonably well designed buildings were studied where, for example, windows had been shaded against excessive solar heat gains, and adequate cross-ventilation had been provided in summer. Therefore, the procedure is applicable to such buildings and would not, for instance, accurately model a house that has been orientated with large west-facing windows.

The precision with which temperatures in buildings were predicted is illustrated in Fig.1.

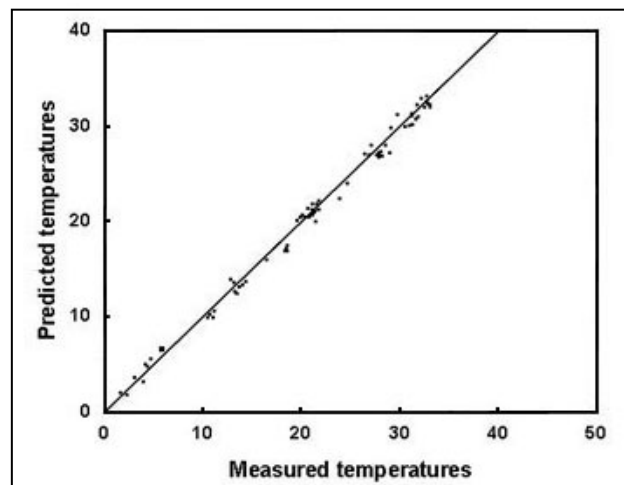


Fig.1 Comparison of predicted and measured temperatures in buildings (Wentzel et.al., 1981)

The reliability of the above procedure was considerably enhanced by incorporating features of a semi-empirical method (Mathews, 1985), which is founded on electric analogue theory, as well as on experimental results.

However, when the validity of the procedure was found to be suspect in the extreme case of very poorly insulated houses of very low-mass construction, comparative thermal simulations were performed with the more powerful thermal simulation tool, NewQUICK (Building Toolbox, MCI (Pty) Ltd.). The climatic and building material databases of TERMO and NewQuick were matched and natural ventilation rates were input for NewQUICK to correspond with TERMO's assumed "provision of adequate cross ventilation", mentioned

above. Furthermore, the houses were orientated with the large windows facing north and NewQUICK was programmed to calculate the extent of shading of walls and windows from the sun.

Comparison of the TERMO and NewQUICK results made it possible to make appropriate adjustments to the thermal simulation procedure of TERMO.

3. Calculation procedure

Fig.2 is used to illustrate the program's general calculation procedure. The graphs show that the shape of the daily indoor air temperature curve is very similar to that of the daily outdoor air temperature curve, but the indoor temperature amplitude (α_i) is normally smaller than the outdoor temperature amplitude (α_o). This so-called 'cushioning effect' typically manifests in buildings that have large mass structural components and a well insulated shell. The daily indoor mean temperature rises above the daily mean outdoor temperature and a time-lag is usually evident between the occurrence of the daily maximum and minimum indoor, and maximum and minimum outdoor air temperatures.

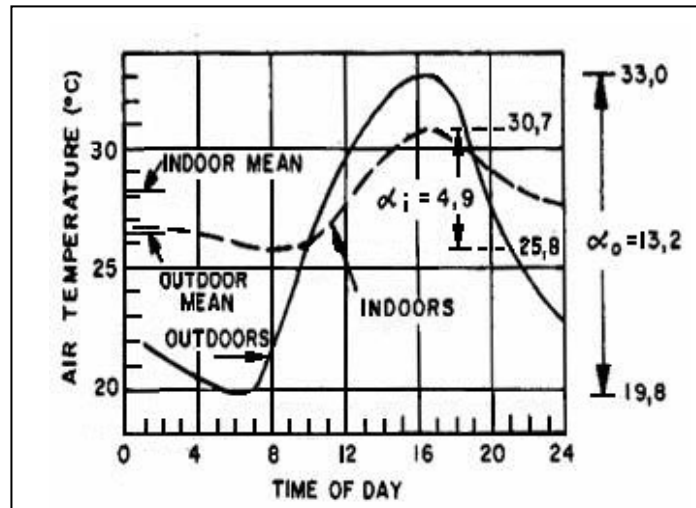


Fig.2 Indoor and outdoor air temperature graphs and amplitudes (Wentzel et al. 1981)

The calculation procedure of TERMO is as follows:

- (i) Calculate the total active thermal capacity of the building structure from the methodology and equations by Wentzel et.al. (1981). The total active thermal capacity of the building structure is a function of the volumetric mass density and specific heat of the material composition of the building, as well as the weighted or equivalent thermal resistance to heat flow of the building shell.
- (ii) Calculate the daily indoor temperature amplitude (α_i) from the methodology and equations by Mathews (1985). The daily indoor temperature amplitude is a function of the total active thermal capacity of the building structure and the mean of the daily outdoor air temperature amplitude (α_o) and the daily sol-air temperature amplitude.
- (iii) Calculate the daily temperature amplitude ratio (α_i/α_o), i.e. the ratio of the amplitude of the daily indoor air temperature variation (α_i) to that of the daily outdoor air temperature variation (α_o).
- (iv) Calculate the daily mean indoor temperature from the methodology and equations by Mathews (1985). The daily mean indoor temperature is a function of the mean of the daily mean outdoor air temperature and the daily mean sol-air temperature.

- (v) Calculate the hourly indoor temperatures from the hourly outdoor temperatures, the temperature amplitude ratio (a_i/a_o) and the daily mean indoor temperature. An appropriate time-lag (the time difference between the occurrence of maximum and minimum indoor and maximum and minimum outdoor air temperatures) is derived from the amplitude ratio (Mathews, 1985) and applied to calculate the phase-shift for the hourly indoor temperatures.

Comparative thermal simulations using the adjusted TERMO procedure and NewQUICK were performed on three different low-income house designs:

- a conventional brick house
- a house of low-mass dry-wall construction
- a large-mass house with unusually thick masonry walls and an exceptionally well-insulated ceiling.

The houses were assessed in each of three main climatic regions, shown in Fig.3, considered sufficient for the thermal design of housing in South Africa.

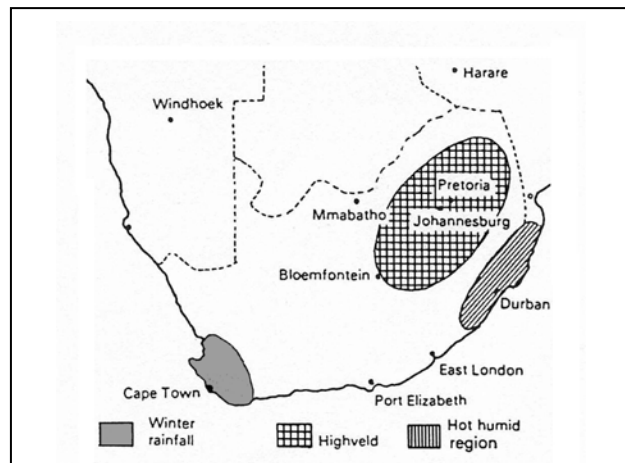


Fig.3 Main climatic regions for the thermal design of housing in South Africa (National Energy Council, circa 1990)

Examples of the comparative results obtained with TERMO and NewQUICK are shown in Fig.4 to 9.

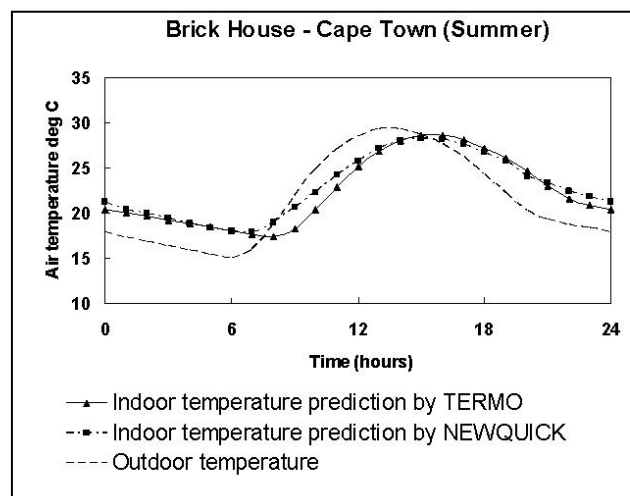


Fig.4 Comparison of indoor temperature predictions with Terno and NewQUICK for the Brick House in Cape Town (Summer)

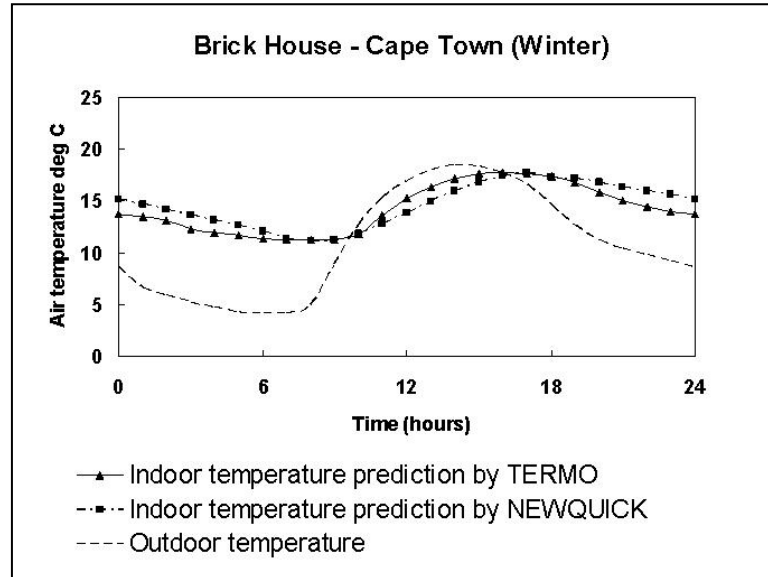


Fig.5 Comparison of indoor temperature predictions with Terno and NewQUICK for the Brick House in Cape Town (Winter)

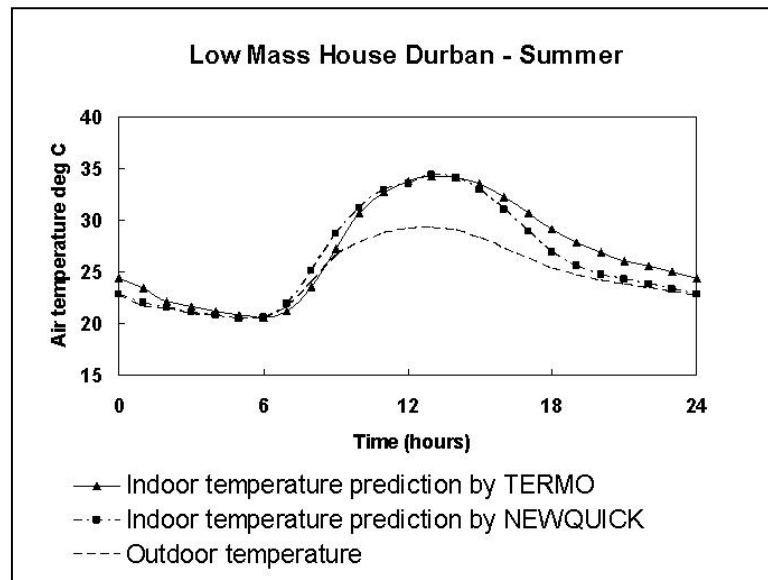


Fig.6 Comparison of indoor temperature predictions with Terno and NewQUICK for the Low Mass House in Durban (Summer)

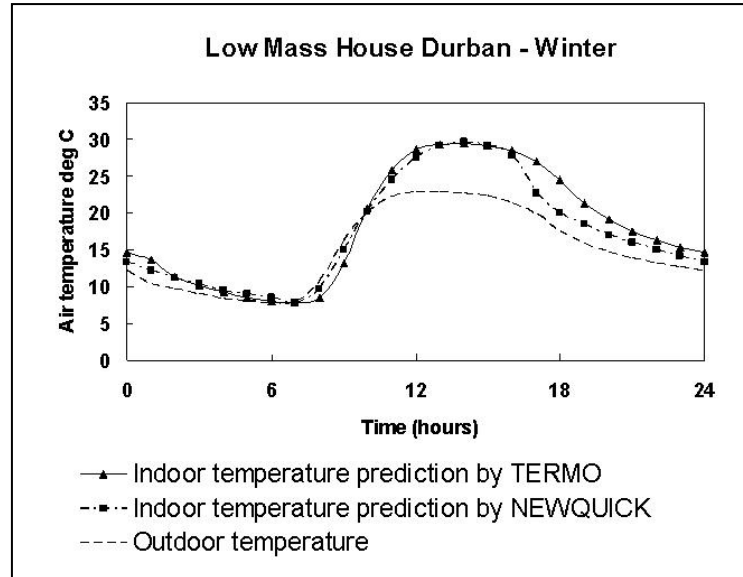


Fig.7 Comparison of indoor temperature predictions with Terno and NewQUICK for the Low Mass House in Durban (Winter)

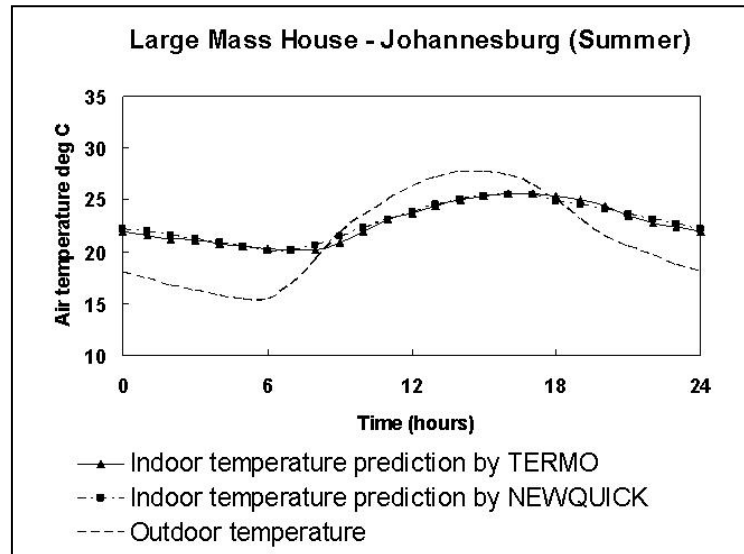


Fig.8 Comparison of indoor temperature predictions with Terno and NewQUICK for the Large Mass House in Johannesburg (Summer)

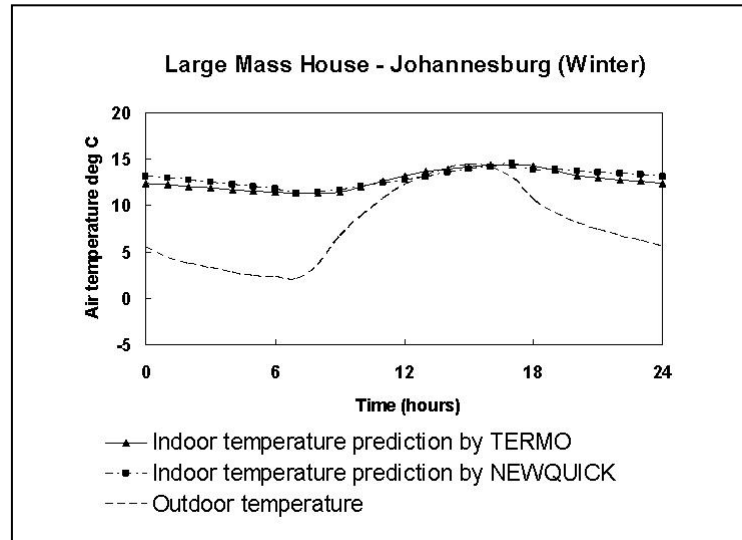


Fig.9 Comparison of indoor temperature predictions with Terno and NewQUICK for the Large Mass House in Johannesburg (Winter)

4. Database

A climate database is provided for seven main locations in South Africa. The database contains hourly air temperatures, the daily air temperature amplitude, the daily mean air temperature and daily solar radiation on vertical and horizontal surfaces for a typically hot and a typically cold day respectively in summer and winter. These values represent 90 per cent design day weather data (Wentzel et.al., 1985), i.e. the mean of the 10 per cent warmest days in summer and the mean of the 10 per cent coldest days in winter. Generally, this means that the design temperature limits will be exceeded on only about 14 days in an average year.

The building database consists of building materials and their thermo-physical properties.

5. Input

Drop-down menus are used to select the geographic location of the house, input building dimensions and specify the walls, floor and roof/ceiling combination. Climatic data and thermal properties of building materials are automatically extracted from the databases and require no user intervention.

6. Output

Hourly indoor air temperatures are predicted for typically hot and typically cold days respectively in summer and winter. The results are shown in tabulated and graphical format. A thermal comfort zone is displayed to facilitate the evaluation of the thermal efficiency of the building design. Details of the building design and results can be printed.

7. Conclusions

TERMO is a simplified computer program specifically developed to enable non-expert users to perform and evaluate the thermal design of housing. The reliability of the program is evident from the comparative thermal simulations performed with TERMO and the more powerful - but much more sophisticated - thermal design tool NewQUICK over a spectrum of house designs and different climatic conditions.

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TOOLS FOR URBAN SUSTAINABILITY

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Abstract

The design and management of the urban built environment has an impact on both environmental and socio-economic aspects of sustainability. There is the need to be able to evaluate the extent of these impacts in a consistent manner for both new and refurbishment built environment projects. Many tools have been developed in the past to assess the sustainability of buildings and urban infrastructure but few of these tools are used in practice. This paper discusses the development of practical tools for evaluating urban sustainability. It focuses on two main tools, namely, the energy and environmental prediction tool (EEP) for municipalities, and the framework of *practical evaluation tools for urban sustainability* (PETUS). The prime aim in the development of these tools and procedures was to provide a set of practical methods to 'operationalise' the concepts of sustainability.

Keywords : Sustainability, Tools, Built environment, Evaluation, Operationalise.

1. Introduction

About 60% of the worlds population are expected to be living in cities by 2025. City living, in its nature, opposes sustainability with the need for energy, transportation and water resulting in the production of waste and sewage, all of which use up natural resources and landscapes. There is therefore a need to develop, build and maintain the built environment to encourage sustainable living, travel and working situations. To achieve this, all infrastructure developments should attempt to balance the core factors of sustainable development; environment, economic and social, to ensure minimum impact for current and future generations. The urban infrastructure includes both the construction of new buildings and renovation of existing buildings, and the construction and renovation of facilities associated with buildings including transport, water/sewage, waste, energy and water and landscaping.

Interventions to promote sustainability are being introduced at national government levels in the UK for example, the UK Royal Commission on Environmental Pollution (2000) has called for a 60% reduction in carbon emissions by 2050 and 80% by 2100 which is supported by the UK Energy White paper (DTI, 2003). The infrastructure and construction industry has significant opportunity to have a positive impact on resource conservation if provided with reliable advice and information. Over half of the resources consumed globally are used in construction and 45% of energy generated across the world is used to heat, light and ventilate buildings with a further 5% being used during construction (Edwards, 2001).

The rate of renewal of the existing infrastructure stock is slow to achieve significant progress towards targets and therefore changes relating to new build and refurbishment of existing infrastructure should include sustainability options wherever possible. This is supported by the EU Directive on the energy performance of buildings (Directive 2002/91/EC) which states that more attention should be made to the existing built environment, particularly during the renovation of large existing buildings.

These initiatives require tools and procedures to assist in decision making processes in order to ensure that they are properly implemented across all aspects of sustainability.

2. Methodology

Sustainable development in urban areas on a city or local authority scale is primarily concerned with managing the existing built environment and planning new developments to achieve minimum environmental and social impacts, in relation to the use of resources, pollutant emission and quality of life for the individual. This requires decisions to be made within sectors, for example, housing, transport, industry, and across sectors, from relatively small areas, say at postcode level up to a whole city/LA region. Tools are needed to assist this process. To fully understand the inter-relationships between buildings, transport and industry, and the potential for using renewable energy sources on a city wide basis, tools are required that can predict the various interactive processes. The following section will present and discuss two tools that have been developed to 'operationalise' the concept of sustainability. The *energy and environmental prediction* (EEP) model has been developed at the Welsh School of Architecture in order to assist in planning for sustainability in cities and urban areas in collaboration with Local Authorities in the UK as part of a unified effort to plan for sustainability and to predict and account for reductions in carbon dioxide and other emissions. The computer model provides information for implementing urban energy management and environmental planning, enabling decision makers to plan for improved energy efficiency and to predict the effects of future planning decisions from a whole city level down to a more local level. EEP uses external procedures or sub-models, selected according to the user's needs, for example, to predict the city's energy and emissions from buildings, transport and industry.

The Energy and Environmental Prediction (EEP) model (Fig.1) was initially developed to provide a modelling framework for sustainable development, dealing with housing and other building types, industrial process and traffic flow. It has been further developed to include new capabilities for dealing with the social element of health in housing, including accidents and injuries in the home, respiratory disease and mental health. Results are presented simultaneously through the associated Geographical Information System (GIS) which contains an Ordnance Survey (OS) map of the city describing the buildings and roads. Sub-models exchange data through a data highway, making all data available to all sub-models. This enables the impact of the built environment to be assessed on a municipality scale for different sustainability issues.

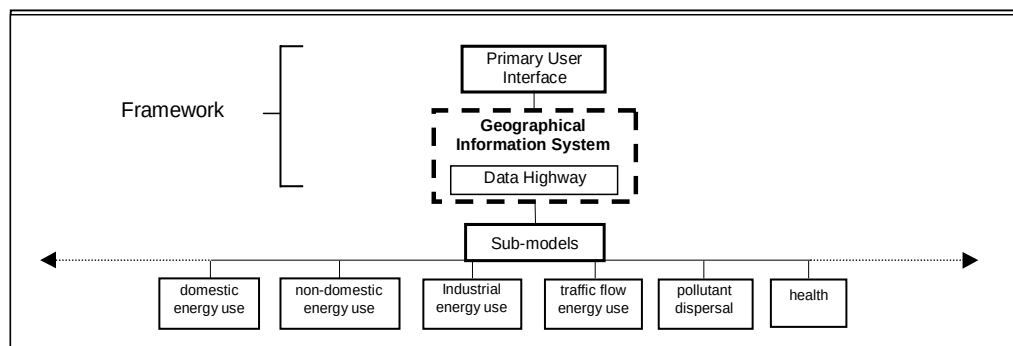


Fig.1 The EEP model framework

The basic premise of the EEP model is that data within a region or city under investigation can be input and examined in small areas to enable the user to pinpoint 'problem' areas relating to excessive energy use and associated pollution 'hotspots' and/or factors that may be incremental to poor health. The EEP sub-models contain standardised descriptions of the built environment that will enable small area analysis at post code unit level, relating health variables to housing types and neighbourhood character. EEP can contain a description of the total housing stock for a local authority area providing a unique sampling frame for population surveys when looking at different types of housing. The spatial presentation of interacting variables within EEP and the associated GIS software is understood by local government and offers an opportunity to engage the public in a new way to illustrate findings.

2.1 Energy Use in Housing

Local policy makers and managers require knowledge of energy consumption, together with the ability to predict how demand might change over time as new policies are introduced and new development

proposed. The housing sub-model used within EEP is based on the UK government Standard Assessment Procedure (SAP), which is an energy rating method for dwellings (Building Research Establishment, 2001). The energy rating is expressed on a scale of 1 to 100; the higher the number, the better the standard. Information regarding fabric, glazing, ventilation, water heating, space heating and fuel costs is required to carry out a SAP calculation.

Within the EEP model data for domestic properties is collected on an individual property basis which is then aggregated to postcode unit level (typically a group of 25 neighbouring properties). Data collected include property age and built form features such as heated ground floor area, façade area, percentage of window to wall area and the end elevation of the property. These characteristics can be collected without entry to the house, making the survey relatively quick and low cost. Data associated with housing standards, energy use, etc., for each house-type are then stored in the EEP database and can be represented on a thematic map to postcode level so that 'hotspots' of energy use and emissions can be identified (Fig.2). Different scenarios can be tested, such as, looking at energy savings from increasing thermal insulation levels for a specific house types or all houses within an area.

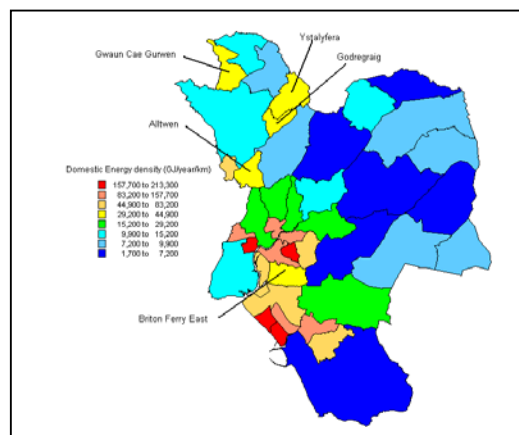


Fig.2 Illustration of domestic energy results on a ward basis for Neath Port Talbot County

The EEP model has been applied to the entire Neath Port Talbot County Borough Council (NPTCBC) area in south Wales which contains over 55,000 houses. This has provided the local authority with a comprehensive database of the characteristics of its building stock and can therefore be used to predict domestic energy use. The EEP model can assist with the allocation of resources from local authority budgets to improve the condition of the housing stock. Fig.3 illustrates the improvements in energy efficiency as a result of installing different combinations of energy efficiency measures to a property.

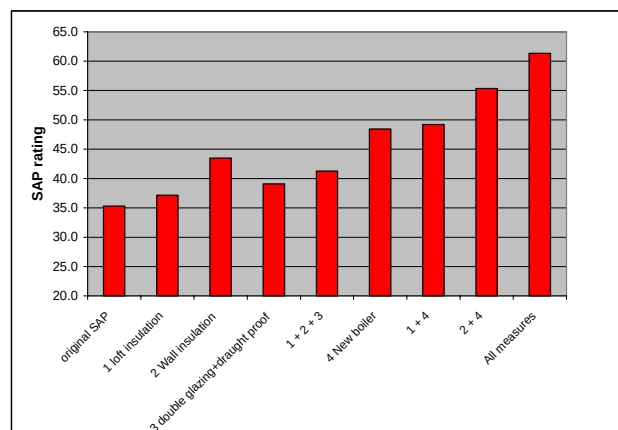


Fig.3 Illustration of improvements in an individual properties SAP rating as calculated by EEP that would result from the installation of various energy efficiency measures

2.2 Traffic Flow and Emissions

The traffic flow sub-model within EEP predicts energy use and emissions for all roads within a city/region using spatial analysis procedures. Spatial analysis is a collective name given to a set of computer based modelling techniques used to objectively represent, quantify and analyse space at all levels of the built environment from a single building to entire cities. The technique is based on methods developed at University College London (Hillier and Hanson, 1984). The method measures the degree in which each road on a map is linked to all other roads. A road is represented on GIS MapInfo system as a line or series of lines that follow the line of sight along a road network - these are axial lines which combined create axial maps. An 'integration value' is calculated by spatial analysis procedures for every axial line within the road system taking into account how well linked every road is to all other roads represented within the network. The traffic flow sub-model is linked to the EEP model through the Primary User Interface.

To validate the model axial maps were created for Cardiff, Leicester, Leeds and Neath Port Talbot County Borough Council (NPTCBC) and real traffic flow figures were obtained from the associated local authority were correlated with integration values calculated by the model. For comparisons within Leeds, results were compared to predictions from SATURN (Van Vleet, 1982). Cardiff was used to test out potential methods and successful methods were then tested on the other city/regions. Features have been developed to improve the correlation between real and predicted traffic flows including;

- *Boundary weighting facility* - Traditionally when using spatial analysis the area of interest is dealt with in isolation. However, in real situations there will be movement into and out of the area. The Boundary Weighting facility has been developed to take into account in and outbound traffic.
- *Weighting of roads* - Some road characteristics act as an incentive or deterrent for use, which have an effect on traffic flow. These are accounted for by weighting factors associated with road type. Roads have been classified into five different types according to structure and speed. These classifications are taken from the Department of the Environment, Transport and the Regions Transport Statistics (1999).

When the characteristics mentioned above were incorporated into the model the regression values between real traffic flow and integration values improved significantly. For Cardiff (Fig.4), Leicester and Neath Port Talbot County Borough r^2 value of 0.69, 0.52 and 0.8 were calculated respectively.

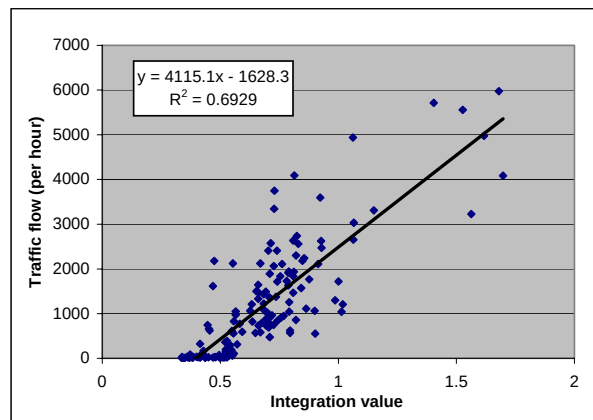


Fig.4 Correlation between integration value and traffic flow figures for Cardiff where boundary weighting and road weighting have been applied.

The study has shown that the spatial analysis procedure developed can calculate integration values that can be correlated with real traffic flows. This enables real traffic flow predictions to be made quickly for every road within a city. Line data from the traffic flow sub-model is converted to emission data using flow data calculated by traffic sub-model, road characteristic information from road maps (classify roads into one of five types) and data from the 'Design Manual for Roads and Bridges' (1999) database for each of the five types of road including speed of light and heavy vehicles and the split of light to heavy.

The three sets of information are combined to produce emission rates per year for each axial line. An emission database containing this level of detail means that the spatial distribution of pollutant concentrations can be readily assessed in areas other than the main roads. Exposure to concentrations can be assessed in relation to the built environment and modifications can be planned in areas of high emissions.

2.3 Modelling Housing and Neighbourhoods and Health

The expansion of the EEP model to include the area of health was the focus of a 3 year MRC/EPSRC funded research project carried out by a collaboration between Cardiff University and the University of Wales, College of Medicine. The overarching goal of the collaboration was to create a multi-level, cross-disciplinary framework for evaluating the impact of the built environment on the health of people and communities. A 'health' sub-model was developed to fit into the existing EEP model framework, that can be used to measure, display and predict links between the built environment and health. The new health sub-model relates to three levels of housing and neighbourhood, and three health outcomes illustrated in Table 1.

Three separate tools have been developed to be incorporated within the EEP framework:

2.3.1 Residential Environment Assessment Tool (REAT), is a survey instrument used to record data about observable characteristics of urban residential environments. Information is collected during a site visit where observations relating to physical environmental characteristics, associated with neighbourhood quality and desirability are recorded using the tool.

Table 1. Spatial levels and disciplines of the health sub-model

Spatial Level	Environment	Scientific discipline	Public Health application
1	Indoor air quality	Building physics	Cardio-Respiratory diseases
2	Housing layout	Design	Injury prevention
3	Neighbourhood and Community	Social science/planning	Mental health

Safe Home Survey, was developed to measure existing home hazards on a room by room basis in an attempt to identify whether hazards are related to different property types.

Domestic mould survey, was based upon a systematic approach to site visits which included the collection of airborne moulds using polycarbonate filters, measurement of temperature and air humidity in the affected rooms, taking mould samples from the walls and assessing occupants' peak flow and allergic response.

The health sub-model should potentially enable the prediction of the three related health outcomes: poor mental health; injuries; and asthma. The data can be represented by using thematic maps, which will highlight variation between areas in terms of particular health outcomes or environmental factors enabling easy identification of areas expected to have poor health that can be targeted with financial incentives for necessary improvements.

2.3.2 Practical Evaluation Tools for Urban Sustainability. Tools such as EEP are used generally at the technical level within a decision making framework, which allowing for both quantitative and qualitative aspects of a specific project to be addressed. As part of the framework there is a need to clearly define more holistic sustainability objectives for a specific project, and to track these objectives throughout the design process and in the selection of tools. The Practical Evaluation Tools for Urban Sustainability (PETUS) project, managed at Cardiff University and developed in partnership with seven organisations from across Europe, is a three year project that began in December 2003 and is funded by the European Community as part of the Fifth Framework Programme Energy, Environment and Sustainable Development, Key Action 'The City of Tomorrow and Cultural Heritage'.

PETUS provides a framework within which practical evaluation tools can be used to analyse and improve the sustainability of urban infrastructure projects. The evaluation procedure enables a

consistent assessment approach across all aspects of urban infrastructure projects including water/sewage, waste, transport, energy, green/blue (vegetation/water) areas and projects of a holistic nature. PETUS will provide access to a procedure and tools that will help to assess projects against a set of standard sustainable criteria and provide information to look at the potential for transferring projects to other areas of the world. This will assist personnel involved in urban infrastructure to develop projects in the most sustainable way possible. The project will provide a set of practical methods to 'operationalise' the concepts of sustainability enhancing environmental, economic and social aspects of a project.

PETUS therefore aims to fill the gap between theory and practice allowing actors involved in urban infrastructure at all decision making levels to undertake an assessment of the likely impact of an infrastructure project on 'sustainability' – environment, economy and society. Actors involved at all levels of the decision making process need to be aware of sustainability however, different aspects are relevant at different levels, for example, staff at a technical level would need to investigate different characteristics of a project to those at a higher decision making level who might allocate funds and may only be interested in whether specific targets are being achieved. The overall sustainability aims of a project should be known and understood across all levels.

Impacts of urban infrastructure need to take place at all scales from a component, building/site, neighbourhood, city to region. Sustainability needs to be considered at all stages of development of an urban infrastructure project from inception of a project idea, design, design assessment, construction, operation to demolition.

There is significant development of conceptual models associated with sustainable development, but making operational such conceptual models through the use of standardised evaluation tools is not widely carried out. There are a wide range of reasons why tools are required, from being used to assess the impact of an individual project through to being used to direct strategic policy decisions at local and regional level. Tools can be very useful for managing and steering a project to be sustainable and efficient throughout its duration.

Benchmarks or information bases can provide confidence at all levels of the decision making process to ensure that minimum required standards are being met, whether these standards are international, national, regional or site specific. The review of tools has identified that there is a limited set of benchmarks available, particularly those that are realistically achievable without requiring vast amounts of data to be able to identify change. These information bases can be difficult to identify and unless from a reliable source, confidence in using benchmarks can be uncertain. Information bases vary greatly at sector and spatial scale.

Many projects are being undertaken that incorporate sustainability into urban infrastructure, but the ability to evaluate sustainability and have confidence in what is a good, useful project that could be transferred to other areas is lacking. Sixty case studies have been selected from each of the partner countries in order to investigate the use of evaluation tools in practice. These case studies have been identified in order to contribute to the understanding of how and why tools/procedures are involved in the decision making process.

The use of tools through the case studies have been seen to provide significant benefit to an organisation as a whole. Tools have been found to:

- encourage joined up thinking through an agreed understanding on what sustainability issues are to be achieved,
- support a consistent method for collection and reporting of data which, without guidance can be time consuming and repetitive,
- enable allocation of responsibility providing a clear understanding of the processes involved in the developmental procedure,
- provide a visible sustainable profile to others. By using an appropriate tool, an organisation can indicate awareness of sustainability and efforts that are being made to incorporate environmental, social and economic factors into practice.

Benefits are not generally considered in a holistic way but tend to be component based with only information that can be measured being measured. The 'added value' of changes to urban infrastructure need to be considered and measured wherever possible in order to be able to indicate the positive and negative impacts of incorporating sustainable innovation.

Cost is the currently the main driver for the building industry. Incorporating innovative, sustainable design into a project is likely to result in an increase in cost, which usually compares unfavourably with more typical approaches. However, these costs will reduce with an increase in demand over time, 'through greater efficiency and better use of natural resources we can break the old link between economic growth and environmental damage' (Environment 2010: Our future, Our choice, 2001). As sustainable practice becomes more widespread additional costs generated by greater innovation will diminish. Projects often need to be carried out as quickly as possible, at the least cost possible. Having to put effort into finding tools to make a sustainability evaluation and then identify appropriate resources and techniques takes time and money that are not often available. If a tool is complicated to understand, difficult to use and implement potential users will be discouraged to incorporate the practice into daily working.

PETUS has so far shown that there is a need for clarification of the concept of sustainable development for decision makers. Uncertainties exist as to what sustainable development encompasses – the tendency is to think only environment with economic and social factors not incorporated into sustainability assessments. Urban infrastructure projects can often be considered and promoted as more sustainable when all three sectors are integrated.

Society and politics are often resistant to innovation and change. There is a need to encourage acceptance of change where sustainable benefits are likely to be experienced. A number of tools encourage public participation which is sometimes considered a hindrance in infrastructure projects as the public often oppose developments, this can increase the time taken during the design and planning stage. However, many of the case studies within the project have illustrated that if the public are involved at the outset of a project and are included as a stakeholder, contributions can assist the long term sustainability of a development particularly by contributing contextual knowledge.

There is often a fear of investment in innovation due to potential failure, financial incentives could be offered in order to offset this. There is also an increasing level of 'environmental fatigue' with people becoming tired of making an effort to be sustainable without seeing a change. Tools should make clear the benefits that are obtained from considering sustainability to enable transparency of the decision making process.

2.3.3 Developing a Framework of Practical Evaluation Tools. Findings from the case studies and tool review have identified the need for a framework that brings together useful tools and procedures in order to assist users in making a quick but informed decision on which approach to take to incorporate sustainability. The framework will include:

(i) A database *of Information* that will contain different levels (simple/complex) of data for case studies, tools and EU legislation. This will enable decision makers of all different levels to read and understand information that is relevant to them.

This part of PETUS will be able to be used:

- independently by end users to select by themselves information that is interesting or relevant to them.
- As part of the monitoring process that will be a data entry system that will guide the end user to appropriate material relevant to their project/plan.

(ii) *Procedure for monitoring of sustainability* will provide a decision support tool that will enable end users to collect together specific information about their project/plan that will be visible to all stakeholders. This will include items such as the sustainability statements and prompts to develop a environmental/social/economic 'GRID' of aims specific to their project but guided by cases, tools and

legislation as specified in the database. *Conflicts and opportunities* between sectors will be illustrated to create awareness to links with other sectors.

Fig.5 illustrates the process with monitoring stages indicated in the boxes on the right and components of the database on the left. PETUS users can simply obtain information from the database or can use the monitoring procedure to track sustainability throughout the development of an urban infrastructure project.

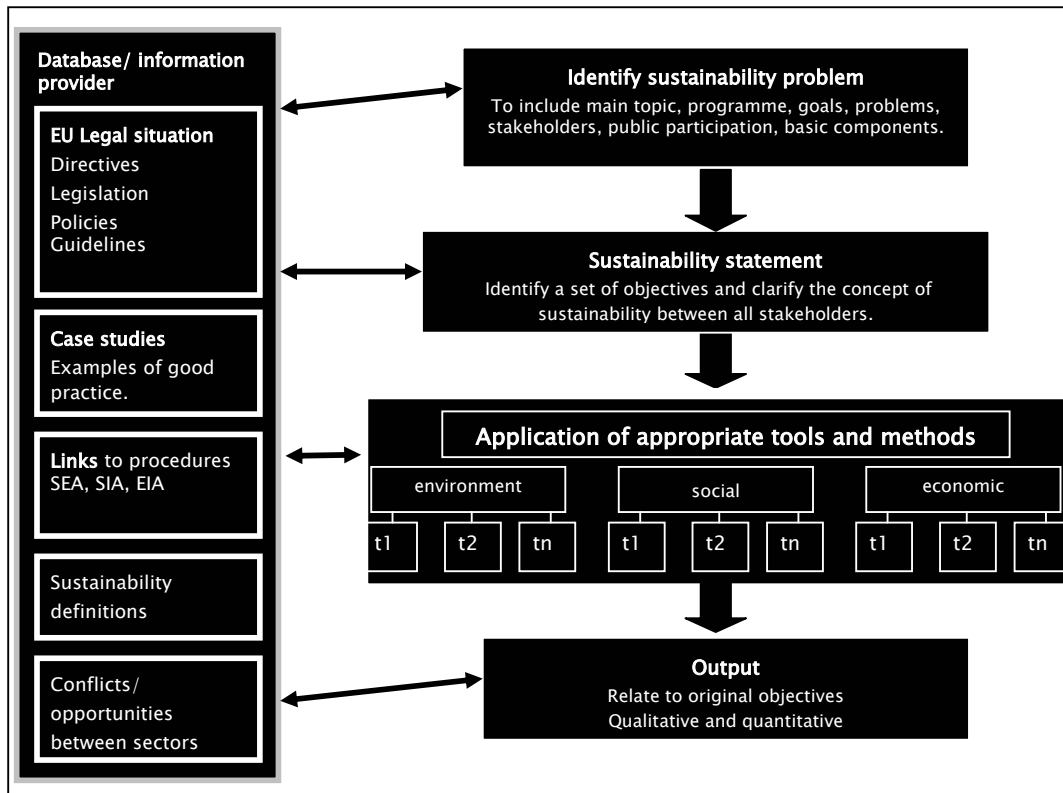


Fig.5 The Decision Support System for the PETUS project illustrating the interaction between the database and the process

3. Conclusions

To be able to plan for sustainability in cities existing situations need to be very familiar before appropriate changes can be made with regards to sustainability. Tools to quantify existing built environment conditions that can be used to manage and plan to improve the overall sustainability of the urban situation are essential. These tools need to be integrated into decision making processes and bring useful data together from different sources into a usable format. The EEP model was originally developed to assist with planning and management for reductions of energy use by buildings and traffic within cities however, the model has since been developed to incorporate a social aspect of sustainability, health. The EEP model framework has been designed to incorporate further sustainability components when available to assist with the drive towards sustainability.

Research indicates that a limited number of tools are being used in practice to assess sustainability in urban infrastructure. However, from discussion it appears that many organisations are committed to make the step to incorporate sustainability into urban infrastructure developments at all levels of decision making. The main factor preventing the step forward is the lack of awareness of what sustainability actually incorporates and also a lack of confidence to utilise the many tools that are available. All levels of the decision making process need to accept that there is a need for change and to work together to ensure that it happens. It is hoped that the framework that is developed as part of the PETUS project will provide clear and concise information on sustainability and also guide actors at

all levels of urban infrastructure towards the use of the most appropriate procedures to ensure sustainability is maximised.

Acknowledgements

The development of the Energy and Environmental Prediction (EEP) model was funded by the Engineering and Physical Sciences Research Council (EPSRC), project codes GR/K19181 and GR/L81536/01.

The Housing and Neighbourhood and Health (HANAH) project was funded by the Medical Research Council (MRC) project reference G9900679.

The Practical Evaluation Tools for Urban Sustainability (PETUS) project is funded by the European Community as part of the Fifth Framework Programme Energy, Environment and Sustainable Development, Key Action 'The City of Tomorrow and Cultural Heritage'. Project partners developing the PETUS project include; Veronica Cremasco, Universite de Liege, Belgium, Norbert Plass, Gudrun Lettmayer and Ingrid Kaltenegger, Joanneum Research Forschungsgesellschaft, Austria, Morten Elle and Jesper Ole Jensen, Danmarks Tekniske Universitet, Denmark. Marcel Miramond, Elham Alfakih and Emmanuel Lardieg, URG-C-Hydrologie Urbaine, France, Kari Ojala, Etukeno Oy, Finland, Rene Wansdronk, Wansdronk Architectuur, The Netherlands, and Elena Dimitrova, Aneta Markova and Ina Kovacheva, University of Architecture, Civil Engineering and Geodesy, Research and Design Centre, Bulgaria.

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SUSTAINABLE FAÇADE RATINGS TOOLS AND ENERGY IN THE TROPICS – HOW USEFUL ARE THEY?

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Abstract

This paper considers the applicability of various methods of rating the sustainable performance of building facades in Hong Kong. It considers approaches to design and construction of facades, from prescriptive indicators such as Overall Thermal Transmission Value (OTTV) ratings to performance measures such as whole building energy consumption. Sustainable façade design must consider energy impacts in relation to thermal transmission, orientation, but also take into account issues and impacts of occupant blind use, HVAC performance and daylight switching. In addition a rating tool should set and achieve wholistic sustainable benchmarks. OTTV rating systems are compared to current methods of predicting performance using whole building energy simulation studies. The paper compares their relative benefits and likely impact on energy use. It highlights several shortcomings of the Hong Kong OTTV rating method and suggests a model for modifying OTTV to take into account other sustainable façade design initiatives that significantly impact on Energy. The paper highlights the overall benefits of whole building analysis and operational rating.

Arup's approach was to test perimeter zones for predicted cooling energy for a number of façade configurations. Reference values from known conventional façade types were used as references to compare the performances of innovative façade options like ventilated cavities. Over 1000 simulation runs were carried out to generate data on thermal energy performance, daylighting and comfort performance. The results generated were also normalised and compared against the existing OTTV scheme. Some discrepancies are identified between the two analyses, and these have been highlighted. Of particular note is the fact that, compared to the current study, the OTTV equations seem to overestimate the cooling load reductions in the northern orientations that get little direct solar radiation. In addition issues such as daylight contribution and blind use were considered to estimate a wholistic approach to façade energy impacts. The results were correlated for cooling thermal performance by utilising a simply understood parameter – solar aperture. Estimated values for fan energy use, etc., allow a simple computation for total electrical energy use in perimeter areas. Estimates of the savings due to daylighting have also been generated. Advanced analysis of glare and daylighting were carried out and the results were broken down into simplified ways of estimating the comfort and daylight saving for the configurations tested.

Keywords : Sustainable buildings, Performance-based, Green policies.

1. Studies on the Annual Energy Performance

1.1 Annual Energy Use

The Annual Energy Performance as developed in this study is the result of a series of DOE2 simulations, which includes electrical energy for heating and cooling, electric lighting, office equipment and has factored in the predicted energy saving from using daylight, the impact of using blinds, and orientation.

As the heating loads are typically small in Hong Kong, electrical heating has been assumed for this analysis. Since only electrical energy use was considered in the study, this indicator is also a direct measure of CO₂ emissions.

This indicator, given in kWh/m² for thermal energy needed for cooling (and heating). It is calculated either by dynamic simulation, or by developing a correlation equation based on the results of many

simulation runs. This indicator is useful for evaluating the performance of a “standard” façade module (or bay) that forms the external wall of a perimeter cabin module as shown in Fig.1.

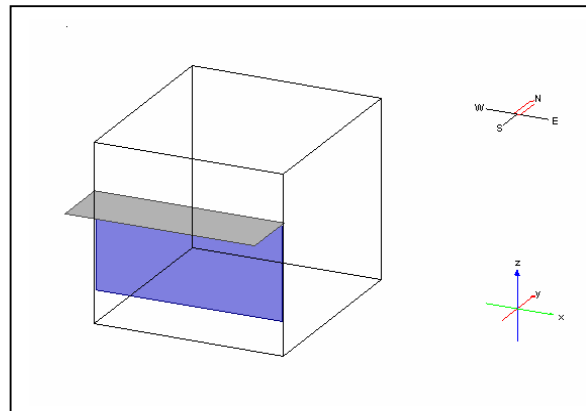


Fig.1 Indicator for evaluating the performance of a standard façade module

- Performance Parameters for the Façade

The glazing system has been shown to contribute the bulk of the thermal transfer in the OTTV calculations. Other studies in Australia, where climate conditions are similar to Hong Kong in some locations have also highlighted this effect. The energy performance of a façade is also related to access to daylight, use of blinds and conducted energy. The following are the key parameters used when simulated façade performance.

- Solar Gain Indices

The **Solar Heat Gain Coefficient** (SHGC) measures what fraction of the solar radiation that strikes the outside of the window actually enters the building.

Limiting the solar gain through the façade either by shading strategies or by specifying glazing products with low values of SHGC or SC have a big impact on OTTV and energy use.

- Daylighting Indices

The **Visible Light Transmittance** (T_{vis}) of the window glazing is an indication of the amount of daylight (electro-magnetic radiation in the frequency range 0.38-0.77 μ m) it will let through. The higher level of natural light transmitted indoors could potentially be used to reduce the energy used for electric lighting in the perimeter areas. A daylight linked lighting control system in commercial buildings will result in reduced heat generation within the space and consequently smaller air-conditioning cooling loads. Detailed RADIANCE simulations were run to predict glare and energy saving by daylighting.

- U-value

The **Thermal Transmittance** or **U-value** of an element is the measure of heat transferred through the element when one side is hotter than the other.

3. Ottv Calculation

A typical building 26 floors high, and is divided into podium and tower sections was considered as an example. The example calculations were used to study the performance of the façade as predicted by OTTV.

The building has an average window-to-wall ratio (or fenestration ratio) of 37%, as shown in Table 1. This figure is considered conservative, as some tower buildings can have over 80% of glass on their façade. The sample calculations use a glass product with a shading coefficient (SC) of 0.7. This is

considered to be very high in the context of modern practise, with modern glazing systems capable of providing a SC of 0.35 or lower.

Table 1: Window-to-wall ratio of example OTTV building

<i>orientation</i>	<i>wall area</i>	<i>window area</i>	<i>façade area</i>	<i>window-to-wall ratio</i>
south	929.12	637.60	1,566.72	40.7%
west	1,286.88	682.08	1,968.96	34.6%
north	1,025.76	540.96	1,566.72	34.5%
east	1,222.16	746.80	1,968.96	37.9%
sub-totals	4,463.92	2,607.44	7,071.36	36.9%

When analysing the façade only, it is seen that the heat transfer contributions from façade windows with SC of 0.7 is almost 95% of the total (Table 2).

Table 2: Thermal transmittance through windows as a percentage of the total, SC = 0.7

<i>orientation</i>	<i>wall gain</i>	<i>window gain</i>	<i>total gain</i>	<i>window % gain</i>
south	2,122.37	81,505.66	83,628.03	97.5%
west	4,173.91	58,488.36	62,662.27	93.3%
north	2,637.88	31,505.51	34,143.39	92.3%
east	4,416.04	77,504.99	81,921.03	94.6%
sub-total	13,350.20	249,004.52	262,354.72	94.9%

Thus the OTTV method confirms the importance of the role played by façade glazing for solar control.

3. Comparison of OTTV and Simulated Energy use

The Solar Factor for vertical façade glazing in the existing Code of Practice for Hong Kong was normalised and compared with the cooling load predictions for the largest (WWR=83.3%) single glazed case of the current study (Fig.2). While this was not strictly a comparison of “apples with apples”, the comparison gives important insights into similarities and differences between the 2 studies. The single glazed system has a SC=0.95, nearest to 1, and the results should be closet to a normalised solar factor. The results are plotted below and show a close match in most orientations. The major differences are in the SE, N and NW orientations.

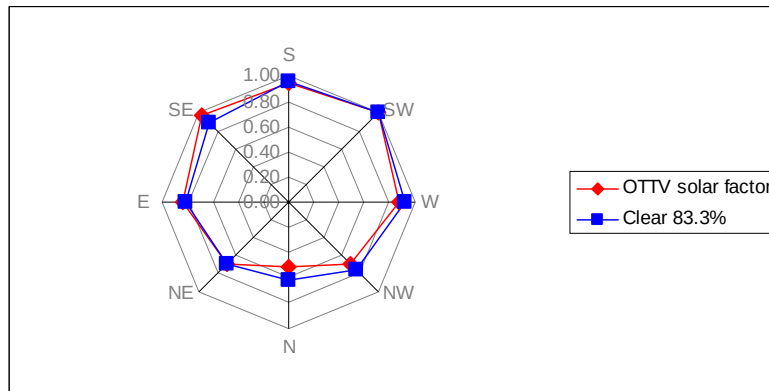


Fig.2 Comparison of OTTV Solar Factor with predicted cooling load for WWR=83.3% single glazing façade

The differences could be explained as follows:

- (i) In the SE orientation, the difference could be explained due to the fact that the plant provides cooling between 8:00am and 6:00pm only. This would not consider the impact of early morning sun in the SE orientation.
- (ii) The discrepancies on the N and NW orientation could be explained due to the fact that the original runs for determining OTTV were carried out over 10 years using DOE2.1-D. It is quite probable that the weather tapes did not contain explicit values for diffuse and direct solar radiation. The calculated diffuse radiation values would most likely have been derived from a clear sky correlation, which has been shown to underestimate diffuse radiation in tropical area with significant cloud cover. This would account for the smaller estimates of solar gain on the orientations with little incident solar radiation.

In addition to these discrepancies blind use and daylight can have an impact on real façade use. To investigate these effects regression analysis was performed to consider impacts.

4. Solar Aperture

A linear relationship was expected, and found to be true, between the predicted sensible cooling load and solar aperture as described earlier. Fig.3 below shows results for the SW orientation.

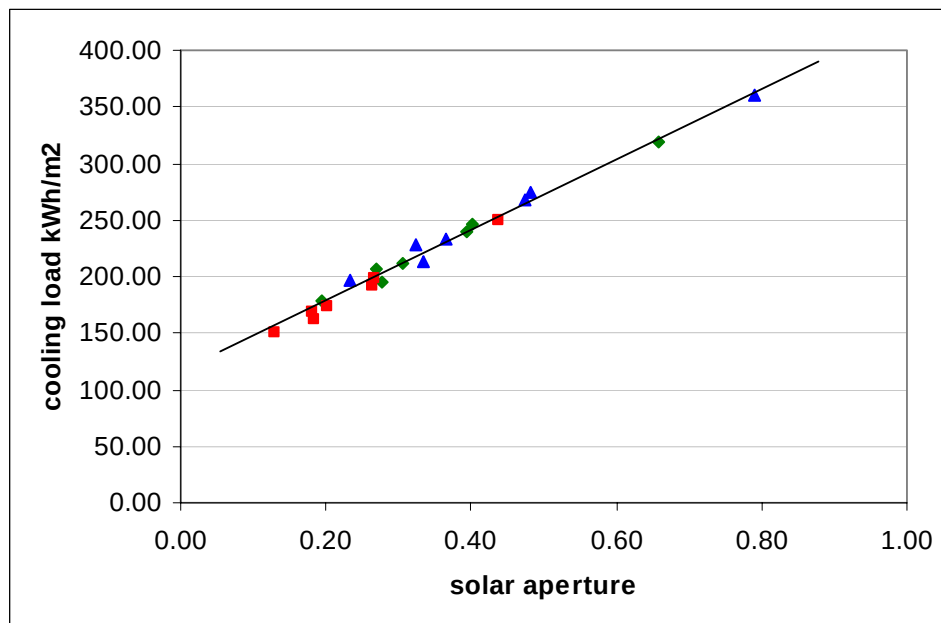


Fig.3 Linear relationship between solar aperture and cooling load for SW orientation; squares are WWR=46%, diamonds are WWR=69% and triangles are WWR=83%

Correlation coefficients were very high, indicating that confidence could be placed in the results. The results are also physically consistent, with the relationship being less sensitive (has a smaller value for slope) for the North orientation that receives the least amount of direct radiation, as shown in the Fig.4 below.

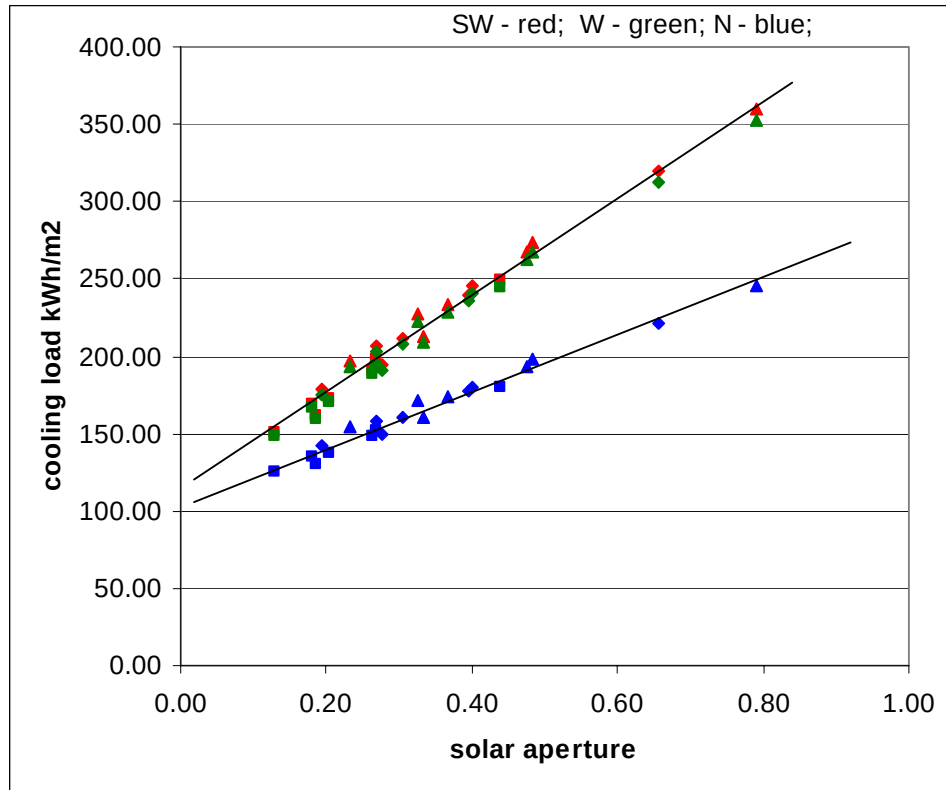


Fig.4 Linear relationship between solar aperture and cooling load for SW, W and North orientations; squares are WWR=46%, diamonds are WWR=69% and triangles are WWR=83%

Based on these results, a set of linear correlations were derived for each orientation as given in Table 3.

Table 3: Correlation between Solar Aperture and predicted annual Cooling Load in kWh-m²

<i>orientation</i>	<i>correlation</i>	<i>intercept</i>	<i>slope</i>
S	0.992	110.4	288.1
SE	0.993	107.6	267.5
SW	0.994	113.1	319.1
W	0.994	111.8	310.5
E	0.993	105.8	249.7
N	0.989	104.0	182.9
NE	0.990	104.8	199.2
NW	0.992	108.2	243.9

These correlations can be used to calculate the predicted cooling load for any glazing system, given it's SC and WWR combination by using a formula of the form:

$$\text{cooling load} = \text{intercept} + \text{solar aperture}_{\text{orientation}} \times \text{slope}$$

where the *intercept* and *slope* are taken from Table-4, and solar aperture is defined as:

$$\text{solar aperture} = \text{WWR} \times \text{SC}$$

It should be noted that for modern buildings with good design, the solar aperture would generally range from 0.2 to 0.6, and have visible transmittance values of about 50% to encourage daylight linking where possible.

5. Internal Blinds

A series of runs were carried out to check the impact of internal blinds, and to develop a relationship to predict this impact. The blinds were configured, as described earlier, to deploy when 200 W/m² was incident on the outside of the glazing, and were positioned to cut-off most direct solar radiation.

The simulations predicted that the impact of blinds was greatest on glazing systems having large solar aperture, particularly on orientations that received large amounts of direct solar radiation. Generally the impact was greater than 10%. The impact of blinds reduced significantly at low values for solar aperture, ie., when high performance glazing was used in the curtain wall. Fig.5 shows the South orientation results.

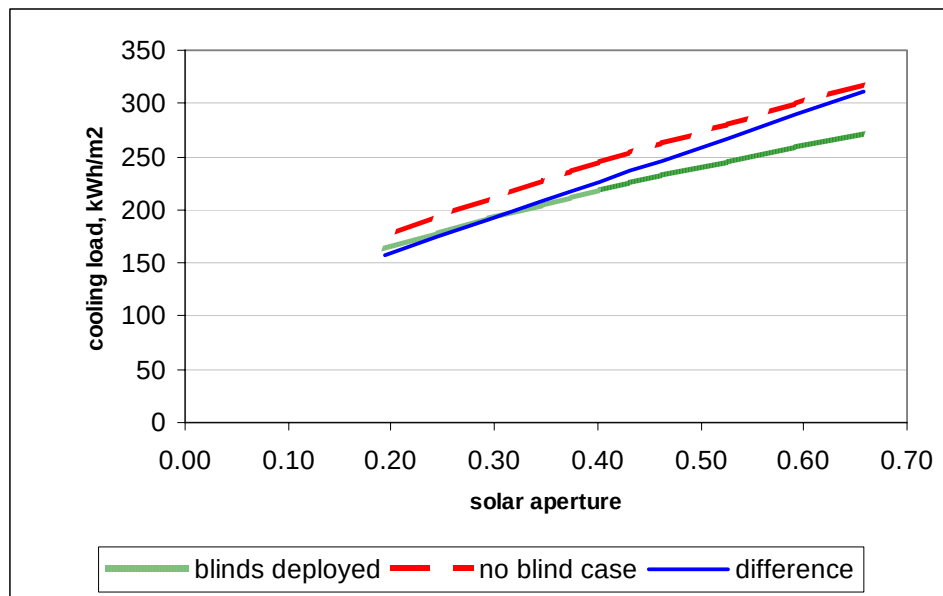


Fig.5 Impact of deploying internal blinds on South orientation

6. Shading Devices

There is a large discrepancy between the ESM (external shading multiplier) for the OPF (overhang projection factor) as given in Table-6 and the values derived in the study using DOE2.2. This study predicts a greater effectiveness for overhangs, as shown in Fig.6.

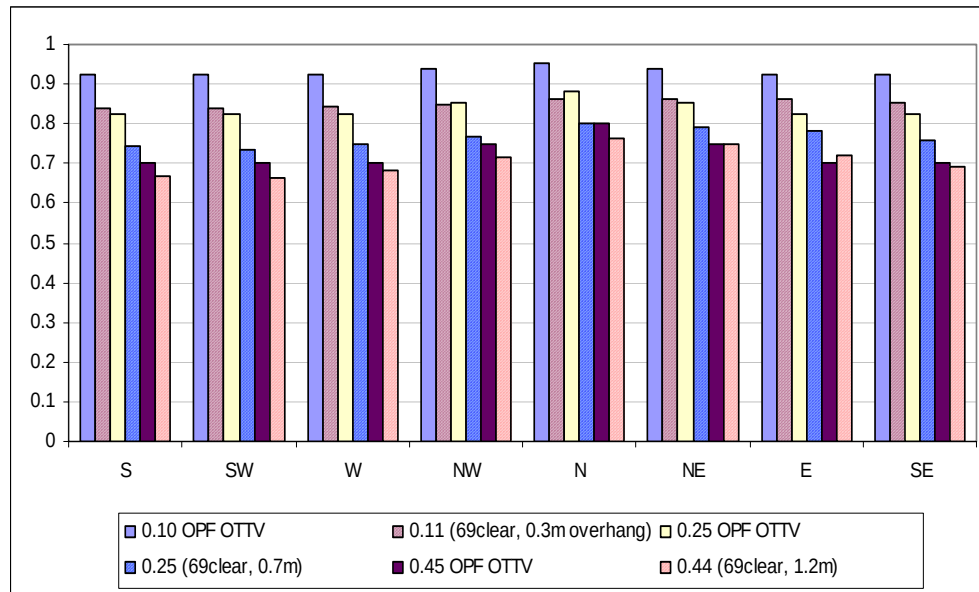


Fig.6 Comparison of ESM multiplier for overhangs (OPF) in the OTTV scheme and current study

The reason for this discrepancy is not immediately evident, and there could be a number of explanations, possibly a combination. Some factors that could be put forward are a different volume, or area for the zones modelled in the respective studies. Internal loads are significantly lower, and this would lead to greater cooling contribution from solar loads that are impacted by overhangs. Only annual sensible cooling is being compared against the OTTV value, which seems to have been developed for total cooling load, and latent loads are significant in Hong Kong.

7. Conclusions

The comparison of OTTV calculations and simulated results for typical buildings in Hong Kong shows significant discrepancies. The discrepancies may arise from one or a combination of issues as follows;

- Services layout and Plant operational assumptions
- Sky and weather file differences
- Simulation engine
- Internal loads and building form
- Use for blinds

These discrepancies can lead to annual cooling load predictions that are 30-40% different to simulated figures. In addition daylight switching and advance vented facades create further discrepancies between OTTV calculations and actual energy use associated with facades.

OTTV calculations are façade design tool which is easy to follow and helps façade designers and certifiers ensure a certain level of performance. They do not however help predict what the final energy use of the building is and have no method to guarantee this. In Australia all major buildings now use dynamic annual energy simulation to help predict overall energy use. These figures can be used to establish operational targets that are metered against actual energy use. In addition it allows designers to make trade offs between lighting design, mechanical systems and façade choice. It also allows flexibility to consider advanced facades such as vented cavities to improve building performance. It is recommended that all major buildings are encouraged to use full building dynamic modelling to estimate total building energy use and that appropriate targets are developed in order to allow design flexibility. This scheme can run voluntarily along with OTTV. Ideally however building energy use targets are established and it is up to the designer to optimise the overall building performance to meet these demands.

A COMPARISON BETWEEN PRESCRIPTIVE APPROACH AND PERFORMANCE BASED APPROACH ON DAYLIGHT FOR HONG KONG

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Abstract

The desirability of a high-rise and high-density approach to urban planning is challenged by an outbreak of SARS in 2003 in a number of populated and densely developed cities. In Hong Kong, awareness to inherent environmental issues such as poor daylight for domestic kitchens in high-rise towers is taken up by a government initiative to introduce a performance based design method to supplement a prescriptive design method Rectangular Horizontal Plane (RHP). Vertical Daylight Factor (VDF) has been proposed as the performance based method. However, this design approach raises critical concerns of its pros and cons. This paper makes a technical comparison of the two methods based on their variables and methodology to improve daylight access for domestic kitchens in a compact city. The study found that as VDF gives more area of light coming from surrounding of the building, it would enhance the provision of daylight in the high-rise residential building in densely urban conditions. As a result, this method may provide better daylight to the domestic kitchen.

Keywords : Daylight access, Rectangular horizontal plane, Vertical Daylight Factor.

1. Introduction

From the 1960s to 2003, local building codes that govern daylight for residential buildings were based on a mandatory and prescriptive approach that guaranteed a minimum external area of un-obstruction for daylight admittance for specified habitable spaces on the lowest floor of a tall building. This minimum area was based on a horizontal plane with depth derived from a predetermined ratio of total building height multiplied by a nominal width of 2300mm. This approach is named the RHP (rectangular horizontal plane) calculation method for daylight design, introduced to architects and building developers since 1959 (HKSAR, 1959).

Recent decade (1990s) shows a tendency of ever-increasing number of stories and building height. The prevailing number of story goes from 30, 40 to 60 floors or more during 1980s to 2000s. Recent field measurements of domestic kitchens in these three generations of towers depict a down drop of daylight level at kitchen worktop as a result of increased stories and height (Lau et. al, 2004).

In 2000, the building controls authority commissioned a consultancy study to review existing byelaws concerning building hygiene and safety for residents (Ng , 2004). The result of this study has been published in the proceeding of Eighth International IBPSA Conference (Ng, 2003). The opinion of the consultancy study was that existing building code that was simply a prescriptive approach was insufficient to guarantee good quantity of daylight especially for domestic kitchens as towers increase their height. It was recommended to adopt a performance-based design approach for daylight design.

The performance-based approach was based upon a daylight factor theory widely accepted by most countries. The consultancy study recommends a Vertical Daylight Factor (VDF) Method as a performance based design approach. In December 2003, the building authority introduced the VDF method as a supplement to the prescriptive method (Building Department, 2003).

Local practitioners of residential buildings design raised doubts about the benefits and limitations of the newly introduced VDF method because of apparent complexities in the mathematic modeling and site planning implications.

This led the authors to undertake a critical review of the VDF method in terms of its practical value and implications. The review process adopted a comparative approach to evaluate both prescriptive approach of RHP method and the newly introduced performance based VDF method.

2. Overview of Building Codes Governing Daylight

2.1 Rectangular Horizontal Plane (RHP)

For the RHP approach, it is stipulated by building regulations of Hong Kong that the minimum distance between building blocks is determined by a minimum prescribed plane of 71.5° , when the window is in a room used for habitation such as a bedroom or living room; or 76° from the horizontal when the window is in a room used as an office or as a kitchen. The minimum clearance of building from boundary is determined by a minimum prescribed plane of 81° when the window is in room used for habitation, or 83° when the window is in a room used as an office or kitchen. This value is obtained by assuming a rectangular horizontal plane, in front of the window, unobstructed and uncovered, and extends from the face of the window such that its length is at least $1/3h$, $1/6h$ (for rooms for habitation) or $1/4h$, $1/8h$ (for rooms as office or kitchen), where h , the height of the building measured from the sill of the of the window concerned (to Fig.1a-c). It is also stipulated that the rectangular horizontal plane should have a minimum width not less than 2.3 m, with an area not less than 21 m^2 ; and the window/ floor ratio of any room should be at least 10%.

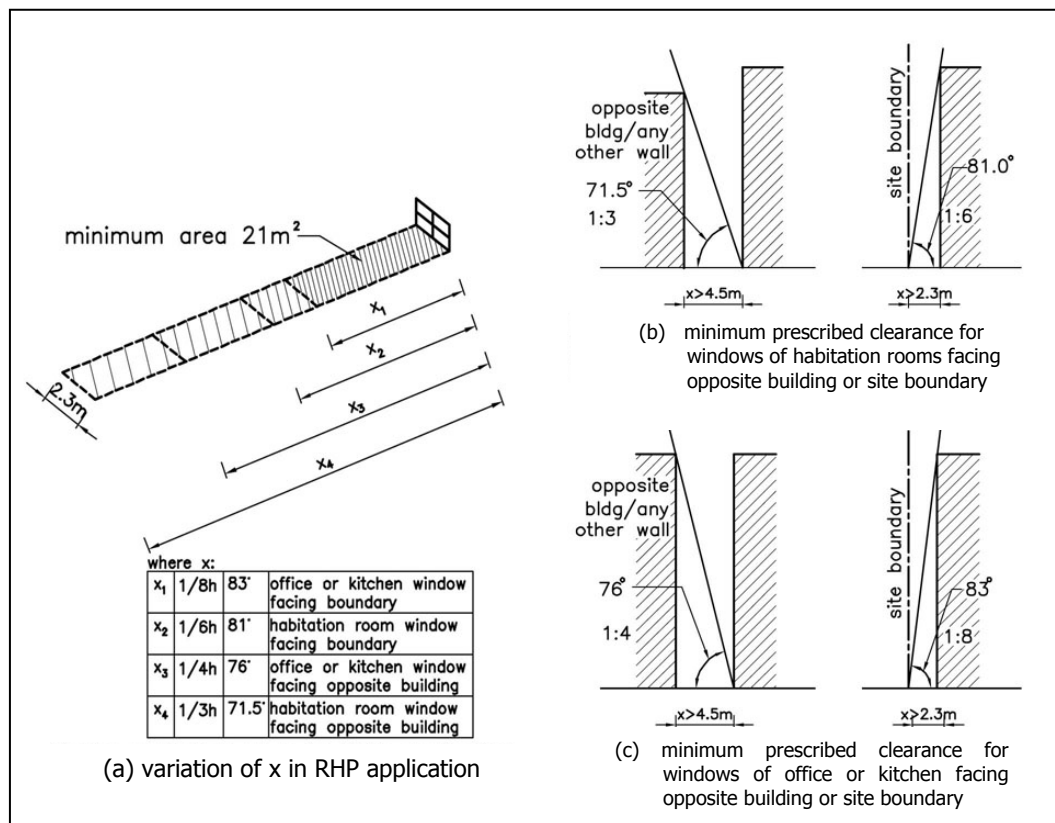


Fig.1 Principles of RHP application

2.2 Vertical Daylight Factor (VDF)

Proposed by the Buildings Department in the end of 2003 (Building Department, 2003), VDF is a new set of standard for the provision of natural lighting in habitable rooms and domestic kitchens described by Building (Planning) Regulations (B (P) Reg.) 30, 31 and 32:

Table 1. Recommended VDF values by the Buildings Department

Room of domestic building	Vertical Daylight Factor (VDF) (measurement taken on the center-line of window plane)
Habitable Room	8%
Kitchen	4%

"Vertical Daylight Factor" means a ratio in percentage of the total amount of luminance falling onto a vertical surface of a building to the instantaneous horizontal luminance from a complete hemisphere of sky excluding direct sunlight. In essence, it takes into account light coming from the sky directly and from reflected light of surrounding buildings and the ground both above and below the horizon.

The Unobstructed Vision Area (UVA) calculation has been recommended as a reliable method to calculate VDF. This method is based on simplified design tool for assessment of Daylight Factor, which was proposed by Ng and Tregenza (2001). Two main UVA principles are as follows (Building Department, 2003):

- Unobstructed vision area of a window is the unobstructed area bounded by a cone with the horizontal angle measuring 100° up to both edges of the window's glazing pane, symmetrical and perpendicular to the window plane (Fig.2a).
- Maximum length of the cone of the unobstructed vision area is equal to the height of façade in which the window is provided (Fig.2b).

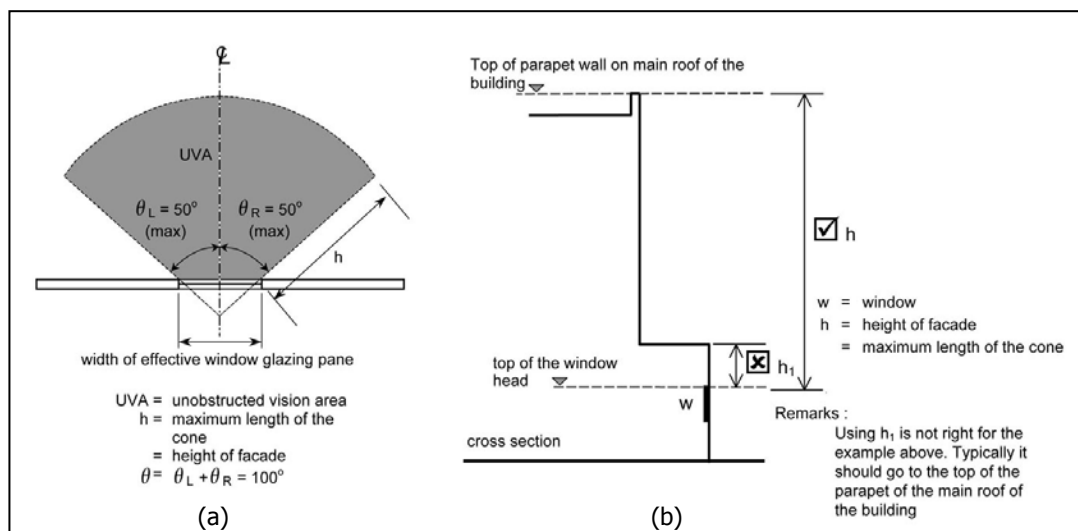


Fig.2 Details of VDF principles

2.3 Assumption

In this paper, we pursue a review on the two approaches by comparing their (i) variables in formulation, orientation, sustained angle, percentage of glazing, and (ii) methodology. For standard of comparison, a typical residential tower of building height of 122 m and height of façade of 120 m is taken for consideration unless otherwise stated.

3. Comparison between RHP and VDF

3.1 Variables

3.1.1 Formulation. Both prescriptive method of RHP and performance-based method of VDF contain variables. RHP guaranteed a minimum area of un-obstruction for daylight admittance into the exterior of a window of a habitable space on the lowest floor of the building. The minimum area is based on a horizontal area with its depth derived from a predetermined ratio of total building height and a nominal width of 2300 mm, i.e. $RHP = x(2.3)$, where $x = 1/3, 1/4, 1/6, 1/8$ of the height of building (Fig.1); while the simplified method of UVA is a sector area calculated as, $UVA = \pi r^2 \theta / 360$, with variable θ and r . Fig.3a shows, in a most critical case, when $\theta = 100^\circ$ (max), then r become minimum (UVA_A), or when r becomes maximum, then θ become minimum (UVA_B). Both cases UVA_A and UVA_B are of the same area, but the shape of UVA cone differs from each other. In between these two critical cases lies a lot of possible combinations of r and θ with the same UVA.

Table 2. Comparison of Variables

	Rectangular Horizontal Plane	Vertical Daylight Factor
a. Area	Rectangular	Sector
b. Formulation	$x(2.3)$	$\pi r^2 \theta / 360$
c. Variables	X	r, θ

In comparison, the flexibility of variable of RHP is less than that of VDF. As in RHP the length of the unobstructed plane is proportioned by a factor, which only depends on the function of the room, whereas in case of VDF there is lots of variation within the maximum θ and maximum r .

3.1.2 Orientation. As stipulated in B(P) Reg31(3), the base of RHP is common with the sill of the window. Further relaxation allows a window not meeting the full requirements of prescribed window under B(P)Reg31(2) would be acceptable if the window when angled at not more than 15° from external wall, meets the prescription requirement. Fig.3b(i) shows the application of RHP by principle. In real situation as in Fig. 3b(ii), the RHP of two kitchens often coincides to minimize the clearance from opposite building.

Whereas in the application of VDF, the orientation of UVA cone has a much greater range of 100° . In Fig. 3c, UVA_A, UVA_B, UVA_C & UVA_D could satisfy the required UVA of $1,900 \text{ m}^2$. It demonstrates that the orientation of projection of UVA is very flexible, and could be manipulated within the range of 100° according to the location of the obstruction, depending on the design of master layout plan.

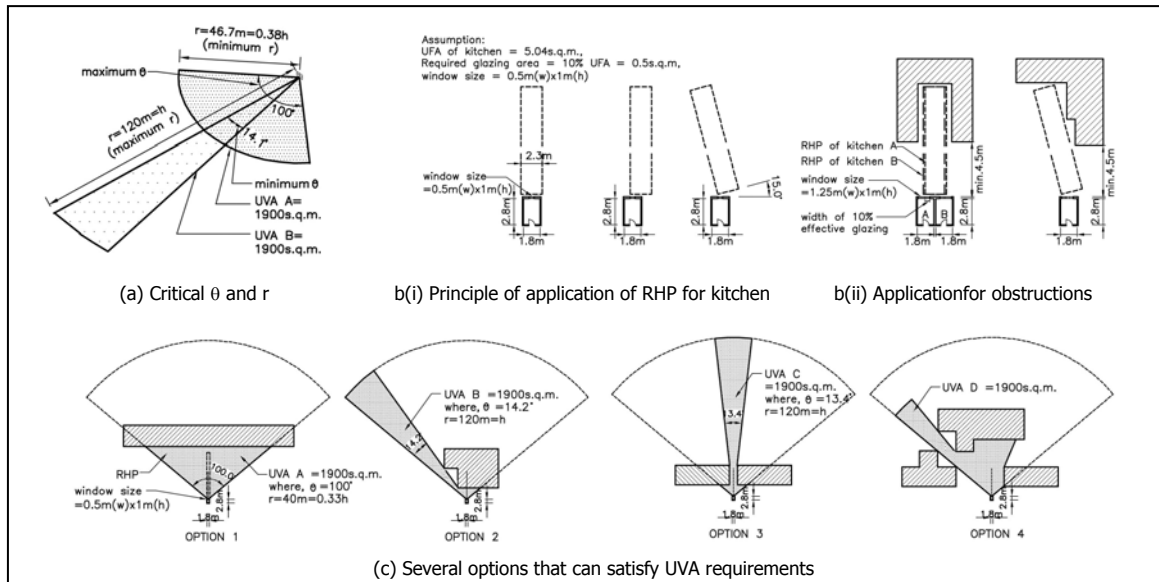


Fig.3 The application of RHP and VDF

3.1.3 Sustained angle. As discussed, the RHP inclined at angle of 71.5° , 76° , 81° and 83° with respect to the function of the rooms to determine the minimum distance from its opposite block or boundary (Fig.4). In a VDF application, a sustained angle of $45^\circ < \theta < 69^\circ$ is adopted. These sustained angles are, however, below the limitation of the use of UVA method as proposed by Ng (2003). Ng (2003) points out that UVA method is robust when the angle $> 70^\circ$, and should be used within its limitation. The smaller the sustained angle, the more the separation between opposite buildings, i.e. more amount of daylight penetrating into the room.

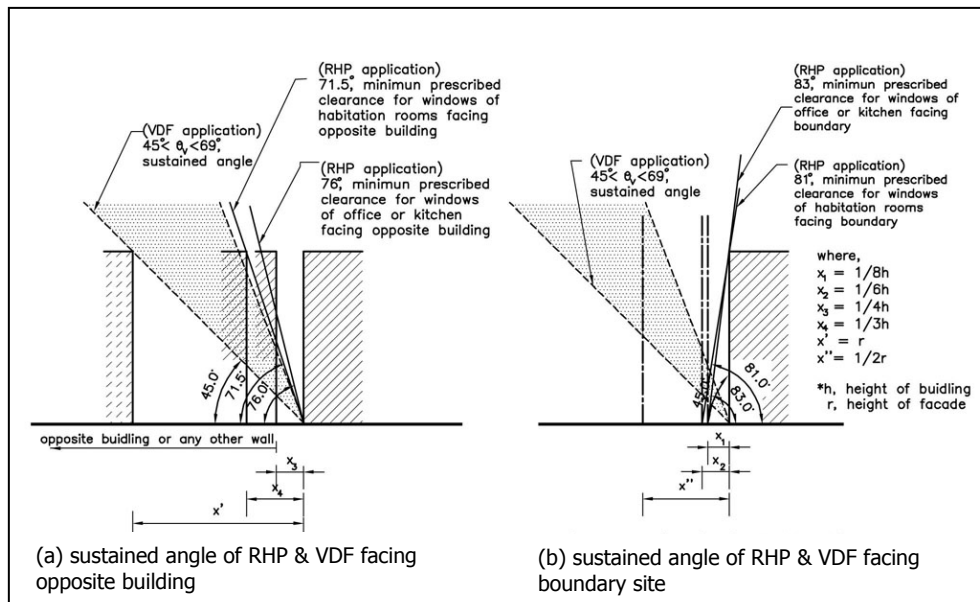


Fig.4 Sustained angle of RHP and VDF

3.1.4 Percentage of Glazing. B(P)Reg30 stipulated that the aggregated superficial area of glass in window or window shall not be less than one tenth of the area of the floor of the room. This minimum requirement applies to both RHP and VDF applications. In the provision of VDF it is taken into account that as larger the

percentage glazing, the smaller would be the required UVA. This encourages the provision of larger window. However, no such provision is allowed in RHP application.

3.2 Methodology

In the comparison of methodology typical 8 units cruciform plan is employed. As in Hong Kong, there is a high demand for residential units, but with little supply of land, so high-rise and high efficient plan is essential. This compact plan with 8 units per floor is an ultimate solution to cater for the high demand for residential units and regulations. Stipulated in Building Regulations all rooms for habitation expect bathrooms have to be equipped with windows, in planning terms, it virtually means that all rooms would have to face outward for a maximum 1 orientation in order to attain adequate clearance for each window. The least important room, being kitchens, are often allocated the worst orientation – a gap on the floor plan, with a limited external view. This narrow gap, called an re-entrant, is usually about 2.3 m wide, i.e. nominal width of the RHP.

In a design application, RHP is considered to be an easy method to use. With known building height and functions of room, the minimum clearance between opposite blocks or boundary could be determined. While in VDF application, more detailed assumptions are required in order to determine the required clearance. Prerequisite information as the height of the façade, function of the room, room size and glazing area are required in order to computer the required UVA of the particular room notwithstanding the fact that such information may be too detailed to be available in an early design stage.

With the above design data, UVA of rooms could be obtained by using the most critical case, maximum θ or maximum r . UVA diagrams of a typical 8-unit plan are obtained as shown in Fig. 5. Not surprisingly, Fig. 5 only shows the possibilities of the two most critical cases, with the manipulation of r and θ , there will be lots of other UVA diagrams for this typical plan.

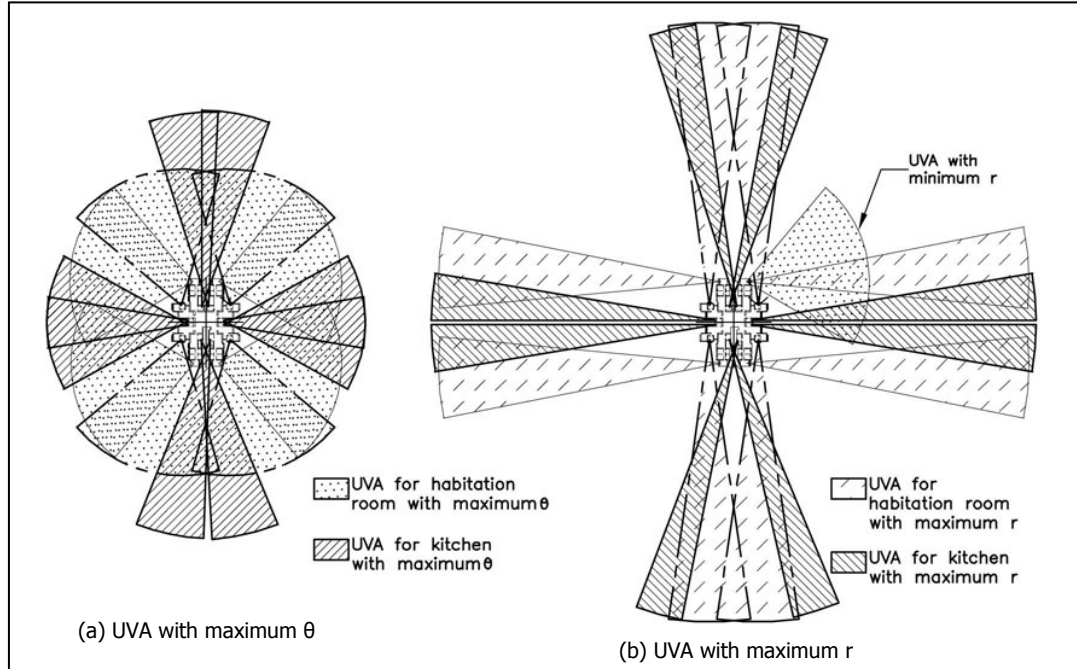
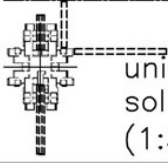
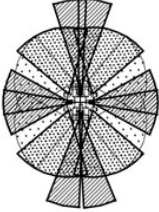


Fig.5 The methodology of the use of VDF in 8 units flat

In other words, the high flexibility in variation of shape and orientation of the UVA cone also resulted in high complexity in the design application (refers to Table 3).

Table 3. Requirements of the application of RHP and VDF

Applica-tion	Height of building	Room function	Room size	Glazing area	Result
RHP	required	required	not required	not required	 unique solution (1:3000)
VDF	required	required	required	required	 multiple options (1:6000)

The summary of the comparison between RHP and VDF can be seen in Table 4 below.

Table 4. Summary of Comparison between RHP and VDF

	Rectangular Horizontal Plane	Vertical Daylight Factor
1. Variables:		
a. Formulation	Less flexible	More flexible
b. Orientation	Less flexible	More flexible
c. Sustained Angle	Smallest of 71.5°	45° < θ < 69°, enhanced
d. Percentage of glazing	10% as minimum requirement	Allowance on 10%, 15% and 20%, encourage provision of larger windows
2. Methodology	Easier to use	More difficult to use; As a checking tool rather than a design tool.

4. Conclusion

The comparison of variables and methodology between RHP and VDF has been done. The study found that as VDF gives more area of light coming from surrounding of the building, it would enhance the provision of daylight in the high-rise residential building in densely urban condition. As a result, this method may provide better daylight to the domestic kitchen. However, there should be further research regarding this method in terms of the quantity of daylight in residential building especially the actual benefit for kitchen from both function and habit points of view before it can be accepted as a building code to replace the RHP method.

Acknowledgement

This paper is developed from a research project no. HKU7205/02H funded by the Hong Kong RGC Research Grants Council. The authors would also like to acknowledge Mr. Li. S.F., and Mr. Lam W.H. for their respective contributions.

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T5 FLUORESCENT LAMP SYSTEMS AND BUILDING SUSTAINABILITY

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Abstract

T5 linear fluorescent lamps are a new member of the fluorescent lamp family. The main advantages of the new lamp are that they are smaller in size, have higher luminous efficacy, better lamp lumen maintenance and more environmental friendly. The smaller T5 lamp saves not only energy but also saves raw materials, e.g. glass, phosphors and packaging material, for the production and transportation of the lamp. Using T5 lamps also helps to reduce the amount of mercury that would pollute the environment at the end of lamp life and/or the cost for waste treatment or recycling. However, T5 lamps require a higher ambient temperature than T8/T12 lamps for optimum light output. This may cause great problems in using open-bottom luminaires in air-conditioned rooms because cool air can enter the lamp compartment resulting in significant reduction in light output. The temperature issue has left many lighting designers wondering whether they should consider T5 systems instead of T8 systems, in air-conditioned new constructions and retrofitting old T8/T12 magnetic systems. This paper clarifies these important issues and discusses the contribution of T5 fluorescent lamp systems to the sustainability of buildings. The discussion will address the 3 issues: energy, economics and environment. Demonstrations will be given using design case studies with economic analysis to compare the performance of T5 lamps systems with T8 lamp systems. The demonstrations show that with careful design, in particular when the temperature issue is carefully considered, T5 lamp systems contribute significantly to the sustainability of the environment.

Keywords : Fluorescent lamps, Luminous efficacy, Optimal operation temperature, Cost analysis, Environmental impact.

1. Introduction

Fluorescent lamps are among the man-made white light sources with the highest luminous efficacy (lumens per watt, lm/W). Because of their high efficacy, good colour rendering, wide choice of colour temperatures and other advantages, fluorescent lamps are nowadays the most widely-used man-made light sources. It has been estimated that more than 50% of all electric lighting applications use fluorescent lamps (Kane and Sell, 2001). Among all forms of fluorescent lamps, tubular fluorescent lamps are the most popular ones. It has become a custom to label tubular fluorescent lamps by a capital letter T (denoting that the shape is tubular) followed by a number that indicates the diameter of the tube in eighths of an inch. When the tubular fluorescent lamp was first put into the market about 70 years ago, it was T12, having a diameter of 38 mm (1.5 inches). Some 25 years ago the T8 lamp with a diameter of 26 mm (1 inch) started to appear in the market. The most recent addition, entering the market about 8 years ago, is the T5 lamp which has a diameter of 16 mm (0.625 inch). Lamp manufacturers market T5 lamps by promoting their advantages as significantly smaller than previous versions, higher luminous efficacy, better lamp lumen maintenance and more environmental friendly. The marketing campaign of T5 lamps have left many lighting designers wondering whether they should consider T5 systems instead of T8 systems, in new constructions and retrofitting old T8 or T12 magnetic systems. Designers and engineers may be confused by the small difference in the efficacy between T5 and T8 systems. They may also be confused by the 10°C higher optimal temperature for T5 systems to operate most efficiently. This paper gives clarification to these important points as well as discusses the new T5 lighting system under three headings: energy, economics and environment.

2. Characteristics of T5 Lamps

2.1 Dimensions

T5 fluorescent lamps were designed with no consideration of compatibility with their predecessors. T5 lamp bases have different pin separations and different lengths from T8 or T12 lamps. Therefore, T5 lamps require different lamp holders and fittings and T5 lamps do not fit into T8/T12 luminaires. The lengths of T5 lamps have been optimized to fit into standard ceiling grid systems so that it is now possible to install recessed T5 luminaires end-to-end in a standard ceiling system. End-to-end installation in a standard ceiling grid is not possible for T8/T12 luminaires because the lamp itself is already of the length of the standard grid size so that the fitting must be longer than the standard grid separation.

2.2 Electrical and luminous characteristics

T5 lamps are available in two versions: a high efficiency (HE) version and a high output (HO) version. High efficiency T5 (T5 HE) lamps are available in 14, 21, 28 and 35 watts, corresponding to nominal lengths of 550 mm, 850 mm, 1150 mm and 1450 mm, respectively. T5 high-output (T5 HO) lamps are available in 24, 39, 54 and 80 watts, corresponding to the same series of lengths as the T5 HE lamps; several manufacturers also produce a 49 W version of the nominal 1450 mm HO lamp. T5 lamps are designed to operate only on electronic ballast. In almost all cases, T5 lamps do not work with T8/T12 ballasts and vice versa. Most manufacturers claim that their high-quality T5 ballasts have total harmonic distortion (THD) of less than 15% and power factor of higher than 0.95. Most T5 ballasts provide constant lamp current so that the lamp gives constant light output within a range of input voltage, say 180-250 V, and independent of the mains supply fluctuations. Dimming ballasts for T5 lamps are also available in the market.

T5 HO lamps are less efficacious than T5 HE lamps. T5 HE lamps have slightly lower maximum luminous flux output per unit length, but consume less power per unit length, than the new generation T8 triphosphor lamps. Therefore, T5 HE lamps have higher luminous efficacy than T8 triphosphor lamps. However, T5 HO lamps have higher maximum luminous flux output per unit length than T8 triphosphor lamps. Here, maximum luminous output refers to the luminous output at the most efficient ambient temperature, which is 35°C for T5 and 25°C for T8 lamps. The energy efficiency comparison between T5 and T8 lamps is complicated by the temperature effects and a detailed discussion on this issue is given in Section 3. Tables 1(a)-(b) list the electrical and luminous characteristics of T5 HE and T5 HO lamps, respectively.

2.3 Effects of lamp ambient temperature

Fluorescent lamp light output depends strongly on the ambient temperature around the lamp. This is due to that light output depends on the mercury vapour pressure which varies strongly with temperature. Some more explanation on this aspect is given by Chung and Yip (2002). T5 fluorescent lamps are designed such that they give maximum light output at a lamp ambient temperature of 35°C (NLPIP, 2002). This is 10°C higher than that for T8/T12 lamps which operate most efficiently at 25°C. Figure 1 shows the relative light output of T5 and T8 lamps as a function of lamp ambient temperature. The significant difference between the two curves shows that comparisons of the energy efficiency based on the quoted maximum luminous efficacy values may not indicate which lamp is more efficient for a given application. The light output and electrical performance at 25°C and 35°C are listed in Tables 1(a)-(b) for all common T5 lamps. The impact of ambient temperature on energy and economics will be discussed in Sections 3 and 4.

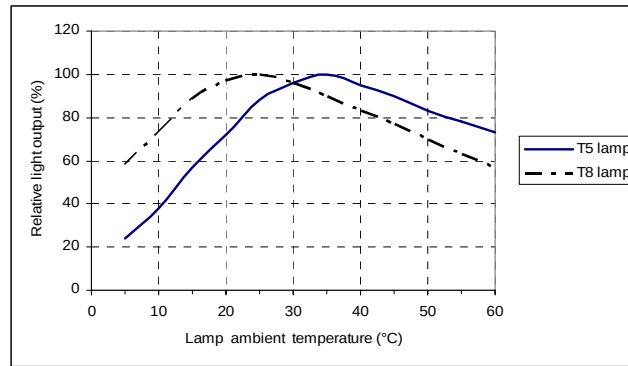


Fig.1 Variation of light output with ambient temperature for T5 and T8 lamps

Table 1(a). Typical electrical and luminous characteristics of T5HE lamps (data from manufacturers' catalogs)

Nominal length (mm)		550	850	1150	1450
Nominal lamp power (W)		14	21	28	35
Lamp power (W)	25°C	14.0	20.6	27.9	35.5
	35°C	13.7	20.7	27.8	34.7
Lamp voltage (V)	25°C	86	126	166	205
	35°C	82	123	167	209
Lamp current (A)	25°C	0.165	0.165	0.170	0.175
	35°C	0.170	0.170	0.170	0.170
Initial luminous flux output (lm)	25°C	1250	1900	2600	3300
	35°C	1350	2100	2900	3650
Luminous efficacy (lm/W)	25°C	89	92	93	93
	35°C	98	101	104	105
Lumen maintenance at 10,000 hours (%)		92	92	92	92
Rated life (165 min on, 15 min off cycles) (hours)		20,000	20,000	20,000	20,000

Table 1(b). Typical electrical and luminous characteristics of T5HO lamps (data from manufacturers' catalogs)

Nominal length (mm)		550	850	1150	1450	1450
Nominal lamp power (W)		24	39	54	80	49
Lamp power (W)	25°C	22.5	38.0	54.1	79.8	49.2
	35°C	22.5	38.0	53.8	80.0	49.3
Lamp voltage (V)	25°C	77	118	120	152	195
	35°C	75	112	117	145	191
Lamp current (A)	25°C	0.295	0.325	0.455	0.530	0.255
	35°C	0.300	0.340	0.460	0.555	0.260
Initial luminous flux output (lm)	25°C	1750	3200	4450	6450	4450
	35°C	2000	3500	5000	7000	4900
Luminous efficacy (lm/W)	25°C	78	84	82	81	90
	35°C	89	92	93	88	99
Lumen maintenance at 10,000 hours (%)		92	92	92	92	92
Rated life (165 min on, 15 min off cycles) (hours)		20,000	20,000	20,000	20,000	20,000

3. Energy Issues

One advantage of T5 lamps over T8 lamps is the higher lamp efficacy. However, comparisons of the performance between T5 and T8 systems based on the maximum light output values lead to a distorted picture. In fact, T5 lamps are not always the most energy efficient light source for an application. Detailed study has to be carried out case by case before deciding which lamp system, T5 or T8, has higher efficacy for the particular application. T5 lamps are designed for electronic ballasts, therefore, the published values of maximum light output and lamp efficacy refer to the values measured using electronic ballast with the lamp at the optimum ambient temperature of 35°C. T8 lamps are originally designed for magnetic ballasts and the published values of light output and lamp efficacy usually refer to the standard photometric condition with the lamp operated by standard magnetic ballast and the measurements carried out at an ambient temperature of 25°C. Table 2 gives a comparison of light output and efficacies at different temperatures among three lamp-ballast systems: 28W T5 lamp (all T5 lamps use triphosphors and must be operated with electronic ballast), 36W T8 triphosphor lamp with magnetic ballast, and 36W T8 triphosphor lamp with electronic ballast.

Table 2. Light output and typical lamp and circuit efficacies at various ambient temperatures in still air

	Lamp and ballast type (nominal 4-foot or 1200 mm)	15°C	20°C	25°C	30°C	35°C
Light output (lm)	T5 28W Electronic	1650	2150	2600	2800	2900
	T8 36W Magnetic	2950	3200	3350	3200	3000
	T8 36W* Electronic	2850	3050	3200	3050	2900
Lamp efficacy (lm/W)	T5 28W Electronic	66	80	93	100	104
	T8 36W Magnetic	84	89	93	89	86
	T8 36W* Electronic	92	95	100	95	94
Circuit efficacy (lm/W)	T5 28W Electronic	57	69	81	88	91
	T8 36W Magnetic	64	68	71	68	65
	T8 36W* Electronic	81	85	89	85	83
*Note: typical T8 36W lamp/electronic ballast system operates with lamp power of 32 W.						

Table 2 shows that at ambient temperature of 25°C, a T5 28W lamp has approximately equal efficacy with a magnetic-ballast-operated T8 36W lamp. When the power consumption of the ballast is taken into account, at 25°C, the circuit efficacy of the T5 lamp system (about 81 lm/W) is higher than that of T8 triphosphor lamp circuit with magnetic ballast (about 71 lm/W) due to the much higher power consumption of the magnetic ballast. However, at 25°C, both the lamp and circuit efficacies of a T5 28W lamp system (93 and 81 lm/W respectively) are lower than the corresponding value for a T8 36W triphosphor electronic system (100 and 89 lm/W). The table also shows that at ambient temperatures of 15° and 20°C, T8 electronic systems have much higher lamp and circuit efficacies than T5 systems. This means that for open-bottom luminaires installed in air-conditioned spaces, where the air temperature inside lamp compartments is near to or lower than 25°C, T8 triphosphor lamp systems with electronic ballasts can be more energy efficient than T5 systems. When cool air from air diffusers can enter directly into the luminaire, the lamp ambient temperature can be quite low and the lamp wall cooling effect is further enhanced by the air flow current around the lamp tube. The above discussion shows that comparisons of lamp and system efficacies based on published maximum values, which occur at different temperatures for T5 and T8 lamps, may be misleading and could lead to wrong decisions in respect of lamp selection.

In addition to higher lamp efficacy, the energy efficiency of T5 lighting systems can be further improved by better optics of the luminaire. The light output ratio (LOR), which measures the luminaire efficiency, of a T5 luminaire is higher than that of a T8 luminaire due to reduced self-shielding of the light by the lamps. Furthermore, miniaturization of T5 lamp gives two additional improvements of luminaire efficiency. Firstly, the thinner T5 lamp is nearer to a line source so that better optical system can be designed for directing more light to where it is needed. Secondly, high reflectance reflector material becomes economic because less material is needed in a T5 luminaire due to the reduced size. The luminaire efficiency depends on the material used and the luminaire design, here a comparison is made for luminaires with high reflectance material. Table 3 gives a comparison of efficacies between T5 and T8 1200 mm (4-foot) single lamp luminaires produced with the same material but with reduced size for the T5 luminaire. The values are estimated based on typical values for power consumption, light output ratio and maximum light output values without considering temperature and other factors.

Table 3. Comparison of maximum efficacies with lamps operating under the respective optimum conditions

Lamp at optimum operating temperature (i.e. T8 at 25°C and T5 at 35°C)	T8 36W lamp with magnetic ballast	T8 36W lamp with electronic ballast	T5 28W lamp with electronic ballast
Initial lamp lumen output	3350 lm	3200 lm	2900 lm
Lamp power	36 W	32 W	28 W
Circuit power	47 W	36 W	32 W
Circuit efficacy based on initial lamp light output	71 lm/W	89 lm/W	91 lm/W
Light output ratio of luminaire	0.7	0.7	0.8
Initial light output from luminaire	2340 lm	2240 lm	2320 lm
Luminaire efficacy	50 lm/W	62 lm/W	72 lm/W

From Table 3, although the T5 lamp produces a smaller lamp lumen output than the T8 lamp, the light output of the T5 luminaire is roughly equal to or even slightly higher than that of the T8 luminaire due to the higher luminaire efficiency as a result of the smaller size and better optical design. Provided that T5 lighting systems are used at or near to the optimum conditions, they can give significant energy savings. However, the effect of temperature has been ignored in the design and application of many T5 lamp systems. In order to demonstrate the effect of temperature on T5 and T8 lamp systems, a comparison is given below for three T5 and T8 lamp systems.

Fig.3 shows the variation of the luminaire light output with lamp ambient temperature of three single-lamp luminaires: T5 28W (electronic), T8 36W triphosphor magnetic ballast, T8 36W triphosphor electronic ballast. Fig.4 shows a graph of the luminaire efficacy (light output from luminaire divided by electric power input) plotted against ambient temperature of these three systems. The graph shows that the T5 luminaire has higher efficacy than T8 magnetic ballast luminaire for lamp ambient temperatures higher than around 15°C. The T5 luminaire has higher efficacy than T8 electronic ballast system for lamp ambient temperature higher than about 23°C. This means that T5 lamp systems using open-bottom louvred luminaires may not be more energy efficient than T8 electronic ballast systems in modern air-conditioned offices where room air temperature is often kept at below 25°C and cool air supply from air diffusers in the ceiling may enter the luminaire lamp compartment resulting in temperature around the lamps of below 20°C. When the luminaire light output and efficacy are plotted for the three different lamp systems with the same light output ratio, graphs like Fig.5 and 6 can be obtained. These graphs show that the T5 system is less efficient than the T8 triphosphor electronic system for lamp ambient temperatures lower than about 28°C if the T5 luminaire provides no extra gain in luminaire efficiency, i.e. not higher in LOR. Even for lamp ambient temperatures higher than 28°C, the T5 system has only a small gain in luminaire efficacy (<15% at 40°C) over the T8 system.

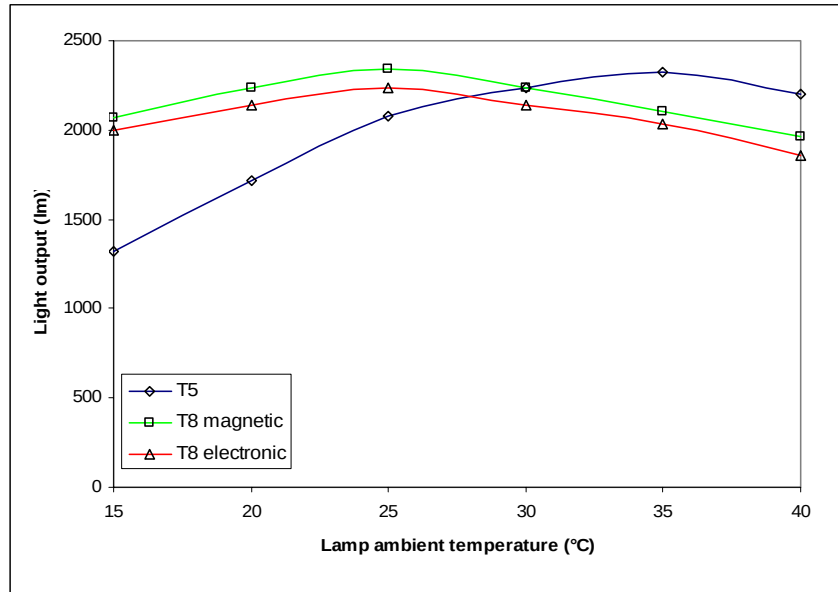


Fig.3 Luminaire light output of 1200mm single-lamp T5, and T8 magnetic and electronic systems at different ambient temperatures.

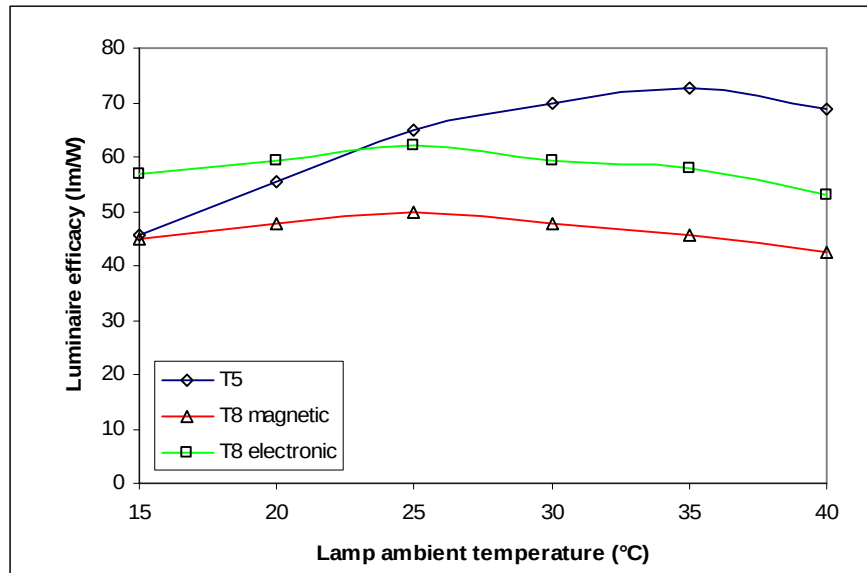


Fig.4 Luminaire efficacy of 1200mm single-lamp T5, and T8 magnetic and electronic systems at different ambient temperatures.

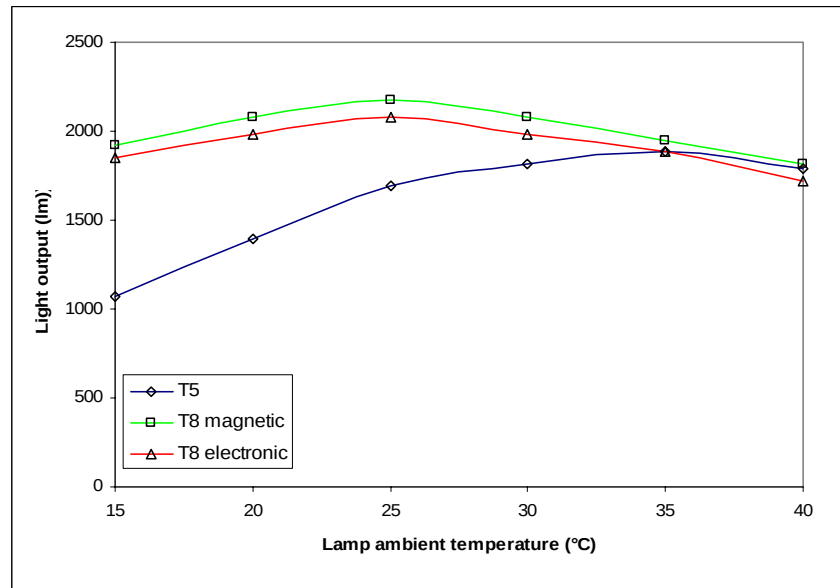


Fig.5 Luminaire light output of 1200mm single-lamp T5, and T8 magnetic and electronic systems at different ambient temperatures when the three systems have the same light output ratio.

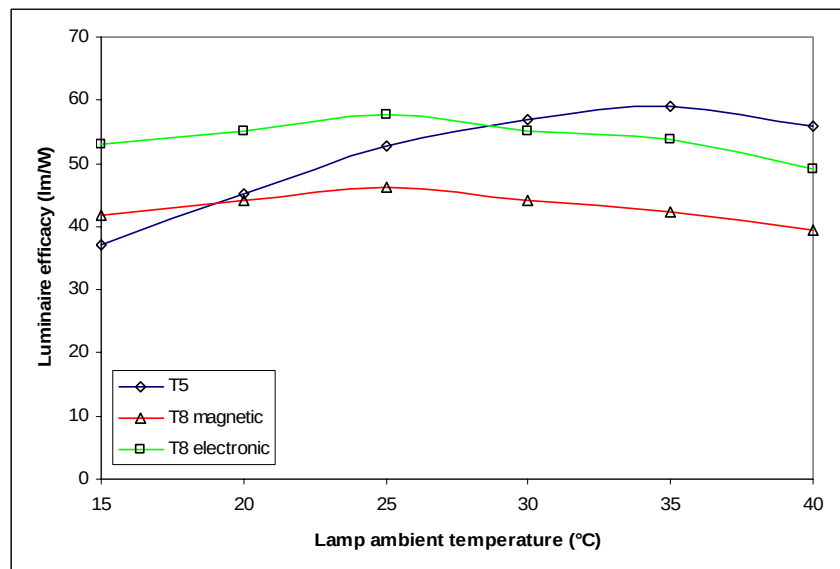


Fig.6 Luminaire efficacy of 1200mm single-lamp T5, and T8 magnetic and electronic systems at different ambient temperatures when the three systems have the same light output ratio.

4. Economic analysis

Lighting costs depend on many factors, which vary with time and location. As a result, accurate economic analysis valid for all places is not possible. Luminaire cost for a given type of lamp can vary widely. Installation costs vary from place to place and from time to time. Electricity costs vary with location and time as well. For demonstration of economic comparison between T5 and T8 systems, lighting costs have been calculated for comparison between: (i) T8 and T5 direct lighting systems; and (ii) T8 and T5 HO indirect uplighting systems. A medium size open-plan office of dimensions 15 m by 15 m was used in the cost analysis calculations. Both the T8 direct and uplighting systems use 36W triphosphor lamps, the direct system uses 2-lamp luminaires with a single electronic ballast while the uplighting system uses 3-lamp luminaires with also a single electronic ballast. The T5 direct lighting system uses luminaires with 2 T5 HE 28W lamps and a single electronic ballast. The T5 indirect uplighting system uses luminaires with 2 T5 HO 54W lamps and a single electronic ballast. The

following assumptions have been made in the economic analysis: (i) the office is illuminated to about 500 lux over the whole working plane; (ii) the lamps operate 3000 hours annually, (iii) the lighting installation has a life of 10 years. The last assumption takes into consideration of the dynamic business environment that offices are renovated in periods shorter than the actual hardware life time of lighting systems, a life of 10 years is a conservative estimate. Table 4 lists the economic analysis comparison results.

Table 4. Cost comparison between T5 & T8 lighting systems for a medium size open-plan office

Lamp system	Direct lighting		Indirect uplighting	
	2-lamp T8 36W electronic	2-lamp T5 HE 28W	3-lamp T8 36W electronic	1-lamp T5 HO 54W
Layout	6 x 6	6 x 6	5 x 6	5 x 5
No. of luminaires	36	36	30	25
No. of lamps	72	72	90	50
Power per luminaire	72 W	64 W	108 W	120 W
Total lighting power	2592 W	2304 W	3240 W	3000 W
Lighting power density	11.5 W/m ²	10.2 W/m ²	14.4 W/m ²	13.3 W/m ²
% increase of initial cost of T5 system over T8 system	-	+11%	-	+1%
% increase of operation cost of T5 over T8 system	-	-8%	-	-6%
% increase of total cost of T5 system over T8 system	-	+4%	-	-2%

Based on current prices, T5 direct lighting system is about 11% higher on initial cost than T8 direct lighting system. T5 direct lighting system is 8% lower on energy and maintenance costs than T8 system. However, the total lighting cost of T5 system is still 4% higher than T8 system if a 10-year life time is considered. For indirect uplighting system, the initial costs of the T8 and T5 systems differ only very slightly since much less T5 luminaires are required. The operation cost of the T5 uplighter system is about 6% lower than that of the T8 system so that the T5 system is 2% lower in the total lighting cost in 10 years. In this medium size office, using T5 HO uplighting can achieve an almost equal initial cost and a significant reduction in operating cost compared with T8 uplighting system. If the project is larger, using T5 luminaires can provide higher economic benefit by reducing initial cost as well as the operation cost (NLPPI, 2002).

5. Indoor visual environment

A disadvantage of T5 lamps is the higher glare they may produce, especially for the direct lighting system. Glare is related to the luminance of the lamp surface. Due to similar light output from a reduced surface area, T5 lamps have much higher surface luminance than T8 lamps. Measurements showed that T5 HE lamps are brighter than T8 triphosphor lamps of similar length by about 15% (for the longer lamp) to 70% (for the shorter lamp). T5 HO lamps have luminance 2.1 to 2.5 times the luminance of T8 triphosphor lamps of similar length. Table 5 lists the luminance, in kcd/m², of T5 HE, T5 HO and T8 triphosphor fluorescent lamps. T5 HO lamps are much brighter than T5 HE lamps due to the increase in light output for the same lamp length.

The higher luminance of T5 lamps leads to larger glare and discomfort for room occupants and may also cause higher reflected glare on computer screens or other visual display units. Proper glare control can be achieved by parabolic louvers, metal mesh filters or acrylic diffusers. Cleef and Bex (1998) have described the use of an omnidirectional luminance control (OLC) system which uses lamella louver to shield the lamp so that it is not visible at critical angles of view while still allowing the maximum amount of light to pass through the louver. If an indirect uplighting system is designed for attaining higher lighting quality, using T5 HO lamps is more sustainable than using T8 lamps as discussed above.

Table 5. Lamp surface luminance for T5 HE, T5 HO and T8 triphosphor lamps

Lamp nominal length	Lamp surface luminance in kcd/m ²		
	T5 HE	T5 HO	T8 triphosphor
550/600 mm	17	25	10
850/900 mm	17	28	11
1150/1200 mm	17	29	12
1450/1500 mm	17	32	15

6. Impact to the global environment

The slightly higher energy efficiency of the T5 lamps makes them more environmental friendly by saving fossil fuels, although by only a small amount as compared with the new generation T8 lamps. Nevertheless, T5 lamps do create less impact to the global environment in other aspects as a result of the use of less material in the production, transportation and sales of the lamps.

All fluorescent lamps contain mercury, which is a toxic material. Earlier fluorescent lamps contain large dose of mercury, up to several hundred milligram, due to the technical difficulty in the past in introducing small dose into the lamp tube. Larger dose was required due also to the absorption of mercury by the phosphor and glass wall. T5 lamps have an improved phosphor coating that prevents mercury from being absorbed into the phosphor and glass wall. Improved mercury dosing technology allows a very small amount of mercury (about 3 mg) to be put into the lamp. Reduction of mercury content in the T5 lamps is a positive contribution to a better environment as less toxic material will go into the landfill even if the lamps are not recycled at the end of their life.

The smaller dimension of the T5 lamps is a real advantage over T8 lamps in the contribution to a better global environment. T5 lamps use fewer materials in the production and packaging. The amount of glass and phosphors used in a T5 lamp is less than 60% of that used in a T8 lamp of the same nominal length, i.e. about 40% saving of raw materials. This not only saves raw materials but also saves the energy used in the production of T5 lamps. The volume of a T5 lamp is less than 40% of the volume of the T8 lamp of similar length. Therefore, the packaging material used for transporting the T5 lamps and luminaires from the manufacturing plant to the user is greatly reduced by over 60% when compared with the T8 system. The packaging material used for one T8 lamp can be used for approximately two and a half T5 lamps. Packaging material is commonly carton paper produced from wood. The large saving in packaging material contributes greatly to the conservation of natural resources and hence to environmental sustainability. The reduced size and weight also allow the use of less energy in the transportation of T5 lamp systems.

The coating applied to the phosphor layer in T5 lamps improves the lumen maintenance of the lamp. The light loss due to lamp depreciation is only about 7% after 10,000 hours of operation of T5 lamps as compared to 15% for uncoated triphosphor lamps. If this is considered in lighting design, then a larger maintenance factor can be used. This results in that a smaller number of luminaires is required to give a certain maintained illuminance. If designed properly, this achieves significant energy saving and hence contributes to a sustainable global environment. The better lumen maintenance also allows a longer economical life of the T5 lamp, which is as long as 20,000 hours, about 25% longer than a normal triphosphor T8 lamp. However, the improved phosphor coating is not unique in T5 lamps; new

generation T8 triphosphor lamps also have this coating which gives similar lumen maintenance and economical life as the T5 lamps.

7. Conclusion

The characteristics of T5 lamp systems have been reviewed and compared with those of T8 systems. The T5 lamp has higher efficacy than the T8 lamp and T5 luminaires have higher luminaire efficacy than the T8 luminaires. However, temperature effects on light output and the fact that T5 and T8 lamps operate optimally at different temperatures make the performance comparison difficult. T5 lamp systems with exposed lamps may not be more energy efficient than T8 lamp systems in air-conditioned rooms. Careful design of the lamp system should consider its interaction with the air-conditioning system so that the most efficient system can be selected. T5 lamp systems do contribute to a better global environment due to the savings in raw material in the production and transportation of the lamps and luminaires and the savings in energy for production and operation of the lamp. T5 lamps produce less pollution to the environment due to the use of smaller amount of mercury. The application of a phosphor coating also contributes to the sustainability due to lengthening of the economic life of the lamp. Economic analysis show that although currently T5 lamps are more expensive than T8 lamps, using T5 high output lamps can provide an economic benefit by reducing the number of luminaires used so that both initial and operation costs are reduced.

Acknowledgements

This work is supported by a Research Grant (G-T454) of the Hong Kong Polytechnic University.

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DAYLIGHT DESIGN RULES OF THUMB

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Abstract

This paper discusses the history and simulation studies conducted to validate simplified daylighting principles or rules of thumb for building. The rules of thumb are gathered from architecture and lighting literatures as well as architectural practices. Incorporated in these day lighting rules are room parameters (such as room depths, floor area, window head heights and widths) related to effective unilateral daylighting. The rules of thumb are tested for a single location (35°S 150°E) close to Sydney, Australia under Standard CIE Overcast and Clear Skies by means of lighting simulations software - Lumen Micro 8, which has a limited verification tolerance of $\pm 8\%$. The simulation studies indicate that under a strict set of criteria the rules of thumb based upon the ratios of window area to floor area and room depth to window head height for task plane illuminance and daylight factor to be valid. The validation process also contributes to a number of new rules associating average illuminance with window to floor area ratio and a modification to an existing daylighting formula proposed by Littlefair (Littlefair, 1996).

Keywords : Daylighting design, Rules of thumb, Daylighting formula, Simulations, Validations.

1. Introduction

Rules of thumb exist in most discipline areas particularly those that involve the application of knowledge related to complex phenomena such as daylight, and also where absolute precision may not be required. They provide "a broadly accurate guide or principle, based upon experience or practice rather than theory" (Brown, 1993) and derive their significance from having been repeatedly used and found to work. However, underlying assumptions may be poorly stated, or missing, for even if they existed initially these can slowly be neglected with use. This can lead to misapplications as the assumptions are contravened and the application boundaries of the rules exceeded.

2. Daylighting Rules of Thumb

In the context of daylighting, a number of rules of thumb can be found that advise on building form, room size and proportions, and window sizing. They have a long history probably stretching back beyond the historical record and may have been influenced by Pythagorean ideas and devices such as the Golden Section to provide numerical proportional rules for building form and fenestration. This can be seen in the work of early architects such as Galerius, circa 300 BC, (Illiadis, 2001) and later mediaeval and gothic structures. There is, however, a two thousand years record of such rules, one of the famous, and earliest author being Vitruvius who provides the advice that for adequate daylighting a significant sky component should be visible from a point in a room:

"On the side from which the light should be obtained, let a line be stretched from the top of the wall that seems to obstruct the light to the point at which it ought to be introduced, and if a considerable space of open sky can be seen when one looks above the line, there will be no obstruction to the light in that situation."

Rowland, 1997

The rediscovery and reformulation of Vitruvius in the Renaissance and later by architects such as Palladio, Scamozzi and de l'Orme expanded upon the former's principles and the Pythagorean tradition of numerical proportion. For example:

"Make sure when making windows that they do not let in too much light or too little light and that they are not spread out or closer together than necessary. One should, therefore, take great care over the size of rooms which will receive the light from them, because it is obvious that a larger room needs much more light to make it luminous and bright than a small one..."

Taverner and Schofield, 1997

From this, emerges specific rules such as: (i) Window width is between one fifth and one quarter of the room depth, (ii) The window height is two and one-sixth the window width. These rules can be expanded into more familiar forms: (a) Maximum room depth is four to five times the height of the window, (b) Window area is approximately one tenth of the square of the room depth.

From the examples provided by Palladio, it appears that his preferred window to floor area is of the order of 25% and his window to window wall ratio is about 35%.

Pragmatic modification of such rules was commonly carried out to address local conditions. For example, Sir William Chambers expressed awareness of the obvious difference between the climates of Italy and England:

"I have generally added the depth and the height of the rooms on the principle floor together, and taken one eighth part thereof for the width of the window; a rule to which there are few objections; admitting somewhat more light than Palladio's, it is I apprehend, fitter for our climate than his rule would be"

Gwilt, 1982

Gwilt in the mid 19th century also criticised Palladio's rules as being unsuitable for the climate of Great Britain (Gwilt, 1982). He based his rule upon room volume and suggested window area for daylighting to be 1% of room volume. Such rules based upon room volume appear to have become less popular except for their use in early 20th century German daylighting standards where window area was specified as one thirtieth of room volume (Price, 1914). With an increase in architectural publishing in the late 19th and 20th centuries and a growing formalism for daylighting as well as other architectural science areas, a number of rules developed usually based on:

- (i) Window head height (or ceiling height) to room depth ratio,
- (ii) Maximum room depth,
- (iii) Window to floor area ratio,
- (iv) Window to window wall area ratio.

A limiting feature of the way these rules can be presented is that they appear to be universally applicable but may be subjected to one or more of the following potential caveats (Robbins, 1986):

- (i) what is the basis of the rule?,
- (ii) what is the sky condition? e.g. overcast or clear?,
- (iii) does it assume typical urban obstructions to daylight?,
- (iv) does it satisfy maximum or minimum requirements?,
- (v) how much light is quantitatively provided and on what reference plane?,
- (vi) what sorts of tasks are suitable under this daylighting?,
- (vii) what assumptions have been made concerning the type of glazing?,
- (viii) what assumptions have been made on internal reflectances?

2.1 Window Head Height to Room Depth Ratio

This is a popular rule of thumb appearing in a wide range of sources including textbooks with some restrictions. For example:

- (i) Maximum room depth is 2 to 2.5 times window head height for continuous fenestration and curtain wall construction where window heads are close to the ceiling (Kaufmann, 1975)

- (ii) Room depth is 2.5 times window head height for continuous or near continuous windows under overcast skies and 3 to 3.5 times under a clear sky (AIA, 1982),
- (iii) 2 times for continuous clear glazed and curtain walling (Rea, 1993),
- (iv) 2.5 with a daylight factor of 2% (Standards Australia, 1994),
- (v) 1.5 or 2.5 times with a south facing light shelf (O'Connor, 1997), (vi) 1.5 times for office work, 2.5 times for residential spaces (Schiller, 1992).

Note that all these rules, and those discussed below, apply to unilateral, or single sided, daylighting unless otherwise specified. In addition, a number of authors give a variant of this rule with a floor depth of twice the ceiling height, e.g. Yeang (1999). As can be seen there is a wide range of advice with varying degrees of contextual information making it difficult to assess validity of the rules offered.

2.2 Limiting Room Depth

Absolute room depth rules also have a long influential history but again are stated without limitations, probably assuming that it is obvious from the context:

- (i) Maximum floor depth of approximately 8 metres and ceiling height of 2.7 metres for adequate daylight and ventilation in reference to 1930's New York skyscrapers (Willis, 1995),
- (ii) Six metres, attributed to Frank Lloyd Wright (Schiller, 1992), British planning legislation (HMSO, 1964), and others including Yeang (1999) who limit this to buildings with window to window wall area of between 15 and 20%.,
- (iii) Five metres for window, or rooflight, illuminating a room from one side (Ruck, 1995),
- (iv) Fully daylight to 4.5 metres (Manning, 1965) and partially lit to 9 metres (Lechner, 2001),
- (v) 3.6 metres for full and effective daylighting (Manasseh and Cunliffe, 1962).

Of course, some unquoted contextual factors could contribute to the significant differences in some of these recommendations given that many are related to the same building type and general location. For example:

"The effect of using glass with an average diffuse transmittance of 50% instead of 85% might reduce the distance from the window where light is adequate from 6 metres to 4.5 metres".

Colin and Colins, 1977

Furthermore, it is obvious that internal room characteristics, especially reflectances, will impact on the perceived adequacy of daylight as recognised by Littlefair (1996) in presenting a more complex rules for room depth than would normally be seen as rules of thumb.

2.3 Window Area to Floor Area Ratio

This rule is possibly one of the most widely known rule in the world as enshrined in many regional and local building regulations as a means of specifying minimum glazing area for habitable rooms. A number of early references to the use of this rule in design of schools has been described by Wu and Ng (Wu and Ng, 2002). For example, 20% window area to floor area was proposed by ER Robson, the architect of the London School Board for health, comfort and effective teaching of children. This was modified in the London Building Act of 1894 to the familiar 10% rule although the 20% rule was still respected for schools (Waldram, 1914). A similar rule existed at the turn of the 20th century in Germany for industrial spaces and for buildings in New York (schools 17% to 25%, offices 17% but residences 10% to 13%) (Price, 1914). Hopkinson later argued that the 20% ratio yielded an adequate daylight factor of 2% at the rear of a room and a consequent task illumination of 100 lux (Hopkinson, 1963).

2.4 Window Area to (Window) Wall Area Ratio

This rule of thumb is probably related to limiting glazing area for thermal reasons, ie. heat loss and gain control, or for ensuring the adequate provision of view. Rules associated with the latter are of more direct interest such as those drawn from studies carried out in the 1970s and 1980s: (i) If the window to window wall area ratio was between 20 and 30% users were satisfied but if it fell below 20% satisfaction declined steeply. It was noted, however, that a 20% ratio will probably result in inadequate

daylighting at the rear of the room (IES, 1972), (ii) Ne'eman and Hopkinson's study showed that a 25% ratio was the minimum acceptable size for 50% acceptance and a 32% ratio gave 85% satisfaction. As well, Keighly placed a bottom limit of 15% (Boyce, 1981).

A survey in Hong Kong has shown that the mean value of window to wall ratio is 27.4%, most being between 25 and 30% with luxury units having ratios greater than 35%. The survey also indicated a good correlation between percentage window area and user's preferences for view (Li et al, 1999). However, thermal design consideration to ensure buildings perform more energy efficiently limits the ratio to 25% (Baker and Steemers, 2000).

2.5 Daylight Factors

Although daylight factors cannot really be categorised as rules of thumb as they require computation beyond using the simple parameters of space, they are included here as they are regularly used in the literature as a guide to adequate daylighting. Also they, unlike other rules, include explicit assumptions posed by Robbin's checklist and may be simply linked to some rules of thumb. For example, Hopkinson suggested that the minimum daylight factor, in that part of the room remote from the window, is equal to one tenth of the window to floor area ratio (Hopkinson, 1969). It should be noted that this rule is restricted to rectangular side lit rooms, up to 5:3 proportions with windows in the long side and without internal and external obstructions. The British have long favoured this method of daylight specification. For example, a guide for office lighting in the early 1950s recommends a minimum daylight factor of 1% for general work and 5% for drawing offices which recognises the need for varying lighting to tasks needs. Similarly, in residences kitchens require 2% daylight factor over major work surfaces whereas living rooms need only 1% and bedrooms 0.5% (Burberry, 1975). Later recommendations expand upon these with average and minimum daylight factors for workplaces (5 and 2% respectively) and state that if the average daylight factor is less than 2% it will be deemed inadequate by the users, whereas over 5% will be seen as "cheerfully lit" (CIBSE, 1987).

3. Simulation Studies

In order to test the incomplete range of recommendations discussed above, a series of simulation studies were carried out. Although it would have been most appropriate to conduct this in real spaces, the possibility of confounding factors and the difficulty in accessing a wide range of interiors to test the boundaries of rules, meant that some form of simulation was necessary. Physical models had the same limitations and it would have been time and labour consuming to construct a large number of models. Consequently, computer simulation was used, allowing a data set of 143 examples to be studied. As this was an exploratory study, a number of assumptions were made to ensure comparability of the data set and testing conditions:

- a. A single location was used (35°S 150°E), close to Sydney but away from the known localized asymmetric daylight climate (Hayman, 1996).
- b. Standard CIE Overcast and Clear Skies were used as they have wide acceptance and application.
- c. External ground reflectance was set at 20% and internal reflectances at 80% for ceiling, 50% walls and 20% floor in line with standard practice (Kaufmann, 1972).
- d. Glazing transmittance was standardised to a nominal figure of 90% to match those rules of thumb that had defined this property.
- e. Test horizontal illuminance levels of 100, 200, 400 and 600 lux were used as typically representative of levels required for tasks of increasing difficulty above a minimum level.
- f. Diffuse daylight only enters the space which was achieved by using south facing windows.

- g. A reasonable minimum daylight condition was possible with such a south facing window and the assumption that testing occurred at noon, mid winter. This had the added advantage that the available diffuse illuminances from overcast and clear skies were similar (11,943 and 12,279 lux respectively) allowing direct comparisons between sky conditions.

Lumen Micro 8 software was used for the simulation study as it is a standardised commercial product so the studies are easily repeatable, it is well known, relatively easy to use and reasonably priced particularly for educational use. It is claimed to have verification tolerance of $\pm 8\%$ (Jongeward, 1993) and its external illuminance prediction appears close to field measurements made by Hayman (1996) in Sydney.

Groups of case studies (CS1 to CS11) were carried out with varying room and window parameters to identify factors contributing to daylight performance of a space. However, in most cases the ceiling height was fixed at 2.4 metres and sill height at 0.82 metres:

- CS1: Square rooms of varying size (2.7 m² to 18 m²) with full width windows;
- CS2: Narrow rectangular rooms of fixed width (2.7 m) and increasing depth (up to 18m);
- CS3: Square rooms of varying size and window width to fix the window to floor area ratio at 10%;
- CS4: Fixed square room (3.6 m²) with varying window size (window to floor areas from 5 to 40%);
- CS5: As for CS4 but with a larger room (10 m²);
- CS6: Fixed square room (5.5 m²) with fixed window but varying ceiling heights (2.4 to 8 m);
- CS7: Fixed square room (5.5 m²) and window but varying window head heights (2.4 to 10 m);
- CS8: Fixed square room (5.5 m²) and ceiling height (3.6 m) and sill but varying window size;
- CS9: Fixed square room (5.5 m²), window size and ceiling height but varying sill (0.8 to 2 m);
- CS10: Fixed central window (1.5 by 0.9 m) with varying square room size (2.7 to 10 m²);
- CS11: As for CS8 but with larger rectangular room size (20 by 40 m).

Once the range of simulations were created they were studied in terms of maximum, minimum and average illuminances, daylight factors in relation to room depth, floor area, window area, window head height under both overcast and clear skies.

4. Results

The results of the case studies are extensive but a representative sampling can be gained from looking at the results of one case study group, CS1. As would be expected the centre line illuminances drop off rapidly with distance from the window as shown in Figure 1. The maximum illuminances, close to the window, are in the order of 25% higher for an overcast sky than a clear but the minima, at the rear of the room, are about 50% higher for clear skies. This is expected as clear skies are brighter towards the horizon than overcast and contribute more to lighting of the rear of rooms as shown by Tregenza (Tregenza, 1999).

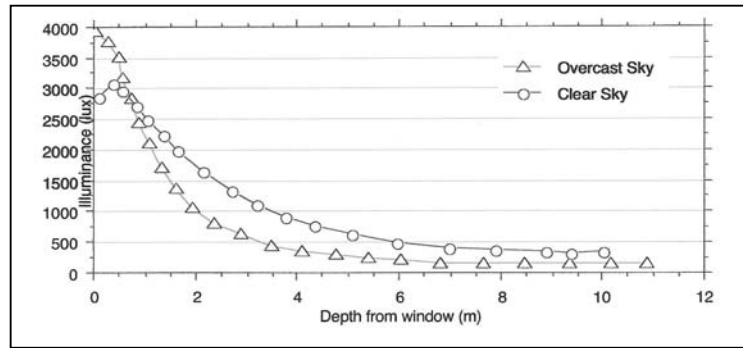


Fig. 1 Room depth vs centre line illuminance (lux)

Minimum values are dominated by the room's indirect component of daylight whereas average illuminances by the direct component except for clear skies where the indirect component is still strong due to the importance of ground reflected light. Window to floor area ratios show the same relationships but with stronger linear association as can be seen in Fig. 2:

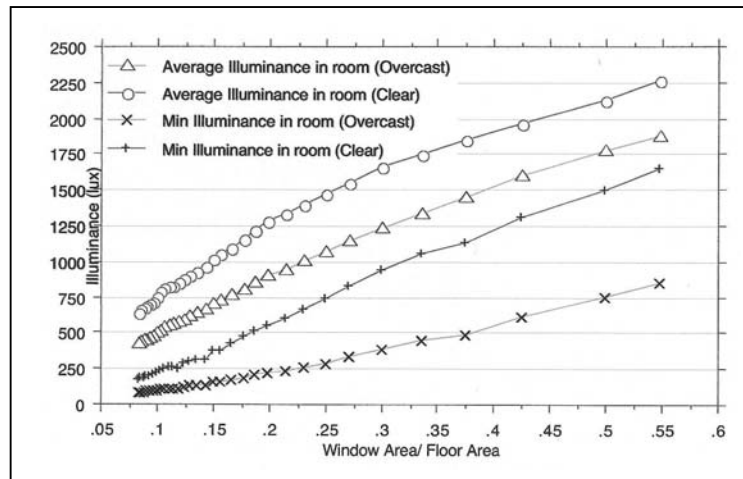


Fig. 2 Window to floor area ratio vs minimum and average illuminances (Overcast & Clear skies)

In terms of traditional rules of thumb, for an overcast sky an illuminance of 100 lux could be achieved at approximately 3.5 times the window head height, 200 lux at 2.5 times and 400 lux at 1.5 times. A room with a window to floor area of 10% yields a minimum of 100 lux and 20% about 200 lux. With a clear sky the figures are higher with 400 lux achieved at 3 times the window head height and 600 at 2.5 times; a 10% window to floor ratio gave greater than 200 lux and 20% a minimum of 500 lux. In all cases the rooms have greater than 2% average daylight factor so would be "adequately" daylit and a window to floor ratio of 13% would ensure that the "cheerfully" daylit criteria of 5% average daylight factor was satisfied.

From this and the results of other case study groups, the most successful rules of thumb are:

- (i) The 10% window to floor area ratio is reliable in providing a minimum of about 100 lux.
- (ii) A daylight room depth up to 2.5 times the window head height and/or 20% window to floor area will, in most cases, provide a minimum illuminance of not less than 200 lux under an overcast sky and higher for a clear sky. The 200 lux minimum cases are also close to providing the 2% average daylight factor daylight acceptability limit. However, if daylight uniformity (minimum to average ratio) is an important issue, for example in a workplace, then 20% window to floor area ratio could be unsatisfactory.

- (iii) In satisfying uniformity criteria two new rules became evident in the analysis. Firstly, that windows should be at least 50% of the window wall width and, secondly, that room depth should be no greater than twice the room width for full width windows (and less deep for less than full width windows).

5. New Rules of Thumbs

To investigate the possibility of other new rules of thumb all cases studies were analysed as a complete data set using plotting and regression analysis techniques. Strong linear association exists between average illuminance and window to floor area ratios, shown in Fig. 3, except for those case studies involving varying window sill height (CS7 & CS9).

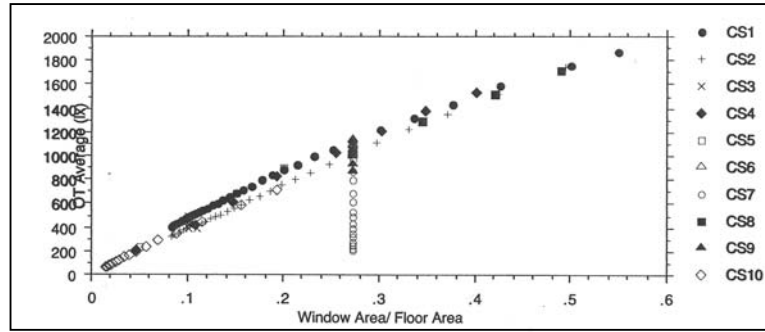


Fig. 3 Window to floor area vs. average room illuminance under an overcast sky

Improvements in modelling can be achieved by either correcting for these anomalies (using window to floor area ratio divided by window head height) or restricting the emergent rule to normal windows. In the latter case regression yields the following:

$$\text{Average illuminance (overcast sky)} = 3,856 \times \text{window to floor area ratio} \quad (R^2 = 0.992) \quad \text{Eq. 1}$$

$$\text{Average illuminance (clear sky)} = 4,859 \times \text{window to floor area ratio} \quad (R^2 = 0.974) \quad \text{Eq. 2}$$

$$\text{Average daylight factor (overcast sky)} = 32.29 \times \text{window to floor area ratio} \quad \text{Eq. 3}$$

These could be rounded off to 3,800, 4,800 and 32 or to 4,000, 5,000 and 30 respectively for ease of memorisation. Additional improvements can be made by use of window to floor area corrected for window head height and/or non-linear models, specifically raising the window to floor area ratio to the power of 0.8. However, this may result in a more difficult to remember rules than the simple ones above.

To explore the possibility of using the dataset as a test source for existing daylighting design tools, a useful approximate design tool by Littlefair (Littlefair, 1996) was selected which equates average daylight factor with a few easily measurable variables:

$$DF_{Avg} = \frac{\tau_w A_g \theta}{A_s (1 - R^2)} \quad \% \quad \text{Eq. 4}$$

where:

- DF_{Avg} = average daylight factor
- τ_w = transmission of glass (0.9 in the studies)
- A_g = area of window glazing (m^2)
- θ = sky angle in degrees measured at centre of window (90° for no obstruction)
- A_s = total surface area of room (m^2)
- R = average reflectance of interior (0.5 is normal for standard reflectances)

In its stated form this formula is applicable to small to medium sized rooms with a maximum depth of 6m. What was immediately evident from the analysis was that the formula was applicable to a much wider range of room sizes but that an improvement in performance could be made by substituting room surface area (A_s) by the much simpler variable of floor area (A_f) shown in Fig. 4, for normal sill heights, and resulted in the following relationship:

$$DF_{Avg} = 0.3 \left(\frac{\tau_w A_g \theta}{A_f (1 - R^2)} \right) \% \quad \text{Eq. 5}$$

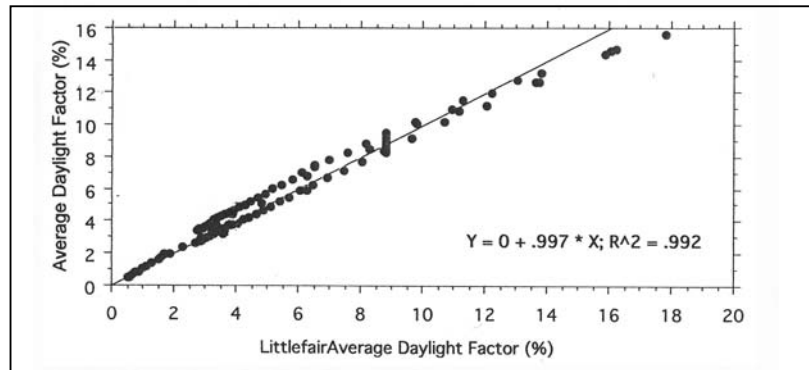


Fig. 4 Average Daylight Factor vs. Daylight Factor from modified Littlefair formula

Conclusions

The simulation studies have shown that under a strict set of criteria, the use of rules of thumb for unilateral daylighting based upon the window area to floor area and room depth to window head height ratios for task plane illuminance and daylight factor appear to be valid. Exceptions will occur when windows have non-standard sill heights or are high level, e.g. celestory, windows which should be clearly stated in the formulation of these rules. Furthermore, as a consequence of the modeling study a number of new rules of thumb relating to uniformity provisions have been found. Future research can be aligned to investigate limitations of the current study in particular application to more locations and the effects of external obstructions which will be necessary for the rules to be used in most urban situations.

Acknowledgements

We are grateful to the University of Sydney for funding the Lumen Micro 8 simulation software and to the Faculty of Engineering, Universiti Kebangsaan Malaysia for financing our participation in this conference.

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THE EFFECT OF DAYLIGHT ON THE NUMBER OF CUSTOMERS IN COMMERCIAL BUILDINGS

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Abstract

The research explores the effects of daylight components in the interior of commercial buildings (shopping complexes) on influencing the number of customers. The research objective is to show that shopping complexes with more daylight in the interiors attract more customers. This paper will only relate to the methodology for the study. In order to verify these contributing factors, the research will look into the basic dimensions, which determine retail patronage. The research will also examine different motives of shopping that explains why people go to shopping complexes to work out these variables. After verifying these variables, the researcher will select shopping complexes with the most similar characteristics and attributes that bear the controlled variables (factors that could affect people to shopping complexes other than light) and then compare the case where light is the only variable. The research hypothesis is that commercial buildings with more daylight components will have more patronage/customers. This ideology is based on the fact that light affects human behaviors. It is hoped that the research could contribute to the awareness on the value of daylight in buildings especially shopping complexes.

Keywords : Daylight, Customer, Commercial building.

1. Introduction

The success of commercial buildings such as shopping complexes is highly dependent on the number of customers. Research, location, site, layout, parking, structure, tenants and management play significant roles in creating a good shopping complex (McKeever, 1953). However, even the best and well equipped shopping complex will falter if it fails to attract customers. This logic is based on the fact that customers generate sales.

Thus, designers should look into factors that contribute to customer generation. The Malaysian shopping scene, especially within the Klang Valley district has shown a rise in the development of shopping complexes due to the rise in consumer demand as in rise in shopping trend (Selat, 1995). The main dilemma of shopping complexes in Malaysia is seen in its declining life span serving as a commercial centre which in the end needs to be revitalized and revived (Zulkhafiz, 2002, Fauzan, 2000). Shopping complexes tend to experience decreasing amount of customers as it age turning it into white elephants. The Johore shopping scenario for instance has witnessed several accounts of the failures of shopping complexes such as Bestworld Plaza, Kemayan City and the recently opened Lot 1 Shopping Centre. This stresses even more on the importance of looking into factors that contributes to attracting customers to shopping complexes. There are quite a collection of views on factors that contributes to generating customers. According to Tauber (1969) on different motives for shopping, he found out that people shopped not merely out of necessity or a desire to satisfy a physical need but even includes the need for social interaction outside of the home such as encounters with friends or salesperson. Tan (1991) studied on shopping behaviours in Singapore and the implications for property managers found that a friend's perception of the shopping centre could also contribute to retail patronage.

The research however would like to see the problem from a different angle. It is based on the grounds of how light/daylight is capable of affecting human behavioural pattern. It is widely known that human being reacts to light. It is also known that light plays an important role in affecting human behavioural pattern and psychological response. According to Ruck (1989) on the subject of the construction of human perception, the quantity and the quality of light received by the human visual receptors, which is the eyes, have a direct influence on how people see things, which could contribute to one's impressions of an interior by giving character and atmosphere. Research by Farihan (2001) regarding human perception towards the usage of daylight in shopping complexes shows that shopping complexes with higher degree of daylight usage evokes positive feelings/emotions in building users within its interiors compared to shopping complexes with less daylight usage. According to a study on skylighting and retail sales by Heschong (1999), a store with skylights is observed to have a sales index higher than an equivalent store without skylights. Research has shown that commercial buildings with higher usage of daylight results to better commerce (Wilson, 2000, Pierson, 1995). Miller. Et.all (1998) studied on the effects of maximising sunshine as a light source in the customer service center of the Sacramento Municipal Utility District. One hundred and fifty six employees were surveyed or interviewed about their impressions and experiences with the lighting and they were generally quite satisfied with the appearance of the lighting in the open offices and more than half believed the lighting was better than similar workspaces in other buildings. Pierson (1995) looks at the advantages of increased light in commercial buildings. Report done by the Rocky Mountain Institute concluded that increased daylighting results in decreased absenteeism and fewer errors and defects; thus increasing the productivity level of workers in commercial buildings. Wilson (2000) reveals the results of a study in California that natural light boosts human productivity in retail sales and school performance with average increase in sales due to daylighting.

The main intention of the research is to investigate the relationship between the usages of daylight in the interiors of commercial buildings in Malaysia on its capability to attract more customers.

2. Research Methodology

The three main sections of methodology are broken into sub-methodologies or preliminary researches in developing the logic structure of the research methodology. In short, the research methodology sequence starts off with the basic understanding of digital camera in image processing. The technicality of the digital camera is unveiled as this will explain why it is used in gauging light intensity levels in shopping complexes instead of the traditional method of the illuminance meter. The end result of this stage will produce camera and image taking guidelines that will be used throughout the duration of picture taking. Before the image-processing phase is executed, a review of potential image processing programmes will be done. This is to ensure that the most comprehensive and reliable programme is chosen to process the pictures taken. Next, a building inventory survey of shopping complexes within Klang Valley; regardless of its lighting condition, will be carried out. Building inventory such as this is crucial at the early stage of building selection, as this will give the researcher a database of existing shopping complexes and its characteristics. Buildings will be scoped down as to achieve the most similar of buildings in many aspects. Pictures of shopping complex interiors will be taken and these pictures will be later processed with designated image processing programme. This is the first level of building selection stage that serves the cause of establishing a database. The second level of building selection stage will eliminate buildings with the least similarity or traits. This is to ensure that other factors that could affect shoppers to come to shopping complexes is controlled. The only uncontrolled variable left would be only light. This is where the gauging begins in determining whether building with more light is capable of attracting more customers or not.

The research methodology is divided to two main sections:

2.1 Data Collection

2.1.1 Review on Instruments Used. Data collection includes review on instruments used, building selection, measured variables and conditions/time for field study. Minolta LS-100 luminance meter which is normally used to measure light has been replaced with a digital camera. This is due to the availability of the luminance meter and the length of time it consumes in obtaining data. During data collection, an imaginary grid will be imposed on a field of view and readings will be taken from each

box that builds the grid (Fig.1). The process consumes time and this is parallel with the changing sun and sky that affects lighting condition.

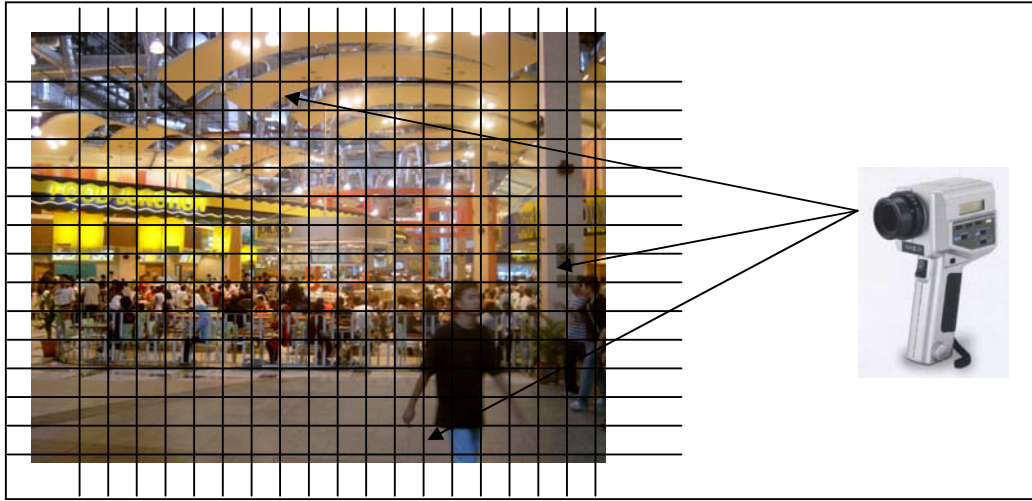


Fig.1 Imaginary grid used for luminance meter

To validate the usage of a digital camera (Olympus Camedia C 5050) as a substitute to luminance meter, prior studies has to be done. Readings and tutorials on image processing is done to understand the concept of luminance in digital imaging. A pixel that builds up a picture bears digital numbers that has energy levels called Radiance in Geoinformation Sciences (GIS) terms. The radiance (or luminance in environmental sciences term) level in these pixels can be decrypted using an image processing program (ERDAS) to acquire light levels. Reviews on image processing programs (ERDAS, PCI Geomatica, Radiance) is done and ERDAS has been selected for its efficiency and ease to process data on luminance readings (Fig.2). An experiment on digital camera versus lux meter is conducted to study its reliability. Lux meter readings and processed image taken using a digital camera is compared. Results show that both method produce quite significant readings. However, the digital camera method proved faster in data collection and processing. Digital cameras are more efficient as it captures the whole light condition of a space and stores the data along with the luminance readings that lies in the pixels.

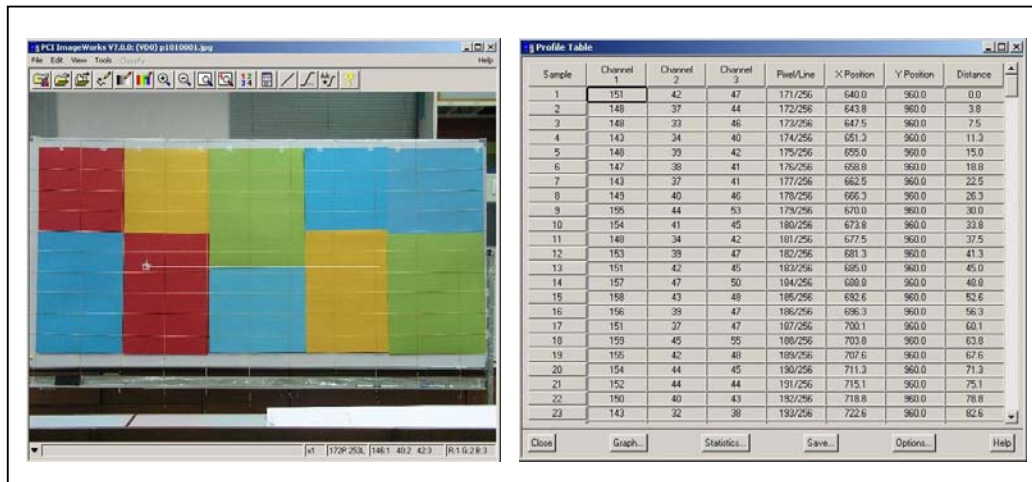


Fig.2 Luminance level acquired using an image processing program (PCI Geomatica)

2.1.2 Building Selection. The selection of buildings requires a building framework. A building framework is a guideline used for building selection. The main aim is to select buildings that are approximately the same to minimize extraneous factors. A building inventory of shopping complexes is produced in the end of the building framework process to facilitate building selection. Prior studies have been conducted to aid the inventory. They consist of:

(i) Definition of Commercial Building

The building inventory survey doesn't have any specific scope or designated criteria to be found on each building. The basic rule on establishing the database is by identifying whether the building is fit to be documented as a shopping complex or not. Shopping complexes should not be mistaken by other typologies of commercial buildings such as shop houses, grocers, warehouses and hypermarkets. Thus, the definition of the term 'shopping centres' should be defined as to differentiate it from other commercial buildings. This is important, as the research would like to scale down the scope to only shopping complexes. Extensive reading and local municipalities helps classification. (McKeever,1953, Northern,1977)

(ii) Review on Benchmarking

Buildings will be documented according to the guideline with the aid of the rating system. Study on benchmarking is acquired to improve the guideline thus making the building more comparable in terms of patronage. (Webster's 1986, Camp, 1989, Longmire,1993)

(iii) Justification of Klang Valley as a Valid Study Area

Klang Valley has been chosen as the experimenting ground for it has an array of highly diverse shopping complexes compared to other states throughout Malaysia. The current commercial scene in Klang Valley supports this statement. (Selat,1995, Kamiso&Ang,2004, AmResearch,2004, Raj,2004)

(iv) Consideration of Extraneous Factors that Affect Patronage

Factors that affect patronage must be defined. This is achieved by studying factors that attract customers (McKeever,1953, Tauber,1972, Tan,1991, Foss,2004,). According to McKeever (1953), there are eight factors that make a good shopping centre. They consist of research, location, site, layout, parking, structure, tenants and management. After much deliberation, these factors are normalized by using a rating system for shopping centers by Kansas State University (Darling,2002).

2.1.3 Measured Variables. Variables to be measured have been identified as acquired data. Acquired data is comprised of both controlled and uncontrolled variables. The controlled variables used to gauge the buildings are factors that attract customers while the uncontrolled variable would be the lighting application and patronage. An overview on factors that attract customers is done through literature reviews (McKeever,1953, Tan,1991, Tauber,1972) and looking at past researches (Heschong,1999) since vast factors that attract customers to a shopping complex existed. Basic physical data of shopping complexes (e.g anchorage, type of lighting used, rough estimation of openings, building material/structure, floors) is obtained to form a building inventory. A rating system devised by Kansas State University (Darling,2002) is used to rate the shopping centers. Patronage count is another uncontrolled variable. Reviews on past research methodologies (Heschong,1999) and other counting methods such as traffic count studies and ROMDAS (traffic count program) is done to look at other methods that could help the patronage count. A brief study on Bill Hiller's "Space Syntax" and Reily's Law of Retail Gravitation is done to aid the process.

2.1.4 Condition/time for Field Study. Since the field work covers a large area, 2843 square kilometres in total (Selat,1995), the probability of sky condition variations is very high. Thus, daylight condition has to be normalized to avoid biasness. Data collection is made during mid-day since it has the longest length of time with the same outdoor illuminance reading which is 80,000 lux during mid-day. (Zain,2001). Time frame is set from 11am to 2.30 pm giving ample time for data collection. Data is collected on a bright day (not cloudy or rainy). A bright day is evaluated through the researcher's observation and local weather forecast. A solarimeter is used to ensure similar sky condition through radiance readings before any data is taken. The same camera setting is used for every building. The use of flash is avoided for it will temper the original lighting condition.

2.2 Data Analysis

The image processing program such as PCI Geomatica and ERDAS will be used for data analysis during the pilot study. Data obtained during the building inventory phase doesn't require any computerized

image processing. The inventory records require data as to compare one building to the other through the building inventory in search of the most similar building. Images of building interiors that reflects its lighting condition will be processed in image processing programs to acquire light levels instead of the illuminance meter.

3. Discussions - Pilot study

The pilot study is conducted to test the research methodology. Subang Parade has been selected for the pilot study. First, a brief observation is done in defining the busiest point within the building. Then, an imaginary line is drawn across the selected area. Patrons that cross the imaginary line will be tabulated using a manual counter within one period of time (12.30pm-1pm). 57 pictures are taken and later processed using ERDAS program. The light level reading for each picture will be summed up and averaged in the end to get a fair overall light level for the building.

In the end of the pilot study, it is found that the methodology needs to be amended. The amendments of the methodology are as follows:

(i) Firstly, the point of reference for patronage count must be more than one. This is to increase the accuracy of the count. There will be four different points of count with four different time period. This is based on the logic of the different types of people that comes to a shopping complex in different times. (office workers, students, housewives etc.). This will cover a wide variety of patrons coming to a shopping complex.

(ii) Digital pictures taken only show one angle of view which is horizontal or vertical; thus not portraying the field of view. This is due to the use of common camera lens (Fig.3(a)) that is unable to capture wide angle views. The field study will be using fisheye lens which shows horizontal and vertical angle in just one picture. The use of fisheye lens (Fig.3(b)) also simulates human's eye view. This method solves the problem of patching two pictures together to form a complete field of view.

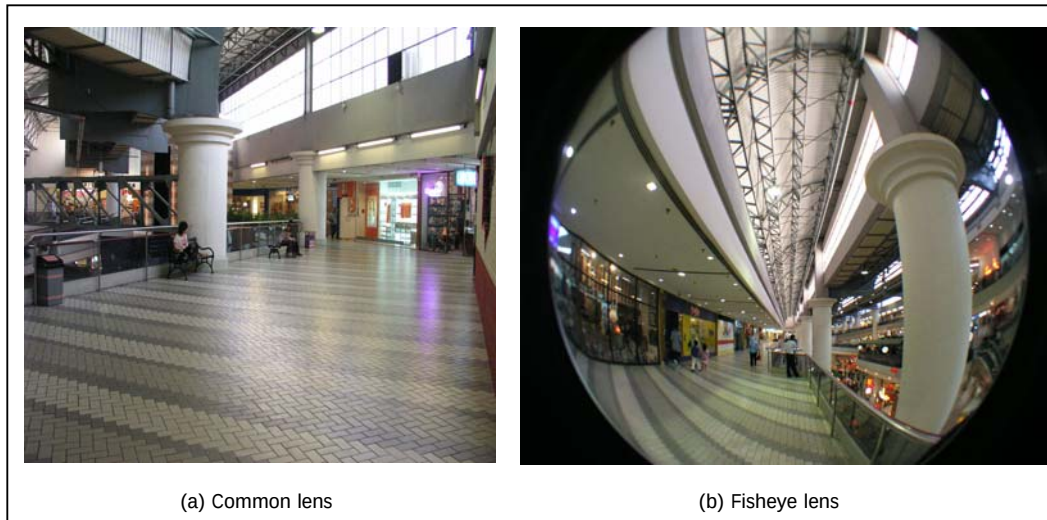


Fig.3 Comparison between pictures taken with fisheye lens and common lens.

(iii) During the pilot study, pictures are taken only during the day. However, pictures of buildings should be taken during day and night from the same location to obtain daylight factor. Logically, the light level during the day is a combination of daylight and artificial light. Thus, daylight factor can be acquired by subtracting light level taken during the day and light level during the night.

4. Conclusions

It is difficult to single out daylighting as the only factor that affects patronage in a shopping complex. Unfortunately, there is no standard found for shopping complex benchmarking unlike hotels, restaurants, universities and so forth. The research methodology of other means of patronage count and past researches (Heschong, 1999) can't be used due to major drawbacks such as financial, time and manpower. However, it is apparent that the usage of digital camera and computer image processing plays a significant role in acquiring light levels. It is hoped that with the proven success of increased retail sale due to skylights (Heschong, 1999), the Malaysian building industry would be more aware of such benefit for future construction..

Acknowledgements

To my guru; Dr. Norhaliza Madros, thanks for your relentless guidance that have guided me through this research. To Dr. Ibrahim Busu, thanks for the enlightenment on the wonders off image processing. To other supporting teachers, staff and friends, thanks.

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THE EXTENT OF ENVIRONMENTAL MANAGEMENT SYSTEM IMPLEMENTATION IN THE UK CONSTRUCTION INDUSTRY

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Abstract

This paper highlights the importance of an Environmental Management System (EMS) as a tool and a systematic way to mitigate environmental problems in construction industry. The benefits of implementing EMS are discussed thus confirming that they exceeded the cost of implementing it. It is believed that the implementation of EMS in organisations in producing sustainable projects will require active roles and participation by the construction professionals themselves.

In order to investigate the extent of EMS implementation in the UK construction industry and obtaining views on these subjects, a questionnaire survey involving 32 clients and client representatives was undertaken. The findings presented in this paper indicate that the implementation of EMS is not popular amongst the professionals in the UK. This implies that greater actions are needed to raise awareness amongst clients and professionals to enhance the quality of sustainable projects in the future.

Keywords : Environmental Management System, Construction Industry, Sustainable projects.

1. An Introduction to the Environmental Management System (EMS)

EMS is a system to aid companies that intent on improving their environmental responsibilities to set up an individual management system and furnish evidence to interested parties that it has done so (Ends, 1992a). EMS standards such as British for EMS BS7750 (1994), the EU eco-management and audit scheme (1993) and the international standard ISO 14000 have been developed to provide organizations with a framework to implement the EMS within their organization.

The EMS should be designed to enable the organization to maximize its beneficial effects and to minimize its adverse effects. In the case of adverse effects emphasis should placed on presentation, rather than on detection and amelioration after occurrence. Clear standards like BS 7750 require that policies be substantiated with publicized targets and objectives thereby focusing and enhancing the credibility of the reports (Ends, 1992b).

2. Benefits of Implementing EMS

There are many benefits of implementing EMS as listed by CIRIA 1993 in its Environmental Handbook for Building and Civil Engineering Projects. Table 1 shows the costs and benefit of EMS implementation. It confirms that the benefits of implementing EMS are more than the cost of implementing it.

Table 1: The costs and benefits of EMS implementation

Benefits	Costs
• Avoidance of fines, clean up and loss of production costs due to non-compliance • Improved health and safety of employees • Meeting and exceeding requirement of parent companies • Reduced waste, transportation and disposal costs • Reduced raw material costs • Increased operational efficiency • Reduced risk of liability • Positive company image • Reduced on site storage space • Improved environment • Identification of future risk • Reassurance to external stakeholders	• Staff organization/training costs • Installation and running costs of monitoring systems to be used • Capital and running costs of any process re-engineering undertaken as a result of the audit • Material/Process equipment costs resulting from process change • External consultancy fees • Report production costs • Temporal costs • Indirect capital costs

3. Research Methodology

This research was conducted with the aim of investigating the extent of EMS implementation in the U.K. construction industry. A pilot questionnaire was drafted and discussed with two local construction companies. Having validated the recommendations from the interviewees, the amended questionnaires were posted to related construction companies throughout the U.K.

4. Questionnaire Response

Sixty questionnaires were sent out to various consultants and major contractors in the United Kingdom who have experience in the design work including in the Design and Build projects. Out of sixty questionnaires sent, thirty three companies responded to the questionnaires.

4.1 Analysis of the Result

4.1.1 Question 1: Company's Experience. The design and construction related experience of the organizations participating in this survey ranged from 4 years to over 100 years. 54.2 Per cent of the respondents have been in the construction more than 25 years, and 30 per cent have obtained more than 50 years experience in design and construction. Only 24.2 per cent (which are the small size architect's companies) have experience less than 10 years.

Most of the engineers or Quantity Surveyor consultants have an experience in the range of 26 to 50 years whilst 15 per cent of the contractors' companies have experience of more than 50 years.

4.1.2 Question no. 2: Company's Turn Over. It was found that 13.3 per cent of the architect's companies (which have experience less than 10 years or a little longer than that) have below 10 million pounds per year. 18.8 per cent of the other consultants have between 11 million pounds to 50 million pounds. 15.6 per cent of the contractors have turn-over more than 500 million with one of the leading contractor's firm has more than 2 billion pounds annually.

It can be concluded that organizations which have longer period of experience, are making more profit than the small companies. All the contractors with experience of more than 100 years have the biggest share in the market. In addition to that they can easily obtain many jobs due to their reputation and many kind of resources that the small companies shall not be able to compete.

4.1.3 Question no. 3: Type of Services Offered. The respondents ranged from small size companies to larger size companies. There are 24.2 per cent of the architect's firms who only offer architectural services. These are mainly small companies together with a few medium size companies. 30.2 per cent of the architectural consultants offer a few range of services such as architectural design, civil engineering, town planning and design and build services. A few architects offer services like landscape architecture and one big architect's company also offers services such as interior design, mechanical and electrical engineering, quantity surveying and structural engineering.

Almost all engineers, quantity surveying and contractors' companies are multi-disciplined companies who offer a range of services as mentioned before.

All these type of services have their own environmental impact on the environment. The multi-disciplined companies usually have more environmental impact towards environment. Hence, all the constructions related professionals have their role to play in minimizing these impacts.

4.1.4 Question no. 4: Specialist Knowledge. When the company has had the commitment and vision towards environmental sustainability, it has to recruit the specialist who has the special knowledge on how to deal with the environmental impact for both organization and building projects' benefit.

From the survey, 75.8 % of the respondents said that they do have in-house member of the staff who has a special knowledge of how to tackle the environmental problems in their projects. This finding is encouraging since it is important to have this knowledge to create more awareness within the staff and to gain more commitment from the top management towards environmental improvement.

However, 24.2 % of the organizations did not have the specialist who can deal with the environmental impacts. From this percentage, 6 % are from the small-size architectural companies, 6 % from the architectural big companies and 12.2 % from the other consultants and contractors' firms.

4.1.5 Question : 5 - Awareness/ Implementation of an EMS. It is hoped that with the availability of an environmental specialist within the staff member in one organization, the company is more aware about the EMS. However, when the respondents were asked about their awareness and implementation of such system for example; BS 7750, EC's Eco-mass or their own EMS within the organization, 75.8 % of the respondents do not implement such system at all even though 42.5 % are aware about such system.

27.3% of the respondents say that they will possibly implement an EMS in the near future. Only 9.1% are currently implementing BS 7750 standard and 15.2% claimed that they have their own EMS system. 6% of the organization do not aware of any environmental management system at all.

4.1.6 Question 6 : Environmental Policy. Environmental policy is among the first document that the company has to formulate to show its commitment towards quality and sustainable environment. With the environmental policy, the company recognize its role to play in environmental protection and realizes the areas where positive contribution can be made. Both policy for the company and its services were asked because these will show the extent of the company's commitment. Usually the company should always begin any new management system for the benefit of the organization first before extending it to its activities or services.

Table 2 : Availability of Environmental policy for company and projects

Availability of the Policy	Architect (%)	Engineer and Q.S. (%)	Contractors (%)	Total (%)
a) Yes	36.3	21.2	15.2	72.7
b) Yes				
a) Yes	3.03	3.03	3.03	9.1
b) No				
a) No	3.03	3.03	0	6.1
b) Yes				
a) No	12.1	0	0	12.1
b) No				

- Key: a) Environmental policy for company
b) Environmental policy for projects

Table 2 shows 36.3% of the architectural consultants had both environmental policies for their company and the projects. The total of 72.7% companies were found to have both policies.

9.1% of the companies have policy for their companies only whereas 12.1% have no environmental policy at all.

4.1.7 Question 7: Other Environmental Assessment Tools. In implementing any EMS, the company or the design team should compile manuals called "Register of Regulations and Effects". One of the important manual is somewhat similar to an EIA with an analysis of the environmental effects of the organization/project globally, locally and to the future occupants.

There are many methods of assessing the environmental impact of buildings. One example is Environmental Impact Assessment by Building Research Establishment Environmental Assessment Method (BREEAM) which can be used for the existing buildings.

The question was asked to check the awareness of the consultants contractors about the various methods of assessment tools available in the market. With the implementation of some of these assessment tools shows some of their commitment towards sustainable development.

Table 3 shows the overall responds of the participants. It shows that both BREEAM and BSRIA Code of Practice are popular among the architect's consultants. 60% of the companies had been using the mentioned assessment tools for their project. 12.4% of the companies used other environmental assessment tools such as BRE Tool Kits, Starpoint Energy Rating and Association for Environment Conscious Building (AECB) Policy. It seemed that most of the small-size architect's companies were conscious about the tools and practicing it because of their ethical attitudes towards environment. However, almost one third of the companies had never used any kind of tools to assess the environmental impact of their projects. This consists of 12.2% architect consultants, 9.2% engineers and 6% contractors. Surprisingly one of the large company had never used such tools even though it claimed to have the specialist to deal with the environmental issues.

Table 3 : The usage of an environmental assessment tools

Environmental Assessment Tool	Architect (%)	Engineer & Q.S. (%)	Contractor (%)	Total (%)
BREEAM	9.2	6.2	4.9	20.3
BSRIA	0	9.2	3.1	12.3
Both BREEAM and BSRIA	21.2	0	6.2	27.4
Others	12.2	0	3.1	12.4
None	12.2	9.2	6.2	27.6

This shows that the commitment towards the environmental improvement does not come from big companies with a lot of profit and resources. It depends to the attitudes of the top management. With their commitment, then some kind of responsibilities are shown in their companies or activities.

4.1.8 Question 8 : Availability of an Environmental Management Programmer and a Set of Procedures (manual). Environment management programmer, or 'action plans', represents the heart of the EMS. The programmer describes what the organization is actually going to do to mitigate its environmental effects. Action plans must be documented and that managerial responsibilities and time-scales are explicit.

Table 4 : Availability of an environmental manual

Availability of Environmental Manual	Architects (%)	Engineers and Q.S. (%)	Contractor (%)	Total (%)
Manual for company	9.1	0	3.0	12.1
Manual for projects	0	6.1	0	6.1
Both manuals	18.2	18.2	15.2	51.6
None	27.2	3.0	0	30.2

This document is known as the "Environmental Manual" . It has step by step procedures of how to improve the environment either for the company or projects (manual varies from project to project).

It was found that half of the surveyed firms had both environmental manuals for the company and projects (see Table 4). 30.2% (which were mostly of the small architect's companies) did not have any manuals at all. They admitted even though they have an environmental policy, they did not write such manuals in details. 12.1% mentioned that they had an environmental manuals for their companies only.

4.1.9 Question 9 : Environmental Manual's Review. At intervals probably not exceeding one year, managers responsible for the EMS should assess the overall performance of the management programmers and manuals. If the circumstances of the organization have changed significantly, for example in respect of its activities, products and services, the programmers and manuals may need to be modified to ensure that it continues to reflect the needs of organization. The review must consider the recommendations arising from staffs and audit reports, and how to implement them if accepted. This review should also revise objectives and targets, and the action plans as appropriate (Taylor, 1994).

It was found from the survey that 60.6% of the companies understood the importance of reviewing their manuals' contents. 39.4% had never done any review at all thus did not upgrade the contents thus again showing their lack of responsibilities towards environment.

4.1.10 Question 10 : Reasons for Introducing an Environmental Policy or an EMS. This question is to check which is the most popular reason(s) that lead to the introduction of an environmental policy or an EMS. Table 5 shows the percentage of reasons given by the participants.

It is found from Table 5 that most of the participants were aware of many reasons of why the introduction of environmental policy and EMS system were necessary to ensure continual environmental improvement. 21.2% agreed the four reasons highlighted above. 9.1 per cent wrote other reasons such as to receive credibility, and to ensure sustainability in the environment.

Table 5 : Reasons for Introducing an Environmental Policy or an EMS

Reason(s)	Percentage of agreement	Key to table 5 <i>a : Client Pressure</i> <i>b : To gain competitive advantage</i> <i>c : To contribute to the environmental improvement</i> <i>d : To increase building life cycle and to reduce long-run energy costs</i> <i>e : Others</i>
a	13.0	
b	23.0	
c	38.0	
d	22.0	
e	4.0	

However, when looking at the popularity of the reason(s), Table 5 shows that 'to contribute to the environmental improvement' appears to have more overall percentage (38%) than any other reasons. This shows that so far the implementation of this system or part of it was mainly due to the ethical attitudes of the companies.

The companies still did not realize of many other benefits from EMS that had been highlighted before. This can be seen from their poor response on item (b), which is gaining a competitive advantage. Only 23% of the companies agreed to this reason.

The main incentive which drive the implementation of any new management philosophy is the demand for it by clients. In this survey, clients' pressure had obtained 13 per cent only. This shows that the clients are still ignorance about the benefit of having an EMS from the design stage of the projects.

The low percentage in item (d) i.e. "To increase building life cycle and to reduce long-run energy costs", reflected that the architect or environmental engineer have not tried to educate the client of this benefit while receiving the project's brief from the client.

4.2 Conclusions

This research indicated that companies involved in the survey are proving to be slow in their commitment to environmental improvement and are allocating insufficient resources to the scheme. Only 24% of the companies have an EMS in their companies and 27% will implement an EMS in the near future.

It has been understood that much will be gained by the clients if they look beyond the short-term goal of project completion to the scheme in use (CIRIA, 1995). Too much emphasis is given to short term considerations at the expense of flexibility and long life. Maintenance should be viewed as a fundamentally beneficial aspect of ensuring a long and satisfactory product life rather than as a necessary evil.

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MANAGING KNOWLEDGE THROUGH VALUE MANAGEMENT FOR SUSTAINABLE PROJECT SOLUTIONS

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Abstract

As increasingly complex construction projects are undertaken using project teams with members from a number of different organisations from across the supply chain, it is more important than ever to build project teams and encourage knowledge acquisition and sharing through communication, especially when these construction projects are expected to deliver sustainable solutions.

In this paper the authors examine the way in which knowledge is managed within individual projects and establish how knowledge management is best utilised by project teams and stakeholders to assist in the delivery of sustainable buildings.

It is proposed that knowledge management can be incorporated within the value management strategy for a project. By establishing knowledge requirements and strategies for its management early on in a project (for example during a strategic-level value management workshop), the project stakeholders can tease out where additional knowledge is required and how this can be obtained, and by whom. This should ensure that projects meet sustainability targets through knowledge-based learning and by better utilisation of stakeholders' knowledge.

Re-visiting the team's knowledge management requirements during the project (value management workshops later in the project life cycle) and encouraging knowledge sharing outside of as well as within the value management workshops, will promote open dialogue, which will in turn enhance relationships within project teams and ultimately go some way to convey the cultural change required within the industry.

This methodology should ensure that knowledge requirements (creation, securing, distribution and retrieval) are all captured during the workshop events and managed effectively to the advantage of the project, its stakeholders and the wider community via sustainable solutions.

Keywords : Knowledge-based learning, Knowledge management, Stakeholder input, Sustainable solutions, Value management.

1. Introduction

Construction has a massive impact on society, the economy and the environment, and all phases of the life cycle contribute; from the mining of raw materials, through manufacture and construction, to repair, maintenance, refurbishment, and ultimately demolition and reuse (Construction Best Practice Programme, 2003). As construction is, after all, essential, the challenge of a sustainable construction approach is to reconcile the impacts of construction with the benefits.

1.1 Sustainable decision-making.

A sustainable decision must be one which is judged to have been a good decision not just at the end of the first year but five years, ten years, generations later.

The decisions that are made at the beginning of any project, will directly impact on the inputs, development, and outputs. Taking the time to install a structured decision making process up front will ensure a 'best value' solution to the project is found. Balancing social, economic and environment issues can be achieved using value management tools and techniques (Hayles, 2003). This is preferable to 'cost-benefit analysis' for example, where the approach is to emphasise cost at the expense of others factors.

As a process, value management enables the client and key stakeholders to:

- consider all the issues surrounding a project;
- develop a mission statement for the project participants to agree on and use as a benchmark for future decision making (using Function Analysis); and
- examine all the options available to them whilst considering their impact socially, economically and environmentally.

Creativity is an important element of the value management process. It is also vital in the transfer of knowledge between stakeholders as creativity encourages individuals to 'think outside the box' and this in turn assists in the transfer of both tacit and explicit knowledge as well as creating new knowledge.

A value management approach offers the means for the client to contribute to a better built environment and ultimately the opportunity to stimulate improvements in the construction process. An important part of this process is the open exchange of ideas and information to create shared knowledge.

1.2 Project Knowledge Management (ProjKM).

Knowledge is information evaluated and organised in the human mind so that it can be used purposefully (The Association for Information Management, 2004). In short it is the psychological result of perception and learning and reasoning (Wordnet, 2003) by both individuals and groups.

Organisational knowledge management and knowledge transfer has been described at length in the literature. However there is little research on how knowledge is managed/transferred between project stakeholders representing a number of different organisations including end user groups and client bodies, each with different skills, knowledge and experience to impart.

Indeed, the last decade has seen an increased interest in knowledge management by organisations in a variety of sectors, and by academia (Despres & Cheuvel, 1999; Grant, 2000; Ives *et al*, 1998; McAdam & McCreedy, 1999; and von Krogh & Grand, 2000).

Knowledge management is defined as the way a company stores, organises and accesses internal and external information (MIT Sloan School of Management, 1994). Knowledge transfer refers to the effective sharing of ideas, knowledge, or experience between units of a company or from a company to its customers (MIT Sloan School of Management, 1994). This knowledge can either be tacit or explicit or a continuum of both.

Taking into account the above definitions, the acquisition and transfer of knowledge amongst stakeholders working on a discrete collaborative project is defined in this paper as project knowledge management or ProjKM and is the way a project team/stakeholders chooses to organise and access internal and external information, tacit, implicit, explicit and cultural knowledge, for mutual gain. This includes the effective sharing of ideas, knowledge, or experience amongst the project stakeholders.

There is strong and compelling evidence that the effective management of knowledge sources and capabilities is vital for the delivery of best practice solutions (Hayles & Egbu, 2004) and to prevent a situation of 'reinventing the wheel'.

It is known that successful organisation-wide knowledge management initiatives provide competitive advantage (Grant, 1991), however it is not known how effect these initiatives are when on large and complicated construction projects, diverse stakeholders representing a range of different interest and organisations come together to exchange knowledge.

In the case of discrete construction projects, it is important for project knowledge management to aim to tap into the existing knowledge amongst the key stakeholders, including the end users. Competences and capabilities (unlike resources) are unique to individuals, discrete project teams and stakeholders (Hayles & Egbu, 2004).

Previous research undertaken by Ruggles (1998) has determined 8 categories of knowledge-focused activities within organisations:

- Generating new knowledge;
- Accessing valuable knowledge from outside sources;
- Using accessible knowledge in decision making;
- Embedding knowledge in processes, products and/or services;
- Representing knowledge in documents, databases and software;
- Facilitating knowledge growth through culture and incentives;
- Transferring existing knowledge; and
- Measuring the value of knowledge assets and/or impact of knowledge management.

These are not only important on an organisation-wide basis, they are also of paramount importance in the delivery of successful facilities projects and therefore invaluable activities to be undertaken within project teams and between project stakeholders.

2. How We Manage Knowledge to Develop Viable and Sustainable Solutions

The purpose of this paper is to examine the way in which knowledge can be managed within the value management process and to establish whether this is a successful approach to project/stakeholder-wide knowledge management for the delivery of successful and sustainable building projects.

Value management as a methodology is still infrequently adopted by project teams as a way of managing the process. This paper demonstrates the strength of the value management process in considering the knowledge required (creation, securing, distribution and retrieval) to deliver complicated construction projects. As knowledge management continues to be a favoured business improvement tool, embedding it within a value management framework can only further improve the construction process.

Projects that set off with the best intentions can often incur set backs when there is not a shared understanding at the outset, when the desires of one stakeholder are not reciprocated, when the environmental issues are not balanced with the social and economic issues. Value management is an excellent methodology which can be used to allow these uncertainties to be resolved up front. It also allows the free flow of information and knowledge between stakeholders. It gives the opportunity for all involved to have an understanding of the project, its aims and objectives, to produce a mission statement that all team members are happy with and to incorporate wide stakeholder consultation.

3. Methodology

In order to test the usefulness of this approach a case study has been adopted. This case study is an example of strategic value management, where a workshop is undertaken at project conception. At this stage the information available is complex and requires synthesis and judgments to make the right decisions; in other words knowledge acquisition and transfer is required. During strategic value

management the purpose for the project becomes explicit, and the knowledge required to complete the task recognised.

3.1 Case study example – Hong Kong's Reservoirs.

The example chosen is an investigation of the operational and structural condition of six impounding reservoirs in Hong Kong, with a view to develop design options for their refurbishment and an upgrading of the reservoirs inline with current standards.

These reservoirs were constructed more than 35 years ago and, in some cases, are nearly 100 years old. As a result of regular inspections, it was established that there were a range of common defects on the six dams, particularly amongst those older structures. These problems were grouped under the general category of asset management and had a significant effect on the operational performance and life of the structures. Issues being investigated embraced technical performance of the dam structures and their accessories, maintaining public amenities to the reservoirs and the wildlife habitats, drinkable water quality and health and safety benefits of the employees of the Water Supplies Department, Hong Kong Special Administrative Region's government.

A one-day, independently facilitated, value management workshop was conducted with all the key stakeholders invited to attend. This workshop followed a structured value management job plan, aimed at developing a strategic review for the project.

Prior to the value management workshop existing information (from the design of the original reservoirs and their structures, to the latest reports on the current status of those structures) was gathered, from a wide variety of government departments and consultants. Digital photographs were taken to facilitate the reporting of the latest issues relating to technical, environmental and social aspects and to ensure all the key stakeholders had up to date information on the current condition of the six reservoirs. In addition, this meant that each stakeholder was given the opportunity to acquire full and equal knowledge on each aspect of the project prior to the workshop.

3.2 Value Management workshop.

During issues analysis, stakeholders found that a lot of important information and data was scattered around and owned by different individuals. As a result no one person or organisation had a full and complete picture of the current situation. The stakeholders found that they needed to actively share their knowledge in order to enable others to obtain a full picture, as well as their needs to be heard and recognised. Even within the Water Supplies Department, knowledge ranged from planning and project management to water science. Other stakeholders included representatives from the Correctional Services Department (as one of the reservoirs was located next to a high-security prison), representatives from the District Land Office, Engineers from the Geotechnical Engineering Office, consulting water engineers, environmental consultants, representatives from the Agricultural and Fisheries Department and Environmental Protection Department. In total, 20 participants representing many diverse disciplines were present at the workshop.

3.3 Knowledge capture.

Besides the explicit knowledge that were collected through time in codified formats, such as reports, detailed calculations or drawings, there was a substantial amount of tacit knowledge made available; knowledge drawn from the representatives' tacit experiences that they gained whilst visiting these and other sites.

The active sharing in the *Issues Analysis* phase of the workshop enabled missing knowledge or information to be shared explicitly and used in decision-making at a later stage. As some of these structures were

nearly 100 years old, a lot of the drawings were not up-to-dated or in such a poor condition that they required human interpretation.

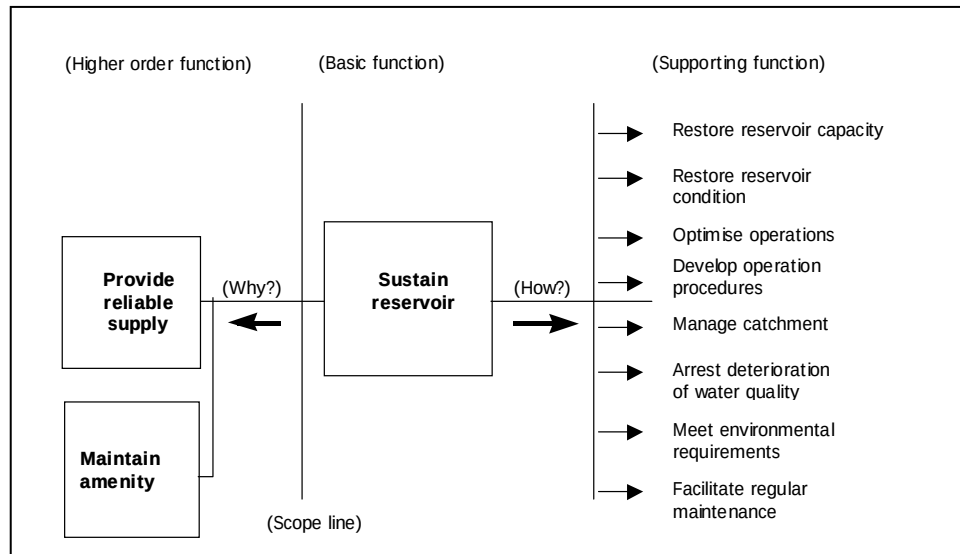


Fig.1 Link thinking hierarchy diagram

After the *Issues Analysis* phase, the stakeholders worked together to construct a link thinking hierarchy (function) diagram as shown in Figure 1. As indicated on the left hand side of Figure 1, the team needed to provide reliable water supply to those residents around the six reservoirs and at the same time maintain local access for boating, fishing, jogging along the reservoirs trails and bird-watching. This implied that the renovation works should not significantly affect wildlife in those areas. If stakeholder knowledge had not been shared during the previous phase of the workshop, a lot of these issues could have been overlooked and leisure activities enjoyed by those using the reservoirs, seriously affected.

In order to sustain these six impounding reservoirs, the options “do nothing” or “abandon any of the six reservoirs” were out of the questions. In supporting the basic function of the project, a series of supporting functions were suggested and validated by the stakeholders. These ranged from restoring the reservoirs’ capacities to facilitating future regular maintenance. Current issues as well as life cycle issues were considered together with their associated costs. Environmental requirements were also seriously examined to prevent the outbreak of ecological disasters. The thoroughness of the function diagram could not be constructed without knowledge input from the various stakeholders.

Once the team had a thorough review of the functions of the project, they entered into the *Ideas Generation* phase where ideas were solicited from the team. Some of the ideas generated were from past experience where they had been subjected to test; others were more free-wheel or sometimes could be classified as “wild” ideas. Since quantity of ideas was of utmost importance, stakeholders were reminded to withhold their judgment and produce as many suggestions as possible. Participants were also encouraged to build on others knowledge and ideas in order to improve those options further. The brainstorming session used the function diagram constructed in the previous phase as the focus. In total, 32 ideas were generated within a short period of time.

3.4 Decision making and action planning.

As not all the options generated in the brainstorming session were workable, a list of eight evaluation criteria was arrived at through group consensus. The team found that precise definitions of those criteria were important to avoid misunderstanding as well as facilitate the understanding by anyone who was not in

attendance at the workshop. The criteria were discussed and debated among the participants and different thoughts and perceptions were elicited in order to arrive at the condensed list. Table 1 charts the evaluation criteria, which ranged from technical performance to social issues associated with the project. This could only be achieved through the active knowledge sharing among the stakeholders as well as the incremental change to individuals' mental models through open dialogue.

Table 1: Evaluation criteria

Evaluation Criteria	Definitions
Cost Implication	Whole life cost
Ease of construction/ implementation	Including implementation time
Environmental implication	Potential adverse/positive effect on natural environment
Impact on water supply	During implementation and long term effect
Added value	Effect on future plans
Social implications	Enjoyment of country parks/community benefits
Technical performance	Including maintainability and sustainability
Effect on dam safety	Positive and negative

Based on the eight evaluation criteria, all the thirty-two ideas were subjected to a rigorous test to see whether they complied with these criteria. As each criterion had different weighting, a score was calculated for each option and those options that scored the highest were considered more favorable solutions for implementation. At the close of the workshop, an action plan was prepared by the stakeholders to determine actions needing to be taken. Responsibility and deadlines for these actions was also agreed.

4. Discussion

The case study above demonstrates how ProjKM is embedded within the value management framework for a project. In addition to generating new knowledge, knowledge-focused activities adopted during a value management workshop aim to tap into the project stakeholders' existing knowledge by introducing tools and techniques which exploit and improve the processes and capabilities already in place in order to enhance the project. The model reproduced in Figure 2 is based on the analysis of a number of value management studies and demonstrates how the value management workshop stages go hand-in-hand with knowledge management and the development of ProjKM.

By establishing knowledge requirements and strategies for its management early on in a project (for example during a strategic-level value management workshop), the project stakeholders can tease out where additional knowledge is required, how this can be obtained, and by whom (action planning). This is increasingly important when social and ecological as well as economical considerations need to be tackled. This structure should ensure that projects meet sustainability targets through knowledge-based learning and by better utilisation of stakeholders' knowledge.

The example given is centred around strategic decision making, however re-visiting the team's knowledge management requirements (ProjKM) during the project, with additional value management workshops later in the project life cycle, and encouraging knowledge sharing outside of as well as within the value management workshops, will promote open dialogue. This will, in turn, enhance relationships within project teams and ultimately go some way to convey the cultural change required within the construction industry. Lessons learnt at each stage of the project can be fed back into future workshops and the workshop results can be used as an audit trail for decisions made and the options pursued.

This methodology should ensure that knowledge requirements (creation, securing, distribution and retrieval) are all captured during the workshop events and managed effectively to the advantage of the project, its stakeholders and the wider community via sustainable solutions.

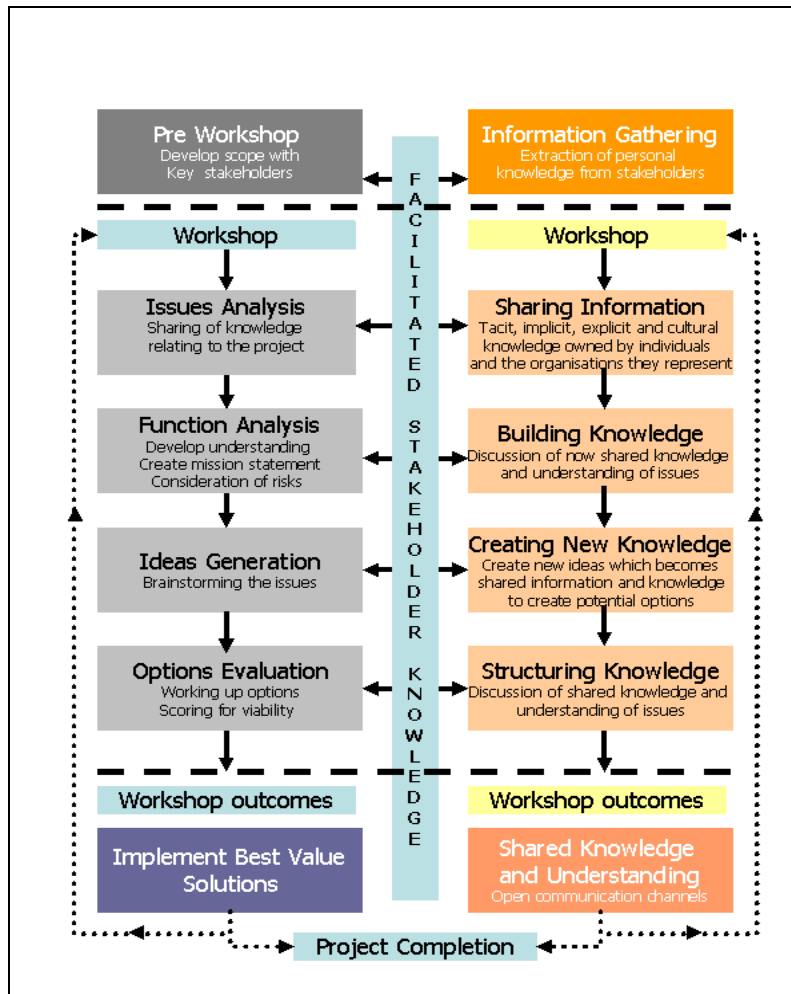


Fig.2 Knowledge acquisition and transfer during a value management workshop at any stage of the project lifecycle

Conclusions

As increasingly complex construction projects are undertaken using project teams with members from a number of different organisations from across the supply chain, it is more important than ever to bring key stakeholders together and build project teams. Using an independent facilitator and adopting a value methodology can assist in this process.

The case study described in this paper demonstrates the benefits of adopting value management and illustrates how this approach enables stakeholder engagement; encouraging knowledge acquisition and sharing. The example shows how both explicit and tacit knowledge is exploited during a value management workshop, and how ProjKM develops as the workshop progresses.

The diverse knowledge, skills and experiences of the project participants are key assets to the value management workshop; neither an organisation nor an individual will own all the knowledge required. By consciously combining value management with knowledge management, essential knowledge is gathered

that facilitates the decision-making process, achieves optimum value for a project and in doing so delivers sustainable construction solutions.

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KNOWLEDGE NETWORKING: LESSONS FROM A METAMORPHOSIS OF BUBBLE DIAGRAM

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Abstract

This paper shares some lessons learned from a simple exploration of a bubble diagram metamorphosis for developing knowledge network in the early stage of a design process. The exploration was done by a small group of architecture students as an exercise to widen up their perception on Knowledge-based Networking (k-networking) and Performance-based Design. The main intention of the exploration is to widen entrée to information, collective learning and sharing of knowledge between groups as well as individual. Despite being 'unsighted' to knowledge management the participants of the exploration were able to identify a few key advantages of k-networking and Performance-based Design. The exploration found out that the pursuit of knowledge networking when supported by vision and right skills can assure considerable gains towards sustainable building.

Keyword s: Bubble Diagram, Performance-based Design, Knowledge-based Networking, Sustainable Building.

1. Introduction

The importance of knowledge in achieving sustainable development is and will continue to be a fundamental concept. In the definition of sustainable development itself, embodies a belief that people are the foremost *knowledgeable force* and should be able to alter and improve their lives in accordance with criteria that take accounts of the needs of others; and which protects the planet and future generation (Nath, 1999).

In preparing the future building professional for the challenging future; there is a call to provide them with skills in utilising information, exchanging knowledge and even reviewing the current working procedures. Building professionals need to acquire new Knowledge Management (KM) skills that are beyond their conventional practice (Rizal at al., 2003); at the same time they have to contribute and participate in developing Knowledge-based Networking (k-networking) in order to play a better role.

1.1 Knowledge-based Networking

In the context of sustainable development, Clark and Howard (1998) defined Knowledge Network as:

"...group of expert working together on a common concern, strengthening each other's research and communication capacity; sharing knowledge bases and developing solutions that are made for use by others outside the network"

Nath (1999) noted that k-networking rest on the strong notion that communities have knowledge and expertise that need to be synergized with existing information, in the context of decision making and initiating judicious action.

An underlying premise of a k-networking is that the whole is greater than the sum of parts. This is the main reason why k-networking approach is so essential for sustainable development; k-networking provides global entrée to information and human resources, collective learning and sharing of knowledge between nations, communities and individual. The action and judgment then can be localized according to the vision and the definition of '*needs*' in a community.

Information and knowledge for sustainable development is ever expanding, there are myriad of information being produced over time, but development professionals are often unable to locate and even access the relevant information. The information whether in conventional form and non-conventional form have to be organized and managed in an appropriate manner as well as highly accessible to the each member of the k-networking. As mentioned previously, this must be an effort of the whole development professional; such form of networking transforms the development professionals from mere information recipients into information provider and decision makers. In order to face these challenges, development professionals need to acquire Knowledge Management skills (Rizal et al., 2003).

1.2 Knowledge Management

Knowledge Management (KM) may be defined as a systematic and integrative process of co-ordinating organization-wide activities of acquiring, creating, storing, sharing, diffusing, developing and deploying knowledge by individuals and groups in pursuit of major organisational goals (Rastogi, 2000). It is a process through which organisation create and use their institutional and collective knowledge. Sveiby (2000) has the following description on the notion of knowledge management:

“Knowledge management involves efficiently connecting those who know with those who need to know, and converting personal knowledge into organisational knowledge”

In KM, both explicit and tacit knowledge are taken into process to solve business problems mainly using information technologies. As explicit knowledge is easy to codify and transform, tacit knowledge poses a great challenge as it resides in the heads of expertise. Too often, KM is thought to be restricted in sophisticated electronic software tools and this ignores the critical human factors; personal and organisational KM skills are far more important than technical tools.

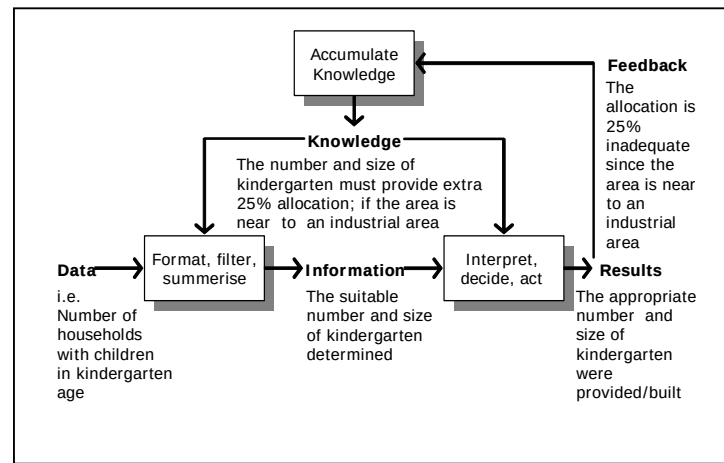


Fig.1 An example describing the use of data, information and creation of knowledge by an architect

1.3 Performance-based Design

Performance-based Design is an approach where the performance objectives are developed during the initial stages of the design. The designer and his team should identify their design intentions, and it is most effective when the design team is involved in establishing the intentions.

Deru (2004) claims that the process starts with a vision statement, such as:

This project will design, construct, and operate a building that provides a healthy and productive work environment and minimizes the use of nonrenewable material and energy resources in a cost-effective manner.

The vision statement should be used throughout the life of the building to help guide key decisions concerning material selection, building design, system operation and facilities maintenance. The vision

statement is a broad declaration about the final building performance, which should be broken down into topic areas that can be implemented by the design team. The building operators will later use the statement to assess performance of the building.

2. The Exploration

2.1 Realisation

The exploration started from a realisation that as an art, architecture is more than fulfilling the purely practical requirements of a design program as described in the Performance-based Design. Ching (1979) explained that:

"Fundamentally, the physical manifestations of architecture accommodate human activity. However, the arrangement and accommodation of the elements of form and space will determine how architecture might promote endeavors, elicit responses and communicate meaning".

These elements of form and space are presented therefore, not as ends in themselves, but as means to solve a problem in response to a condition of function, purpose and context; that what architect defined as *architecturally*. Those kinds of information are precious in outlining their legacy, strategy and expected performance; unfortunately the information are seldom communicated between the architect and the other member of a design team as well as the facilities manager throughout the building lifecycle.

From the Knowledge Management (KM) point of view, there is a knowledge leakage that leads towards a knowledge gap between architect and his design team. The gap, in this case is very much caused by the way the architecture design has been practiced; leads to lack of knowledge exchange on particularly intent of an architect and legacy of the rest of his/her design team (Teicholz, 2004).

2.2 Intention

The main intention of the exploration was to develop a design process that enables a wider entrée to information, collective learning and sharing of knowledge by manipulating hyperlink and simple IT tools. It has been realized that representation of data beyond the textual can be employed to make information more accessible and detect patterns and relationship (Rafi at al, 2002). According to Tufte (1994), the world is complex, dynamic and multidimensional; the paper is static and flat. He also poses question "How are we represent the rich and visual world of experience and measurement in mere flatland?".

2.3 Explorers

The explorers consist of 12 students in their second semester 2004 of Higher National Diploma (HND) Construction majoring in Architectural Studies; and guided by 2 architecture lecturers of International University College of Technology Twintech (IUCTT). The students were taking three units on the semester; Architectural Design 2, Design Procedures and IT Applications-CAD.

To provide a context, the students have been exposed to the basic design exercise at least in their first semester of the HND program; most of them enrolled the program with a few years working experience. All of the students were capable in utilising Microsoft Office application such as Ms Word, Ms Excel and Ms Power Point at least at intermediate level; the outcome level for them to pass IT Application-General, a subject they took in their first semester. Some of them further the skills on their own through their work experience and self-teaching.

3. Methodology

The design challenge was to design a kindergarten on an identified site; at the beginning of the design process, as usual the students (in 3 groups) have been asked to prepare at least a precedent/case

study on kindergarten design and make a site visit. During the visit the students were required to make an analysis on the site; beforehand the students were introduced to site analysis in a Design Procedure's lecture. The main product after the early stage is a report that consists of:

- (i) *The Precedent/Case Study*: Analysis on the types of space, building elements, furniture, color, dimensions and material identified.
- (ii) *The Site Analysis*: Analysis on the site location, context, climate, view, access, natural elements, built in elements, topography etc.
- (iii) *The Space-Performance table for their proposed kindergarten*: The extract from the case study and site analysis, part of the brief is a table showing the spaces required for the kindergarten and the performances expected for each space. The type of performance needed were space dimension, furniture, opening size (for circulation, lighting and ventilation) as well as the materials for the floor, wall and ceiling.

In the next task, the students were asked to produce their bubble diagram for the kindergarten design. The bubble diagram was then transferred into digital form using Ms PowerPoint. Using the hyperlink technology the rationales for the space design and provision were linked with the data collected in the precedent study and site analysis. The approach was adopted with the vision that the students will be more attached to the information in the site analysis throughout their design and their decisions will be more reactive to the natural environment.

The Space-Performance table was introduced as the first step in introducing Performance based Design to the student. From the point on, the bubble diagram and the Space-Performance table were used as an integral component for information network of the exploration; where all the design development data, rationales, interpretation, decision and comments were linked. This is what was described as a '*metamorphosis of bubble diagram*'; from the traditional uses as tool in studying the relationship of the spaces into a tool for developing knowledge network. At the end of the exercise the Ms PowerPoint works were used for the student's presentation as well as for the lecturer's assessment on the student design.

4. The Findings

The little change in the design process (bubble diagram's metamorphosis) had brought a few expectant outcomes in the design process and products. Outlined here are some of the lessons learned:

- (i) *Understandable Design Decision*: The students were able to provide more acceptable and understandable design rationale since they are able to identify and relate their design decision with the data and facts from their case study and site analysis.
- (ii) *Sharing and Utilisation of Information and Knowledge*: The students realised on the importance of data collection and site analysis as part of an early exercise in design process; the site analysis and case study were more utilised and shared among the student.
- (iii) *Clearer Design Intent*: The Space Performance table provided the student a better design direction and more consistent in their design decision.
- (iv) *Sustainable Design*: I was noted that most of the final design by the students in this group have shown a consistent approach towards sustainable development (despite their lack of exposure to sustainable development).
- (v) *Knowledge Sharing*: The digitalised and hyperlinked data enable the students to pool the data and information in creating a bigger collection of data and information.
- (vi) *Knowledge Networking*: The bubble diagrams became a centre of 'mind map' for linking the decision and the data collected. The digital format of the data reduce the

sense of possessing on a piece of information thus encourage the development of a knowledge network.

- (vii) *Justified and transparent advice/decision:* The assessor's advice and decision were more transparent and justified since they were recorded and can be accessed by all the students.

The main resistant in the application of the bubble diagram metamorphosis were:

- (viii) *Digital data:* Some of the data need to be digitised and the process needed extra peripherals as well as skills in using computer peripherals. The students were more attracted to search the data from Internet since they are already in digital format.
- (ix) *Working culture:* Most of the data were in text format whilst the students were trained to use drawings and sketches. The exercise of recording and linking the data to decision in text format was awkward and time consuming to both the student and the assessors.
- (x) *Overflow of Information and the Usage:* The lack of experience and training in handling information led towards overflow of information since they were not properly filtered and managed. At certain occasion, there were collided pieces of information being used together and linked.

There were some opportunity and space for improving the metamorphosis:

- (xi) *Knowledge Management:* The importance of KM skills and tools were identified. The overflow of data for example can be reduced by proper management of the data. The use of KM tools will enable us to analyse the findings further in a batter approach.
- (xii) *Width of Process:* The exercise coverage can be widen throughout the design process to analyse further the impacts of the metamorphosis to the final product.
- (xiii) *Internet based:* The process can be done by utilizing the Internet technology since all the data is in digital format; with appropriate technology and skills. This will enable a wider participation and data.

5. Concluding Remarks

In the exercise, although systematic, is not scientific and has several limitation as well as a few shortcomings. From an educational point of view, did the metamorphosis improve or inhibit architectural design process? What were the consequences to student's learning and studio culture? The general consensus among the students is not one was better than the other, but the exploration enriched the design process. The project had a few positive effects by introducing the student a better approach for managing the design data as well as understanding the data network. The method has brought them to a more systematic approach in achieving a design that is more responsive to the natural environment and contribute towards sustainable development in general. Base on the findings of this exploration we believe that there are calls for development professionals to continuously revise their strategic mission, skills, technology and knowledge to adopt and manipulate the currently available information in facing the wave of changes in the industry.

Acknowledgements

I would like to thank the cooperation of the HND Architecture Design students who was involved in the process and my IUCTT colleagues for their support in the completion of this paper.

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WHAT DO WE MEAN BY CORPORATE SOCIAL RESPONSIBILITY IN THE CONSTRUCTION SECTOR?

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Abstract

Since the UN Conference Rio-92, when the Agenda 21 formulated international key policies for achieving sustainable development, all sectors have been in the process of interpreting and making plans, which includes goals and commitments to take into account stakeholders concerns. The Agenda 21 for Sustainable Construction in Developing Countries (CIB, 2002) was formulated specially for the building industry to go towards achieving sustainable development on its environmental, socio-economic and cultural dimensions. The transition to sustainable development requires the focus on corporate social responsibility (CSR), integrating principles of ethics and responsibility into the day-to-day actions and decisions of both individuals and companies. The aim of this study is to evaluate how top management in the construction industry in the State of Bahia, Brazil, understands the concept of CSR and how they integrate social responsibility into their activities. The analysis of this case study shows that the CSR remits two major key perspectives. First, CSR can be defined in ethical terms, and second it can also be viewed from an instrumentalist perspective where corporate image and business goals are of prime concern. The findings show that CSR can be found to be multifaceted, covering areas such as employee welfare, environmental issues, corporate sustainability and sustainable building construction practices. The main issue is to understand that the success of the sustainability in the construction sector will ultimately depend on the CEOs' choice to adopt or reject the principles of sustainable development aligned with strategic corporate social responsibility.

Keywords : Corporate social responsibility, Sustainable development, Construction sector, Developing countries.

1. Introduction

The corporation has long been regarded by law as an artificial being, possessing rights, duties, and powers, and assuming some of the individual's obligations. For more than half a century, managers of these legal entities have encountered the proposition that such organization should not only be economically efficient, but should possess a corporate conscience, a recognition that it has an obligation with the society and the environment. Today, the corporations' concerns, influences, and obligations are greater than ever before. Business can be seen as a citizen, an integral part of a larger community. Because of this relationship, the question of corporate obligations to the society is paramount. Critics argue that managers can no longer focus solely on the firms' fundamental business mission. Other concerns come into play such as the value and the importance of sustainable development to long term business success aligned with strategic corporate social responsibility (CSR).

However, only few organizations in the construction sector of the State of Bahia¹, have managed to integrate CSR and sustainable development effectively into their daily operations and business practices. Most of today's business excellence models focus predominantly on a single bottom line of financial results rather than dealing with social and environmental impact of business. Although the construction industry

¹ Bahia is the fifth State of Brazil in size, with 566,978 km², a population of 13,070,250 inhabitants, and its capital is the city of Salvador. The Gross Domestic Product (GDP) of Bahia is US\$ 20,8 billions (4.5% of Brazil's GDP) and the construction sector is responsible for 8.8% of the GDP of the State. (IBGE, 2002)

plays a major role in improving the quality of the built environment, it also impacts the wider environment in a number of ways. According to Pinto (1999), construction and demolition waste, in the construction business in Brazil, alone, represents 41-70% of total waste of the country. Too many buildings are environmentally inefficient and do not make a better use of the limited resources such as energy and water. The environmental efficiency of building in Brazil remains lower than in many developed countries. Promoting sustainable construction is difficult especially because of the industry's size and fragmentation. In 2003, this industry provided 7.1% of Brazil's gross domestic product (IBGE, 2004), and in accordance with the General Register of Employed and Unemployed - CAGED (2004), from January to August 2004, 1,466,446 new ranks of formal work were created in Brazil, and the construction sector was responsible for a total of 90.057 workers in this same period.

But what is meant by corporate social responsibility (CSR) in the construction sector? Responsibility for what and to whom? Who is calling for firms to be socially responsible? This work examines the ideas behind CSR within the literature and some of the current attempts to define the social responsibility based in the concept of sustainable development, in order to evaluate the perception of the top management and the dimension of CSR in the construction sector in the State of Bahia, Brazil.

This research is part of a MSc dissertation project in course, in the Post-Graduate Course on Urban Environmental Engineering School at Federal University of Bahia. The project aims to contribute for that companies in the construction sector in the State of Bahia, come to integrate in its operations, the economic, social and environmental impacts, based on the triple bottom line – TBL. This means business goals related not only with the profits, classic concept of the Capitalism, but also with a concern with the planet and the people. The research involves three major stages for evaluating how top management, in the construction industry, understands the concept of CSR and how they integrate social responsibility into their activities. The first stage is an unstructured interview applied to leaders of the two major representative institutions of the construction sector. The main goal here is to explore preliminary information about CSR in the sector, and use these data for elaborating a questionnaire to be applied to top management of construction companies. The second stage is a questionnaire survey to ascertain the perceptions, attitudes and expectations of practitioners on the CSR in the construction sector. The preparation of the questionnaire is already on the way and is been preceded by a review of the literature and the results of a small pilot survey to fine-tune the questionnaire. In the last stage, to further and deepen understanding in relation to CSR in the sector, three study cases will be undertaken in companies with different scales, in order to triangulate the data of the other stages. The evidences of the case studies will come from documents, visits, interviews, direct and participant observation.

At the end of the project, it will be possible to draw a picture of the CSR in the construction sector of the State of Bahia, the conceptual perception of the managers, the real reasons for which the companies embrace or not this concept, and which are the achievements and the difficulties during this process of changing the route to a New Age, where the global economy is compatible with social justice and equity, and with environmental protection.

2. CSR compromised with Sustainable Development

How does business and society actually define CSR? According to the International Institute for Sustainable Development (IISD, 2004) no universally accepted definition of CSR exists. Some suggest that it's about what business puts back — and can show it has put back — in return for the benefits it receives from society. Others say that CSR is about a company's interaction with the legal and social obligations of the societies in which it operates and about how it accounts for those obligations. The World Business Council for Sustainable Development (WBCSD) proposes a definition for CSR as the commitment of business to contribute to sustainable economic development, working with employees, their families, the local community and society at large to improve their quality of life (WBCSD, 2004). In July 2001, the European Commission presented a Green Paper 'Promoting a European Framework for Corporate Social Responsibility'. They consider CSR as a concept whereby companies integrate social and environmental concerns in their business operations and in their interaction with their stakeholders on a voluntary basis (COM, 2002). For

organizations to be socially responsible is to evaluate the effect of their action on community, acting as citizens, respecting the rules instituted by society and to consider shareholders interests. For Chanlat (1997) CSR means refuse in earning more, while making lose all society, and in relation to environmental preservation, it is to worry about the effects of its activities on the ecological balance in order to ensure that a planet will be bequeathed for the future generations.

A new concept of CSR based on sustainable development is emerging in the field of business studies. In 1987, the Brundtland Report, by the World Commission on Environment and Development, defined sustainable development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED, 1987). Lima (1997) argues that the Brundtland Report innovates, while treats the ‘sustainability of the development’ and proposes the necessity of a multidimensional perspective that articulates economic, political, ethics, social, cultural and environment issues, avoiding the reductions of the past. Inclusively, Rattner (1992) affirms that the concept of sustainable development should not be worked in the operational level, or only seen as an adequate economic science or technology, nor for the inclusion of environmental concerns in project investments. He believes that its true meaning will be derived only from systematic efforts for the consolidation of a more steady, rational and harmonious society, based in principles of fairness and justice in the relations between people inside each society, as well to a global level.

Sponsored by the United Nations, in 1992 was realized the Conference on Environmental and Development, formally known as the Earth Summit, which brought together business and political leaders from around the world to evaluate the growing dangers of environmental degradation and the urgent need for economic development in poorer nations. Since then, a growing number of companies now acknowledge the importance to base CSR in the principles of sustainable development. Yet, companies are faced with the problem of how to put this new concept of CSR into practice. Recently various theoretical frameworks have been developed to assist companies in their efforts to implement CSR. For Cramer (2004), the journey to CSR is not clear-cut; it is a searching process in which leaders have to develop their own identity based on finding a responsible balance between people, planet and profit while taking account of what the outside world requires from them.

Leão-Aguiar *et al.* (2004) propose a theoretical model for CSR elaborated from the understanding of the concept of social responsibility associated to the commitment with sustainable development (Fig.1). The companies while adopting this model of CSR, certainly will have a larger democratic participation of the diverse groups of interest, in short terms far from the simple financial return. This model holds a strong ideological dimension, bringing significant material consequences for all involved actors. Inclusively, the proposal of the model is to dislocate the debates on CSR of the management level to an institutional order, and according to Kreitlon (2004), would be, without a doubt, effectively a radical and an ethical move.

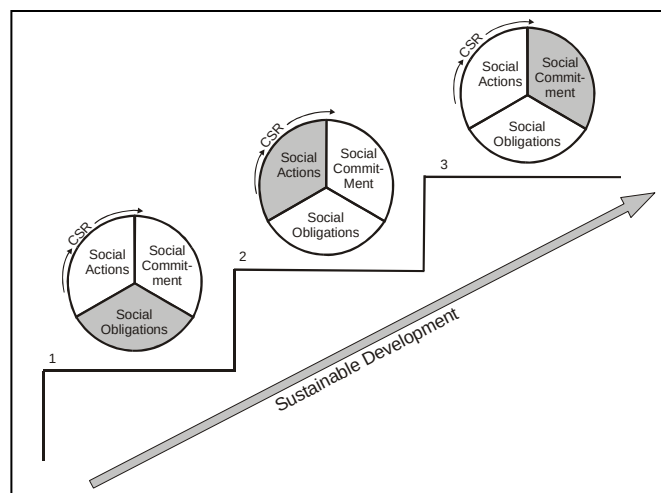


Fig.1 Leão-Aguiar *et al.* (2004) CSR model

Who opposes CSR? Many people in the business world stills believe that business should stick to making profit and leave social matters to other groups in society. Those who adopt this neo-classical view of the firm believe that the social responsibilities to be adopted by business are the provision of employment and the payment of taxes. According to Carroll (1999), this view is most famously taken to the extremes of maximizing shareholder value and reflected in the views of the economist Milton Friedman, whose famous objection to social and environmental issues is familiar to most. Despite these arguments, many authors believe that when corporations support the right causes in the right way, according to Porter and Kramer (2003), they set in motion a virtuous circle of philanthropic efforts, gaining a greater improvement in competitiveness, supporting important benefits both to the corporations and causes. However, companies do not become socially responsible overnight. The process takes time, new attitudes, routines, policies and actions. Once a company is prepared to implement strategic CSR, many obstacles must overcome such as the need of accountability.

According to Leão-Aguiar *et al.* (2004), the compatible values with the new vision of the world in promoting the sustainable development in business management, gives the organizations a duty to not only to take into account the expectations and the respect of the shareholders, as also of the stakeholders (all interested parties in the company's activity). According to Altvater (1995), the main challenge of the big corporations, especially those who act in developing countries, is to fulfill the expectations of the communities, the pressure from the environmental activists and the bargaining power of the governments, which means learn to deal with multi-stakeholders' interests.

The process of internalizing the concept of CSR based on sustainable development does not develop in the same way in all sectors of the economy. Generally, sectors traditionally known as big polluters, such as petrochemical, metallurgic and pulp and paper, as well as multinational companies, advanced more in terms of social responsibility. This is most in consequence of the pressure from society and NGOs, and the magnitude of the costs associated with the environmental passive. "Certain sections of industry, notably nuclear power, chemicals productions and waste disposal, have become the 'Frankenstein' of the twentieth century [...]" (SMITH, 1993, p. 173) In agreement with Smith, this incidents combined with others that occurred in the late sixties until the eighties, have raised questions concerning society's ability to control the actions of the corporations. According to Handy (2003), in the wake of the recent corporate scandals, it is time to reconsider the assumptions underlying American-style stock-market capitalism and many wonder if the America model is corrupt: "Whom and what is a business for? And are traditional ownership and governance structures suited to the knowledge economy?" (HANDY, 2003, p. 65)

3. CSR and the Construction Sector

The construction sector impacts intensively the society and the environment. Buildings and structures consume raw materials, energy and water in their construction and operation, and they generate waste and potentially pollution. They have a significant impact on the use of non-renewable resources. According to CIB (2002), the environmental impact of the construction industry is probably larger in developing countries than it is in developed countries due to the fact that they are virtually still under construction and that they have a relatively low degree of industrialization, making the construction industry one of the biggest factors impacting on the biophysical environment. However, at every stage of the development and use of natural resources, choices can be made which respect the principles of sustainable development.

The construction industry has a generally poor record on employment matters and under-performs on issues such as gender and ethnics. Large sections of the population particularly women and ethnic minorities are under-employed. The industry needs to demonstrate that it values all their workforce, their health and safety, their working environment, training and personal development and diversity, and that it maintains an active commitment to an equal opportunities policy. What a construction business produces, how it affects the environment, how it recruits, trains and develops its workforce, how it invests in the community and respects the rights of people are all factors that determine the overall impact of that business on society in general. For business reasons as well as for social reasons, construction firms should be committed to carry out their business in a socially responsible way and uphold the following key

principles: to treat employees fairly and equitably, to operate ethically and with integrity, to respect basic human rights, to sustain the environment for future generations and to be a caring neighbor in the community. Commitment to community and social responsibility is about delivering benefits to both business and society and working continually to improve the positive impact of business on society. However, Sethi (1975) argues that a specific action is more or less socially responsible only within the framework of time, environment and the nature of the parties involved. The same business activity may be considered socially responsible at one time, under one set of circumstances and in one culture and socially irresponsible at another time, in another place and under different circumstances.

The pursuit of CSR based on sustainable development, presented in this paper, throws the construction sector into a big paradigm: provide proper housing and the necessary infrastructure for transport, communication, water supply and sanitation, energy, commercial and industrial activities to meet the needs of the growing world population, and at the same time deal with the issue of limited natural resources and how to reduce the impacts on the natural environment. According to CIB (1999), recently also the culture heritage implications of the built environment have come to be regarded as a preeminent aspect in sustainable construction. Marinho (2001) suggests that sustainability involves education, culture shift and accountability, especially considering common interests.

4. Methodology

In this stage of the project, the agents of the two major representative institutions in the construction sector from the State of Bahia were interviewed: the Association of Directors of Companies in the Real Estate Market (Ademi-Ba) and the Union of the Civil Construction (Sinduscon-Ba). The interviewer had a list of topics which were addressed and like other qualitative methods, was able to gather some idea of what is happening with CSR in the construction sector of the State of Bahia. In this situation, quality, rather than quantity, is more essential for the purpose of this stage. The interviews were tape-recorded with the permission of the respondents.

The interviews were structured in three blocks: a) what the representative of the sector understands as CSR, b) how they see the level of adoption of the CSR by associated companies, and c) which are the practices of CSR by associated companies. This first stage worked as a 'pilot interview' to gather basic information about the field before the elaboration of the quantitative research that is now being applied to the top management in the construction industry. Investigation and data triangulation were used to check the information from more than one perspective. Two observers were used in the interviews and the documents of both institutions were identified as ways for checking the veracity of the responses. According to Marinho and Barton (2004), the triangulation is essential in qualitative research in order to compare the information provided by the firms, their interviewees with other documentary evidences.

5. Results

According to the analysis of the interview data, it can be found that the concepts of CSR of the agents are broad and dialectical. In the most general terms, they understand that CSR deals with the role of business in society. According to them, its basic premise is that corporate managers have an ethical obligation to consider and address the needs of the society, not just to act solely in the interests of the shareholders or their own self-interest. In a way, CSR can be considered a debate, and what is usually in question is not whether or not corporate managers have an obligation to consider the needs of the society, but the extent to which they should consider these needs.

The interviewees disclose that the great majority of the companies of this sector do not possess a code of conduct. They also believe that the code of conduct should be used for its internal public, and second for customers and suppliers, as a strategic action. Although the interviewees agree to the importance of social reporting systems, they believe that the great majority of the companies of the sector do not adopt social

accountability, mostly because they do not know exactly what this means and secondly, how far it influences in the business economic results.

The interviewees perceive the adoption of the CSR in the sector for two main reasons: a) the commitment of the companies with the employees' welfare and due to ethical reasons, and b) with the concern with business performance. The main reasons in relation to business are the employees' motivation and the companies' image with customers.

An important practice of CSR that occurs in the Construction Industry in Brazil and is implemented by most construction firms is the Education Program for Adults in the construction sites, based on guidelines of the Industry Social Service (SESI). According to the interviewees, the main goal of this program is to reduce the illiteracy index among the workers of the construction sector, today around 33%, according to the International Labour Organization (ILO). The program is not only limited to initiate the workers to reading and having knowledge of mathematics, but also to rescue the self-esteem and citizenship, to understand their rights and duties in society. The reduction of employees' illiteracy is the initial step so that businessmen can introduce new technologies and quality programs, such as ISO 9000 certifications.

The agents argue that great part of the benefits of the employees, in this sector, are due to collective agreements between the unions and the workers. The benefits are related to nourishment (breakfast and lunch), nursery schools, funeral aid, transport, retirement, insurance with accidents, extra-hour value and places for leisure (television and game rooms). One of the great problems that these representatives observe is the existence of informal workers, which they believe corresponds to 60-70% of the workers of the sector.

In relation to the suppliers, the interviewees perceive that the sector demands only commercial aspects such as price, product quality and services, and the government obligations. They do not identify concerns with the society and the environment. But the construction firms worry about the origin of the wood and the sand, which have government control. In relation to customers, the concerns are practically associated with the maintenance service, and with customer's satisfaction research at the end of the enterprise.

According to the agents, they do not believe that exist too many corporate philanthropy in the sector. For them, the great difficulty is the crisis that affects the sector in the last years: the business community is more concerned with financial issues rather than on social issues. However, the Ademi, through partnerships with the businessmen, develops voluntary programs in the area of hospitals and nursery schools, with money and material giving.

The CSR related to the environment, according to the interviewees, are more reduced to the legal requirements. This gives the idea that most companies in this sector are still in the level of social obligations, described in the first level of the Leão-Aguiar et al. model. (Figure 1) They assume the idea that society, government and NGOs, already make hard pressure for environment preservation. Inclusive, the new Federal law related to waste management, pressured the union associated with the local government, to promote training in order to help the sector to attend this new regulation. The business representatives did not discuss the use of scarce goods like energy, water, other raw materials, and the environmental impacts in the product chain, which means the sector is far from the second and third level of the Leão-Aguiar et al. model for CSR.

6. Discussion

Based on the exploratory research of the literature, there is no simple way to evaluate the many demands of business and society. Sometimes, the top executive, acting alone, decides how to respond to CSR, but in other cases, outside consultants can be engaged in the process. Much depends on leadership, experience, and the nature of pressures. According to Steiner and Steiner (2003), commitment at the top management, or lack of it, determines the extent of a wide range of organizational responses, and when founders or CEOs have a strong social responsibility philosophy, it is reflected throughout the organization. Hopefully, in

agreement with Vinha (2003), more and more organizations and CEOs understand that the financial costs to reduce the environmental passive and to deal with social conflicts could be higher than to do the right thing.

The results of the interviews show that the emerging role of CSR in the construction sector of the State of Bahia has been found to be multifaceted, covering areas such as employee welfare, environmental issues and corporate sustainability. Within this understanding, two key perspectives emerge according to the interviews. First CSR can be defined in ethical terms or acceptable as ethical behavior in current society at large. From this standpoint, CSR is found to have a strong 'ethical anchor'. Second, CSR can also be viewed from an instrumentalist perspective where corporate image and goals are of prime concern. Another perception in this stage is that not all companies currently have a commitment to the principles of CSR, and it is unlikely that all will, at least not voluntary. The agreements between the unions and workers, without a doubt, are responsible for the great majority of the advances of CSR in the sector.

Already in this study, CSR points out to be a concept occupying spaces in business, not as a management tool, nor a economic science, associated with more adequate technologies and for the simple inclusion of some social and environmental concerns in projects of investments in the construction sector. This sector has a huge impact on natural resources as it influences the appearance of town and countryside, consumes natural finite resources and generates substantial waste. Together, these impacts initiate the need for a sustainable construction strategy based on CSR. Its true meaning will be derived through systematic efforts for the consolidation of a more steady, rational and harmonious society, based in principles of fairness and justice in the relations between the people inside and outside the organizations, also in a global level.

There is a need for broader and deeper studies to see if the organizations in fact approach to CSR such as presented in this first stage. The results also indicate a significant gap between what is important for the top management and how well is performing the firms in terms of environmental and social sustainability. The corporate performance of the sector, according to the interviewees, is still single bottom line (financial performance) rather than triple bottom line, which differs from the traditional growth and profit-maximization model in that it places a much greater emphasis on environmental, social, and economic performance, and the public reporting on this performance.

Conclusion

The practical insights gained within this project revealed that CSR is a dynamic process. This article reviewed a brief understanding of what it is meant by CSR in the construction sector of Bahia and how and why business might undertake such behavior. However, the results are only the first stage of a broader project, whether actions of CSR by business benefit most stakeholders is a question that remains open. The studies revealed that the construction sector with its labour-intensive nature activities is able to play a major role in human development and improving the quality of life for the poor, that represents the major workforce of the sector. This means that there is a window of opportunities to work CSR in the construction firms, associated with the commitment with sustainable development.

CSR contributes to corporate sustainability by providing ethical arguments towards sustainable development. If society believes that sustainable development is a worth while goal, corporations in the construction sector have an ethical obligation to help society move in that direction. This study attempts to raise issues for the agenda of corporate managers in the construction sector, hoping that the corporations will, in time, become more responsive to the social and environmental issues that face them and that we can break out the cycle of rhetoric and learn to manage business within a strategic CSR manner and within a 'greener' corporate culture.

Acknowledgements

The authors are grateful to the vice-president of Sinduscon-Ba and the director of Ademi-Ba, who participated in this first stage of the project.

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IMPROVEMENTS TO THERMAL COMFORT IN LOW-INCOME HOUSING IN MALAYSIA

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Abstract

Malaysia, a developing country, has a continuing need to provide increasing numbers of low-income housing to accommodate families who migrate from rural to urban areas in search of work. The houses should ideally be built from sustainable materials and incorporate technologies that work with the climate to provide thermal comfort for the occupants. They should also be affordable and suit the social and cultural customs of the people. The paper investigates the current situation on the provision of thermal comfort in a typical low-income house built in Malaysia. The investigation was carried out by measuring airflow rates, temperatures, relative humidity and mean radiant temperature at specific points in the house. Results are presented and analysed using the Corrected Effective Temperature (CET) Index and show that the typical low-income house often failed to provide thermal comfort. A series of technical design improvements are then recommended to improve the thermal comfort inside the house. These are evaluated by using computational fluid dynamics (CFD) and the CET Index. The results show that thermal comfort in a house can be improved by incorporating construction details, which improve the airflow through the house, without increasing the cost.

Keywords : Low-income housing, Thermal comfort, Corrected Effective Temperature (CET) index.

1. Introduction

In Malaysia and other developing countries, the migration of residents from rural to urban areas has created a great demand for housing. To fulfill this demand, the government has been funding the construction of many housing schemes. While the design of these take many factors into account, the houses often fail to provide basic levels of thermal comfort. Due to their poor design, they often overheat during the day and can be too cool during the night for comfort. Previous studies (Madros 1998) have indicated that the thermal design of low-income housing could be ineffective and resulting from this, the majority of their occupants are not satisfied with the thermal comfort levels provided.

Malaysia is located within the Equatorial Zone and therefore its climatic temperature is stable ranging between 27–32°C during the day and 21–27°C during the night. There are large variations in rainfall according to the season but relative humidity is high throughout the year at about 75%. The wind has a low but variable speed and most of the time blows predominantly from a southerly direction. The country has abundant sunshine and associated radiation for up to 6 hours each day. Most of the radiation reaching the earth's surface is diffused due to the characteristic cloud cover.

In order for occupants to be thermally comfortable in an interior space it is generally accepted that four environmental parameters need to be present in adequate proportions (Givoni 1976, Markus et al. 1980). These are air temperature, air velocity, mean radiant temperature and relative humidity. In a warm-humid climate, the predominance of high humidity necessitates a steady, continuous air movement over the body to increase the efficiency of sweat evaporation and to avoid any discomfort caused by moisture forming on the skin and clothes.

Most of the published research agrees that the effective temperature range for thermal comfort in a tropical climate seldom exceeds 30°C with a minimum temperature not lower than 22°C (Jones *et al*, (1993) Zain *et al* (1997) Gail *et al* (1998)). Therefore in this study, the effective temperature required to promote thermal comfort has been taken to be in the range 25°C to 28°C. Using these figures as a guide, thermal comfort may be assessed in Malaysian houses in quantifiable terms. Hanafi, (1991) stated that as recommended by Burt and Button (1969) and Koenigsberger (1973), the CET is the most appropriate index to use for the assessment of thermal comfort in a hot – humid climate. This scale is one of the most widely used and better-understood scales and so has been used in this work for the evaluation of indoor thermal comfort.

The collection of site data required to determine the thermal comfort inside a house is both time consuming and expensive and its reliability is often restricted to the specific time and areas being monitored. In order to keep the collection of site data to a minimum while at the same time evaluating thermal comfort across as much of the house as possible, Computational Fluid Dynamics (CFD) was used in this project to extend the monitoring area. CFD has been used for predicting air movement in and around buildings since the early 1970s and many researchers have applied CFD to airflow and temperature analysis inside rooms. Differences between measured and simulated air temperature and air flows being typically 2% and 7% respectively (Tinker and Woolf 1994, Al-Garny 1999, Roberts 1999).

2. Experimental Design

The modern low-income house selected for the study was located in the city of Kuching. A photograph of the typical terraced housing type is shown in Fig.1. The manufacturers claim that this type of house speeds up the construction process and that the materials and technology used, help to reduce internal heat gain and so provide thermal comfort. Thousands of similar houses are being built each year in Malaysia. The houses are built from lightweight, insulating materials, but there are some parameters of the design which are of some concern. The pitch of the roof is only around 10° and the roof overhangs are narrow giving little solar protection to the walls and the ventilation provision in the walls of the house is very limited when compared to the ventilation provision in a traditional Malay house. To economise on the design, the houses have no ceiling and they incorporate very little roof insulation. A major concern which prompted this study is that despite the mass building of this type of house, no technical evaluation has been done to establish that the technology provides the necessary internal airflows to provide a thermally comfortable environment for the occupants.



Fig.1 Low-income housing located in Kuching, Sarawak

2.1 Experimental Design

To establish to what extent this type of house promotes thermal comfort, the temperature and airflow patterns inside the house were investigated. Air speeds and direction were monitored using anemometers while temperatures were measured using thermocouples that were protected with foil to reflect radiant heat. The thermocouples were located in the house at pre-defined node points at which air speeds were also measured. The location of the measuring points is given in Fig.2 which shows a plan layout of one of the houses. The measuring points shown in the figure (A-F) were also referenced to node points in the CFD code. The general humidity in the house was measured using a whirling sling hygrometer and the mean radiant temperature was measured using a globe thermometer.

During collection of the experimental data, simultaneous outdoor climatic air temperature and wind speed data were also recorded.

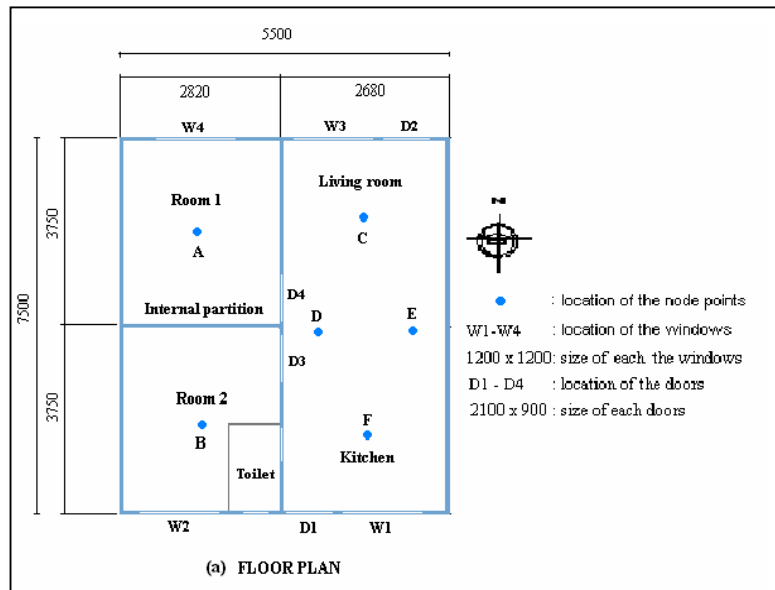


Fig.2 Plan layout of the house showing the location of the node points

Due to publishing restrictions, only a limited number of results are presented. Two typical experimental sets are included in the paper:

- Experiment 1: All windows and doors in the house closed
- Experiment 2: All windows and doors in the house open

2.1.1 Experiment 1 All the windows and doors in the house closed. Direct solar radiation falling on the outside roof surface was rapidly absorbed by the metal roof causing high external surface temperatures. The heat conducted through the roofing material and elevated the internal ceiling surface temperatures to 32°C which then radiated heat into the room below. The roof in a modern low-income house has no ventilation (Fig.1) and no ceiling to reduce the heat transfer. Added to this, blue coloured galvanised metal sheets were used to construct the roof of the house and this made the condition worse. The darker colour of the surface absorbed more solar energy.

Due to the absence of permanent ventilation in the modern low-income house, when all the windows and doors were closed, the outside air velocity could not contribute to any internal air movement. Rajeh (1994) and Adam (1997) reported that in terraced housing (such as the modern low-income housing considered in the study) with poor ventilation, CET values exceed the maximum comfort levels.

Data presented in Fig.3(a) shows that in the absence of air movement in the house, air temperatures exceeded 31°C at all the measurement points. Data presented in the same figure shows that the air velocity in the house is very low at around 0.1m/s due to the doors and windows being closed. Although the air velocity in the house is within the desired range for tropical climates (CIBSE Guide A), due to the higher air temperatures, thermal comfort is not achieved. Corresponding CET temperatures

are also shown on the figure from which it can be seen that the temperature exceeded the maximum comfort temperature through out the house. A typical example of the CFD simulated air temperature and air flow distributions in the house, when all the doors and windows were closed is given in Fig.3(b) and 3(c) respectively.

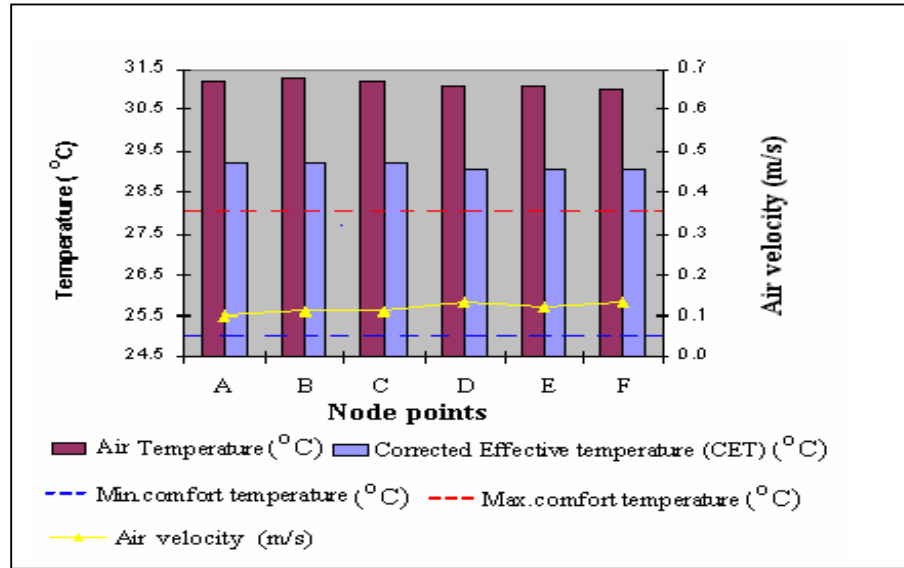


Fig.3 (a) Bar chart to illustrate the relationship between measured parameters and CET

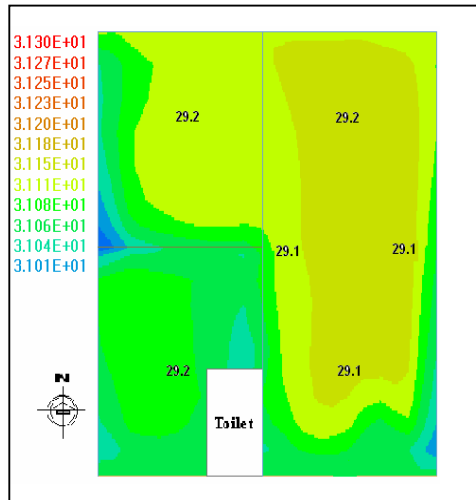


Fig.3 (b) Plan view of air temperature distribution

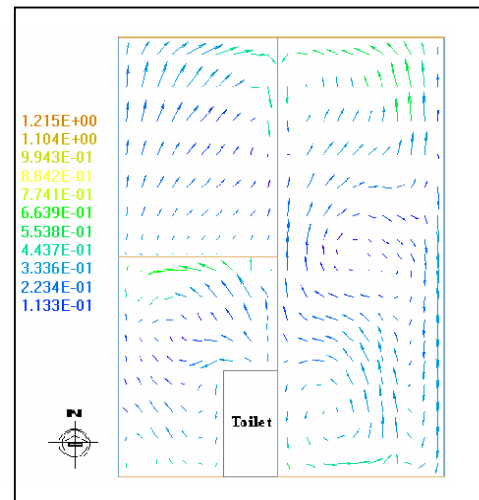


Fig.3 (c) Plan view of air velocity pattern

2.1.2 Experiment 2 All the windows and doors in the house open. At this point it should be noted that comfort condition inside the house were investigated with intermediate door and window openings and the results from these are reported elsewhere (Ibrahim, 2004).

Data presented in Fig.4(a) shows that a much improved air movement is generated throughout most of the house when all the doors and windows were opened with air velocities increasing to 0.5m/sec. Air temperatures remain about the same as those outside but the improved air movement lowers the CET to within the comfort zone. Unfortunately air speeds remained low in room 1 (node point A) where a partition between room 1 and room 2 acted as a barrier to airflow and the CET was on the borderline of the upper comfort zone. A typical example of the air temperatures and improved air flow distribution in the house when all the windows and doors were opened is shown in Fig.4(b) and 4(c) respectively.

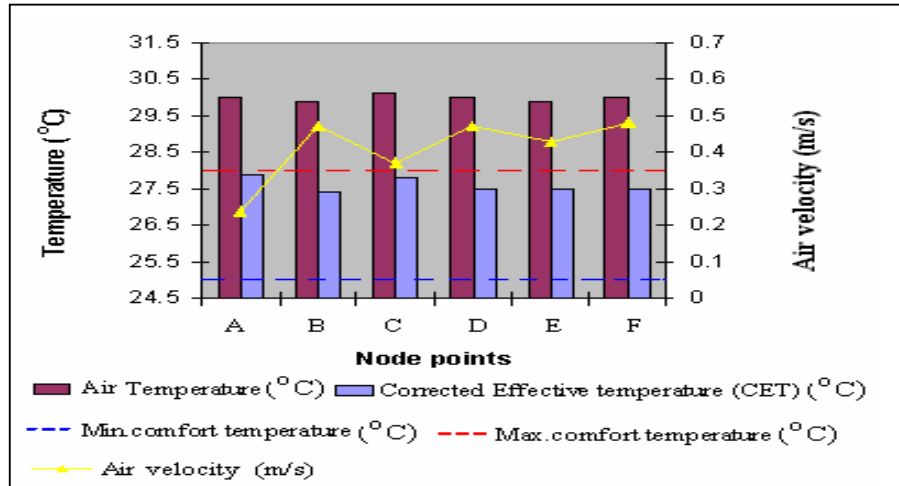


Fig.4 (a) Bar chart to illustrate the relationship between measured parameters and CET

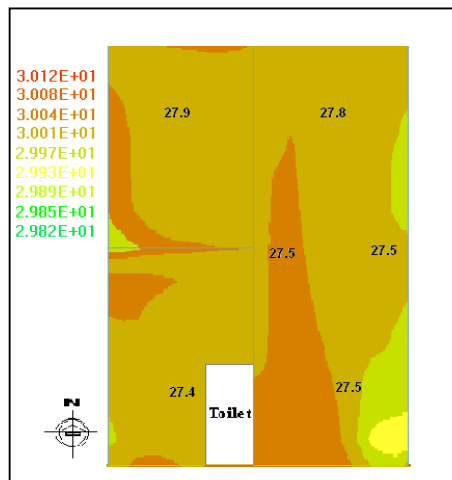


Fig.4 (b) Plan view of air temperature distribution

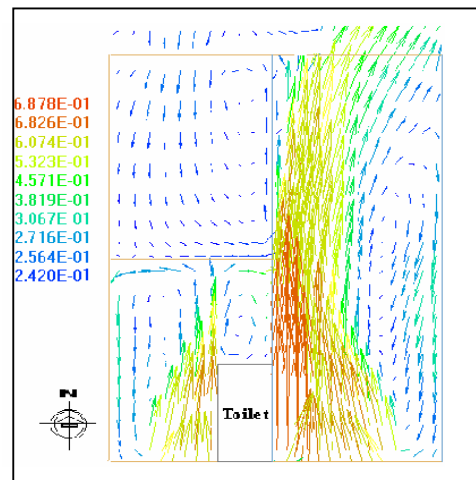


Fig.4 (c) Plan view of air velocity pattern

To overcome the thermal comfort problems that exist in the current house design, a typical modern low-income house has been modified by systematically altering its original design. The modern low-income house used in previous studies and shown in Fig.2 was taken as the bases for comparative purposes. Different designs were evaluated by changing the following features:

1. increasing the pitch of the roof up to 30°
2. using perforated panels above doors and windows
3. increasing the length of the roof overhang
4. incorporating a ventilated roof space
5. improving the cross ventilation by changing the room layout

To test whether the proposed design changes produced the desired effect, CFD simulations were carried out. Data resulting from the simulations is shown in Fig.5 when all the doors and windows were closed. The inside air velocity showed a distinct improvement in the new design. In particular, the air velocity in room 1 doubled when compared with the original design. It should also be noted that even though the inside air temperatures were similar in both designs, the CET improved in the new design (Fig.5). Also and more importantly, the ventilation in room 1 significantly improved. The improved air velocity was achieved in the house by providing, along with other changes, perforated panels above all the doors and windows. The improvements to air temperature distributions and air movement are shown in Fig.6.

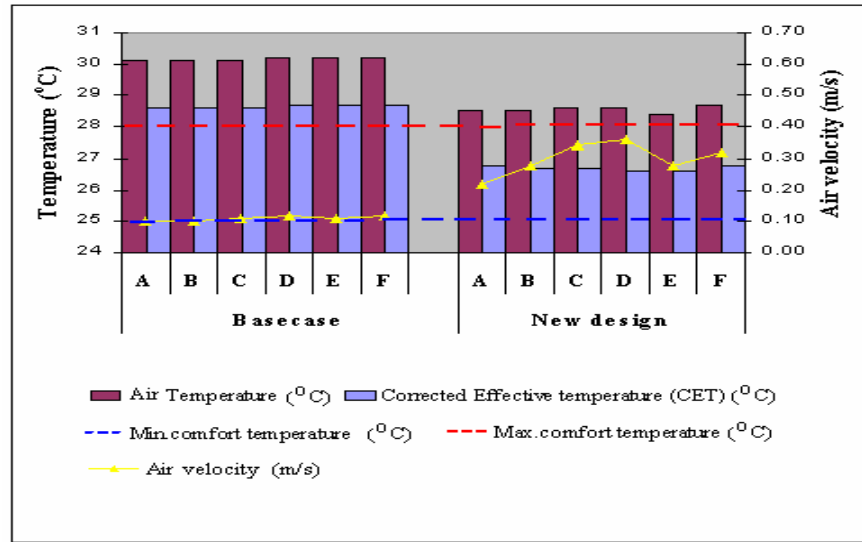


Fig.5 Bar chart showing the relation of thermal comfort parameter points for the new design (doors and windows closed)

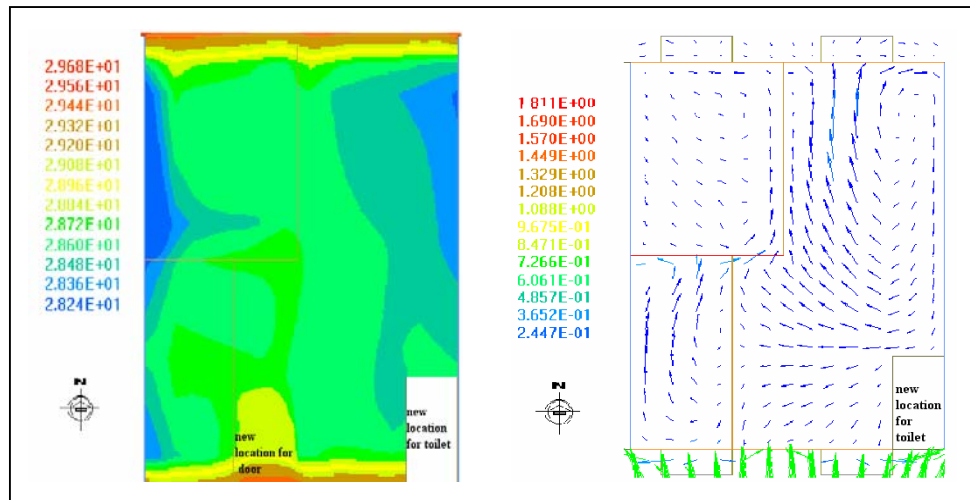


Fig.6 Temperature distribution (left) and airflow patterns (right) in the new design (doors and windows closed)

It was hoped that the modified design would make additional improvements to comfort levels particularly in room 1 when the doors and windows are opened. To check the extent of any improvement, another simulation was carried out.

When all the doors and windows were opened the air velocity in room 1 increased to 0.30m/s. The improvement in air movement is illustrated in Figure 7. By extrapolating results obtained from the CFD simulation work to other parts of the room, the CET index at any other location could be determined. Using this technique it was established that thermal comfort was provided across the entire room area (Ibrahim 2004).

Data from the CFD simulation presented in Fig.8 which shows improvement in the internal environment.

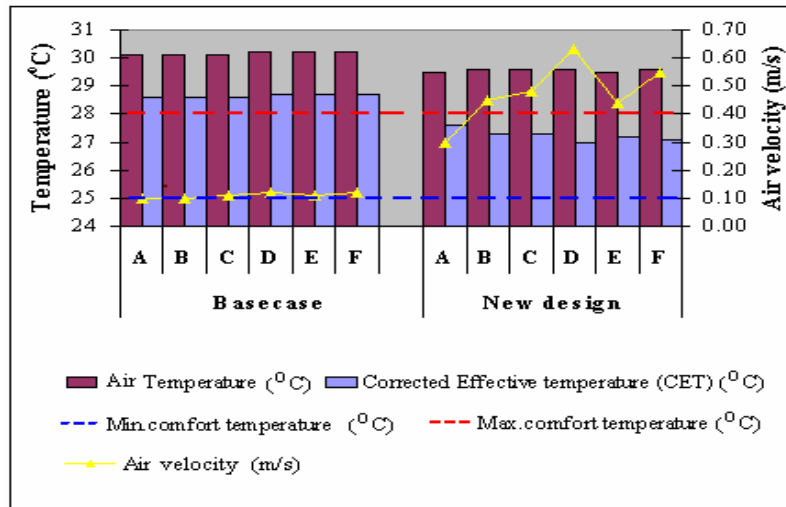


Fig.7 Bar chart showing the relation of thermal comfort parameter points for the new design (doors and windows opened)

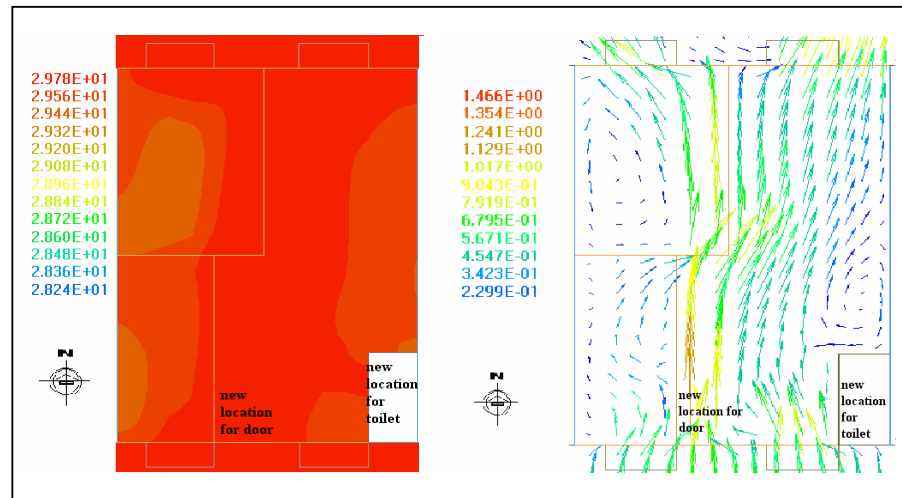


Fig.8 Temperature distribution (left) and airflow patterns (right) in the new design (doors and windows opened)

3. Conclusions

From the CFD simulations it can be seen that it is possible to improve the comfort conditions inside a modern low-income house by making changes to an existing design. The modifications considered are shown in Fig.9 on an annotated section through a proposed house.

A comparative evaluation of thermal comfort achieved under different door and window opening configurations in a modern low-income house showed that good thermal comfort was achieved even when all the windows were closed. Good shading provided by the roof overhang gave shade to the walls and a ventilated roof space allowed air to flow into the attic space above the ceiling to remove heat transmitted through the roof. These also contributed to thermal comfort.

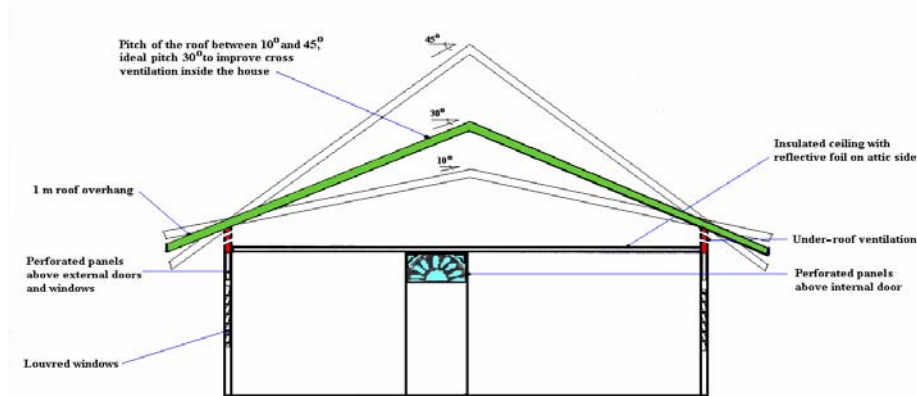


Fig.9 Section through proposed house showing design modification

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EVALUATION OF THE THERMAL PERFORMANCE OF CONCRETE TILE UNDER TROPICAL CLIMATIC CONDITIONS

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Abstract

The roof surface temperature is an important property affecting the optimisation of internal comfort conditions as well as reducing attic temperature. A field study of the thermal performance of concrete tiles in Malaysia was evaluated by recording surface temperature at different times of the day using a Raytek Raynger ST "Infrared thermometer". The effect of evaporative cooling on concrete tile under hot humid condition and clear sky condition was evaluated. The limitations of the formulation used for estimating the roof surface temperature were discussed. This investigation concludes that the effect of roof orientation on indoor temperature is insignificant and evaporative cooling may offer an alternative solution. Roof surface temperature varied from eave to ridge with temperature discrepancies up to 8°C at mid-day. It is also shown that the temperature variation on the same concrete tile varies throughout the day with differences reaching to 2°C. The large discrepancies imply that the assumptions used to govern the formula are inaccurate. A more comprehensive methodology taking into account all parameters affecting roof surface temperature should be considered in improving the accuracy of the analyses.

Keywords : Concrete Tile, Roof Temperature, Roof Orientation, Attic, Temperature.

1. Introduction

The excessive heat fluxes transferred through the roof are one of the main causes of thermal discomfort in warm climatic conditions, prevailing in tropical zones. In this region the path of the sun generally goes through high altitudes during the daytimes, subjecting the roofs of dwellings to intense sunlight. The sun in tropical regions is almost perpendicular to the horizontal surface for solar noon with slight variation all year round "60 to 83" in Kota Kinabalu. Roofs receive more solar radiation than walls, which create intolerable overheating during daytimes. In Kota Kinabalu, the solar irradiation under clear sky condition for horizontal surface could reach about 1074 W/m² at Midday on 21 every March. As the roof surface is heated to high temperatures, the ceiling radiates heat to the room below and increases the physiological heat stress and the thermal discomfort of the inhabitants as mentioned in the research by the authors (Vecchia, et.al.,2001). Extensive research has already been conducted to determine the impact of other parameters that could affect roofs temperature such as winds velocity, winds direction, rain, orientation and roofing material. However the combined effect of all parameters included solar radiation on roofs surface temperature and attic temperature is quite complicated and less understood. The estimation of roof surface temperature using sol-air temperature, which is based on several assumptions, may not be valuable under tropical humid climate. The effect of humidity and the direction of wind velocity on roofs temperature are not clear. Moreover, the determination of convection coefficient h_c with an accuracy of 10% is not possible even sophisticated computer simulations of roof temperature suffer from this same complexity in estimating h_c as reported by the authors (Berdahl et.al.,1997). The absorbed solar radiation is not as simple as that suggested by ASHRAE, and the aged roof is less cool than the new one as revealed in the research by the authors (Levinson et.al. , 2005). Therefore, some value in taking a preliminary look at the possible consequence of all these parameters on roofs surface temperature could help in the future to put sound solutions into practice. Our study has been carried out on site to assess the thermal performance of concrete tile in Malaysia, which is widely used in residential building. The following research has its principal objective the evaluation of roofs surface temperature of concrete tile under tropical humid climate, which is one of the least understood and its effect on attic and indoor temperature. The effect of evaporative cooling on concrete tile is tested and the impact of roof orientation on surface temperature and on indoor temperatures is discussed through a case study in east Malaysia, Kota Kinabalu, Sabah.

2. Experimental Conditions and Method

The experiments were conducted at Taman Prestige in Kota Kinabalu, Sabah, in east Malaysia. This kind of residential building is widely used throughout Kota Kinabalu. The semi detached houses number 9 and 10 were selected as a case study. The building is a double story; the First floor consists of one living room, two three bedrooms and two bathrooms. The location and the plan of the house are given in Fig.1. The structure is a reinforced concrete frame and the walls are made of red bricks ($e=151.8$ mm), covered by plaster and have large window openings. The roof is built with narrow overhanging eaves and covered by red concrete tiles. The roof is not ventilated with a pitch of 25° . Zinc sheet is installed between the trusses to avoid leakage. Gypsum board separates the attic from the interior. The thickness of the ceiling is about 14 mm.

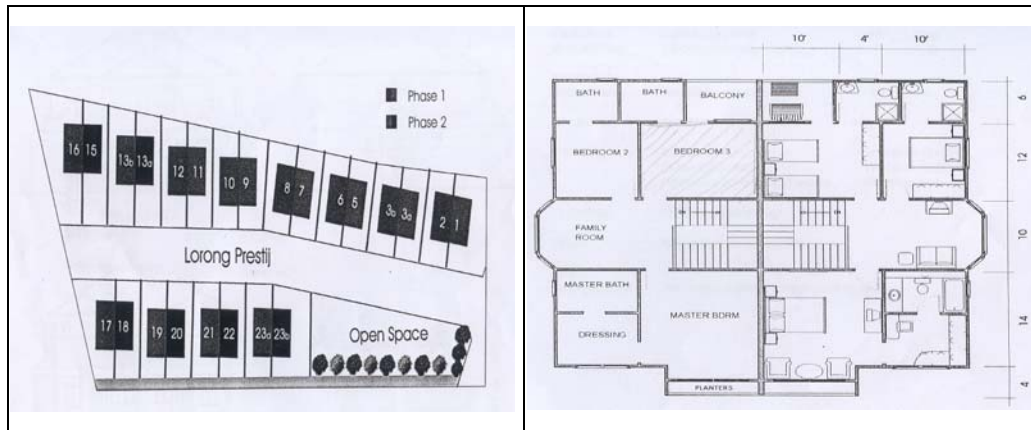


Fig.1 The Location of the Residential Building Plan and the First Floor Plan

Measurements using data-loggers HOBO was carried out from 25th May 2004 to 10 June 2004. The data loggers were set to record air temperature with an interval time of 15 minutes for indoor, outdoor and attic temperatures. The spots with a number show the location where roofs surface temperature of the concrete tiles were measured at different times of the day with a "Raytek Rayner ST" infrared thermometer. The spot locations are shown in Fig 2. The same equipment was used for the same purpose to assess several roofing materials under hot arid climate in previous work by (Cook et.al., 2003). The attics temperatures of house 9 and 10 were also measured.

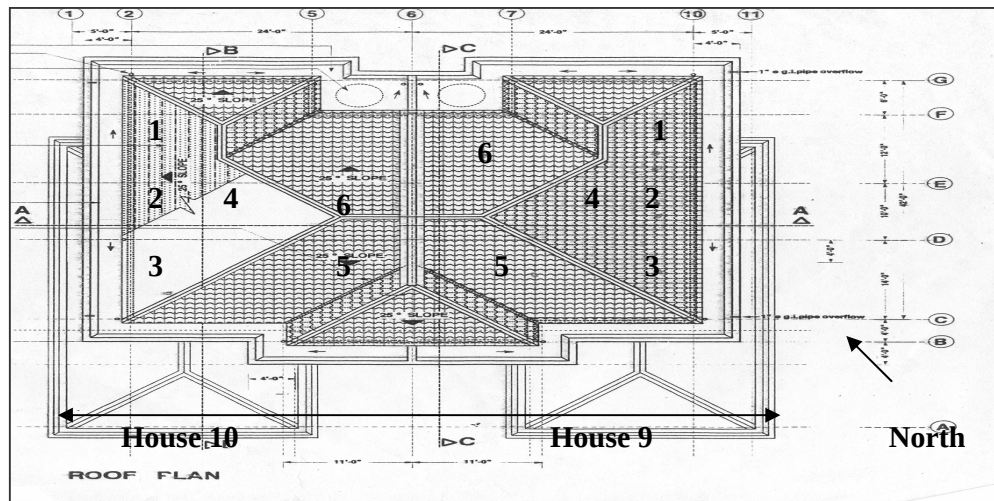


Fig.2 Roof Plan with Spots Locations

The readings were recorded under clear sky conditions and the same spots located just under the roof were selected to assess the effect of roof orientation on attic and indoor temperature using data- loggers. The windows were kept closed. Air speeds and relative humidity were also measured.

3. Results and Analysis

3.1 Impact of roofs orientation on attic and on indoors temperature

Fig. 3 shows a sequence for 13 days of the daily indoor, attic and outdoor temperature of the first floor. The outdoor temperature range was from 25.17°C to 33.59 °C, while the indoor temperature range of the first floor was from 27.12°C to 31.12°C.

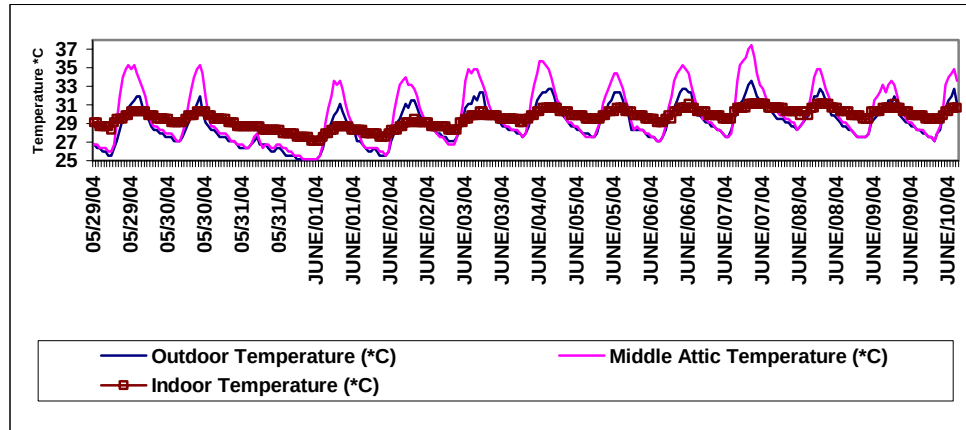


Fig.3 Daily Outdoor, Indoor and Attic Temperatures of a Residential Building

The chart also shows the attic roofs temperature ranges between 25.17°C -37.44°C. The indoor temperature follows more or less the shape of the outdoor and the attic temperature curve. In general, the temperature variation into attic is approximately sinusoidal. A clearer picture for one day's variation for a typical hot day and a typical rainy day are given in Fig. 4.

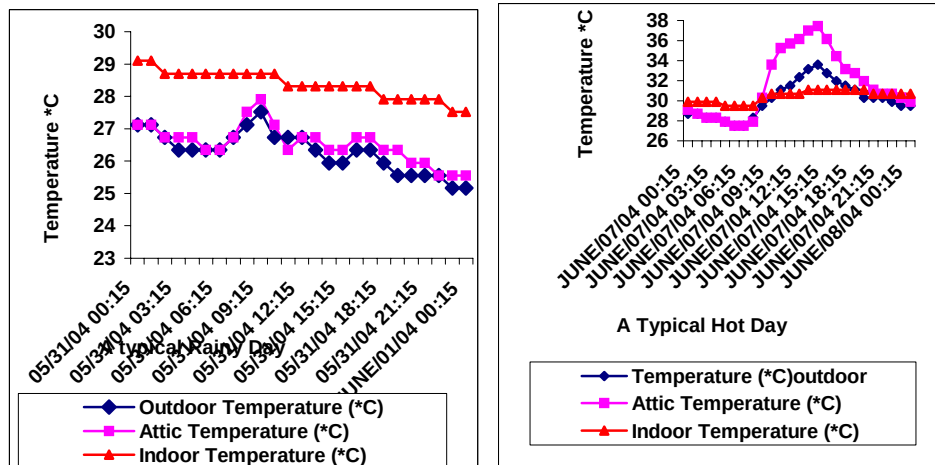


Fig.4 Hourly Outdoor, Indoor, and Attic Temperature of a residential Building

The maximum, minimum, and average temperatures for a typical hot day and a rainy day are reported in table 1. Inspection of Fig. 4 shows that the attic temperature for a representative rainy day has followed closely the outdoor temperatures. In addition, the attic temperature is noticeably lower than the indoor temperature. This suggests that much of the heat gained by walls was stored and then dissipated to the inside.

Table 1. Max, Min, and Average Temperatures of a Residential Building

Rainy Day (RD)/ Sunny Day (SD)	Outdoor Temperature	Indoor Temperature	Attic Temperature
Maximum Temperature (RD)	27.52	29.10	27.91
Minimum Temperature (RD)	25.17	27.52	25.56
Average Temperature (RD)	26.29	28.37	26.54
Maximum Temperature (SD)	33.59	31.12	37.44
Minimum Temperature (SD)	27.52	29.9	27.52
Average Temperature (SD)	30.16	30.48	31.68

In the example presented in Fig. 4 the hourly evolution of attic temperature for one hot sunny day's variation on June 7th is noticeably higher than the indoor temperature and well below the ambient outdoor temperature, this is more visible in the sharp peak of attic and outdoor air temperature. The maximum indoor temperature was lower by about 2.47°C below the maximum outdoor temperature and about 6.32°C below the maximum attic temperature. However on average, the attic temperature was 1.52°C higher than the outdoor air temperature and was 1.2°C higher than the indoor air temperature. Note that the variation of attic air temperature during the night is lower than the indoor air temperature and follow closely the outdoor temperature. The minimum air attic temperature was 2.38°C below the minimum indoor air temperature. Indeed, the clay tiles cools faster during the night and the attic temperature reaches more quickly the outdoor air temperature than the indoor air temperature. The results show that roof system becomes a source of heat only during daytime. The time lag of concrete tile is insignificant. Several hobo thermometers were fixed in several parts under the roof and into attic to record air temperature in order to assess the effect of orientation on attic and indoor temperature. The measurement was carried out for 3 days from 13th June to 16th June 2004. Fig.5 shows the temperature variations with time of the day at six distinct locations in the attic.

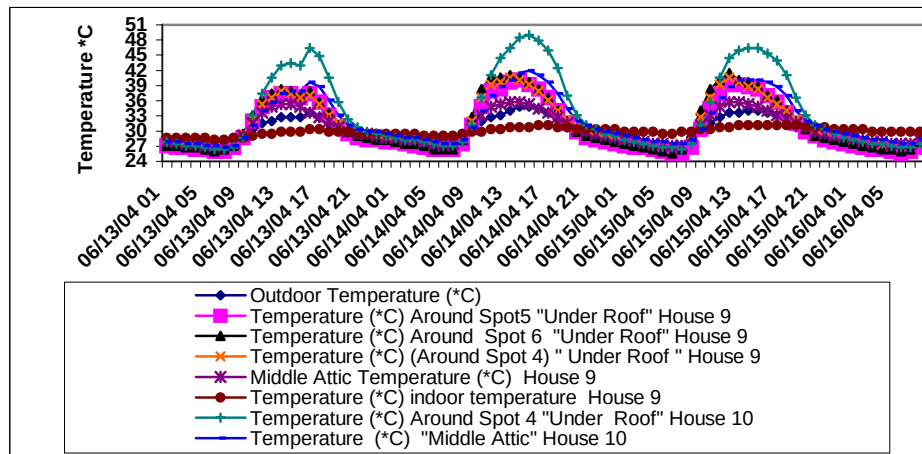


Fig.5 Impact of Roof Orientation on Attic Temperature

Figure 5 demonstrates again that roof orientation has a great effect on roof surface temperature and attic temperature. The hourly attic temperatures of house 9 were always below than the attic temperature of house 10. The impact of the orientation on indoor temperature of house 9 and 10 is less noticed in the BJD house even when the attic air temperature reach its maximum as can be seen in Figure 6.

1 house 10 whereas at spot 1 house 9, the roof surface temperature was around 48.2. The difference between the same spot location of house 9 and 10 with dissimilar orientation attains 14.2 °C at 15 pm. From this figure it is clear that spot 5 was the cooler one. The orientation of roofs has a great impact on roofs temperature. It is worth mentioning that the temperature difference of the same concrete tile could reach until 2 degrees Celsius, which depends mainly on the sun position on the sky and the design of concrete tile. It is definitely an advantage since the shadow launched by the relief over the curves between tiles reduces the amount of radiation absorbed by the tile. However, during the monitoring period, the discrepancy of temperature measured from the eaves to the ridge of the same roof alignment is noticeable and could reach 8 degrees Celsius; the higher temperature was identified near the ridge. It indicates that the pitch of roofs seems to have an effect in increasing roof surface temperature and the amount of heat absorbed by all roof surface of the same orientation is not

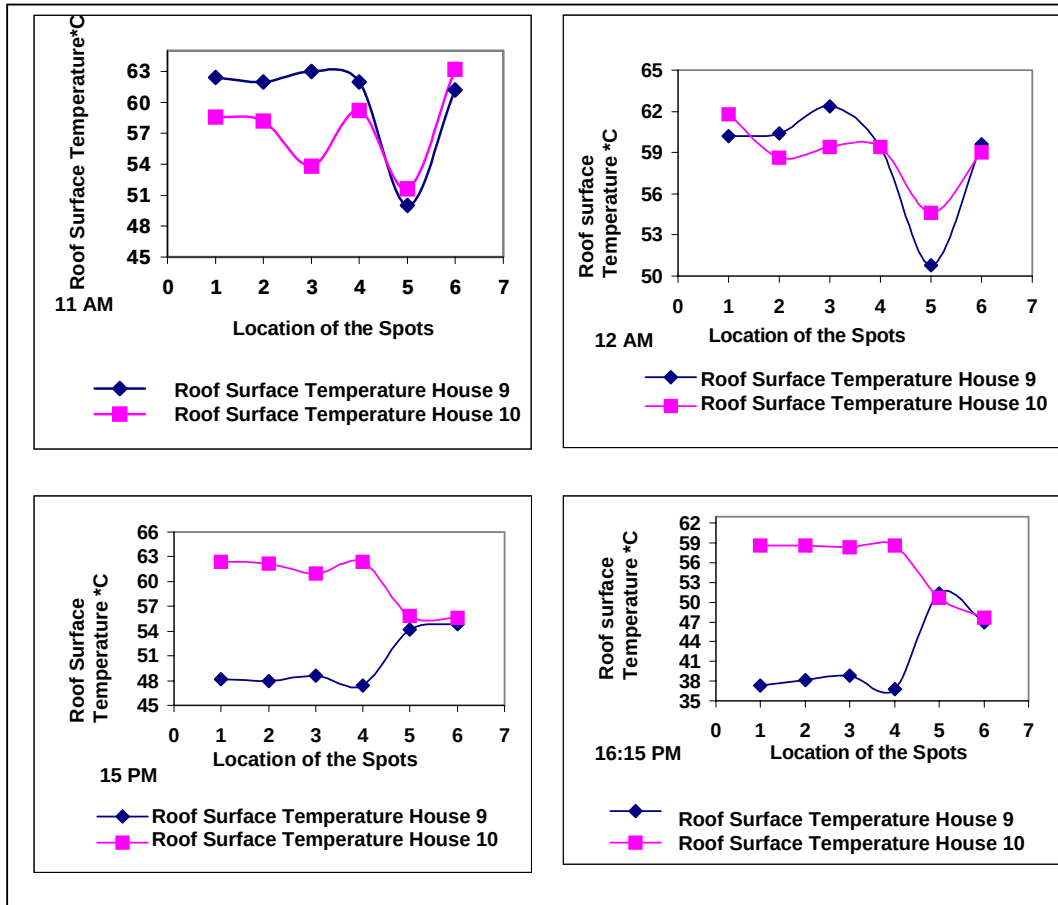


Fig. 8 Roof Surface Temperature Measurements

unvarying. During the investigation of 3 days, it was noticed that the surface temperature measured could change extremely when the wind velocity increases unexpectedly. The field measurement and analysis gives us more accurate understanding of the limitation of the formula used to estimate roof surface temperature. We observed that the direction of wind and the velocity could affect greatly the concrete tile temperature. Apparently, the effect of winds and temperature on roof-oriented east is not the same as roof-oriented west or north and south. In addition, the dust accumulate on roof surface could increase the concrete tile temperature which could be easily detected by measurement and the same with the irregularity of the painting of the same tile. It appears that, on the whole, all these parameters should be taken into account for the estimation of surface temperature, however the use of thermocouple or the infrared thermometer could not give the accuracy required even with the average reading and other alternatives for measurements of roof surface temperature still limited, which complicate any research related to roof thermal performance. Another possibility that could decrease roof surface temperature and which is rarely used under Malaysia climate is to spray water on roofs

surfaces. The wet roof concept utilizes the cooling capacity of water by conduction, radiation and by evaporative cooling to cool down the surface of the roof as reported in previous works by the authors (Cook et.al., 2003, Givoni, 1997). This technique has been simply tested by pouring the water on concrete tile around spot 5. The relative humidity was about 57% and the concrete tile temperature at 9:20 am was 56 °C. After that the surface temperature of the concrete was dropped to 49°C. However it was observed that the concrete tile become rapidly dry and the surface temperature increases within less than 1 minute. It may be necessary to mention that the same conclusion was reported in previous work by (Cook et.al., 2003), the clay tile seems to perform better than concrete tile as mentioned from the same source. However this is very encouraging results, since it is possible to cool down the roof surface when the humidity diminishes and could be very useful since the humidity level attains its minimum when the outdoor temperature reaches its maximum. Further more; the surface temperature is also influenced by conduction and radiation. The realization of a system which; could detect the humidity level and roof surface temperature may well be helpful under Malaysia climate to spray roofs automatically using cold water. This technique had been utilized for a research purpose in USA and Mexico and published by Givoni (Givoni, 1997).

Conclusions

Data monitoring carried out on site, has shown that ceiling temperature and glazing are the only source of heat during the daytime under Malaysia climate. The orientation of roof could increase temperature of the surface and attic considerably but conversely, the effect on indoor temperature is insignificant. However, the radiant temperature from warm ceiling causes the greatest discomfort in residential buildings and increases the physiological heat stress. This study shows that attic temperature was always lower than indoor temperature during night time. Water on evaporative cooling is a potential means of cooling down the surface of temperature.

Acknowledgements

This work is supported by the CIDB grant #02-002. The authors thank the Managing Director of BJD properties Mr. Brian Lim for making the houses available for research purpose and Prof. Dr. Eduardo L. Kruger –CEEET- PR, Brazil, for his advice and useful suggestions.

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REDUCING URBAN HEAT ISLAND EFFECT with THERMAL COMFORT HOUSING and HONEYCOMB TOWNSHIPS

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Abstract

Urban houses in Malaysia are too hot for about half the days of the year and Kuala Lumpur has become the world's worst urban heat island on record. However, these problems are not the inevitable consequences of urbanisation and can be corrected and avoided with a sensible application of the technologies available to prevent the thermal mass of houses and roads from absorbing solar radiation. This paper describes a technology known as Cool House to reduce the effects of urban heat island on occupants.

'Cool House' technology, developed at Universiti Putra Malaysia can achieve almost passive thermal comfort without air-conditioning, even on the hottest days of the year. 'Honeycomb townships', a recent architectural invention by one of the authors, is a new method of subdividing land which saves greatly on roads, thereby permitting larger gardens and courtyard parks in front of the houses. Large fruit bearing fruit canopy trees can shade nearly half of the township from direct sunlight. The cooler environment and the creation of interconnected diverse microhabitats will allow the introduction of large numbers of birds and small non-aggressive native animals, bringing 'Watchable Wildlife' into highly populated urban centres.

The adoption of this rather simple technology will potentially save Malaysia RM200 billion (USD52 billion) in saved electricity for air-conditioning urban houses and apartments over a 30 year period. Electricity savings on this scale will greatly benefit other developing countries intending to rapidly urbanise, particularly China, India and Indonesia with much larger populations.

Keywords : Heat island, Thermal comfort, Energy efficiency, Wildlife technology, Honeycomb townships, Test reference year.

1. Introduction

Many cities suffer from overheating, whereby the ambient air temperature in suburban and downtown urban areas can be 2°C to 3°C hotter than in rural areas. This is termed the urban heat island effect and is caused by fewer plants and trees and the greater absorption of solar radiation by more buildings and roads. These temperature increases, although seemingly small from an engineering viewpoint, have profound effects on human comfort. In the Malaysian humid tropics, urban houses overheat by about 3°C which is the difference between human comfort and human misery (Davis *et al*, 2000). With urban development the temperature during the summer has been increasing over the last 30 to 80 years in many cities around the world by 0.1°C to 0.4°C per decade. For example, Shanghai is increasing by 0.1°C per decade, Washington by 0.2°C, Tokyo by 0.3°C and Los Angeles and San Diego by 0.4°C (Akbari, 2000). Designing houses, townships and cities which do not overheat compared to the surrounding rural environment will greatly improve their liveability and save a colossal amount of energy for cooling.

2. Methods and Analysis

2.1 Outdoor Heat Stress

Meteorological data collected between 1975 and 1995 from the Subang weather station, Kuala Lumpur, Malaysia reveals that the average outdoor temperature in Kuala Lumpur has increased by 1.2°C during this 21 year period. This previously unreported data was part of a larger study to construct a Malaysian weather year, termed a Test Reference Year (Reimann et al 2000). As shown (Figure 1) Kuala Lumpur is getting hotter by 0.6°C per decade. To our knowledge this is the world's highest value so far reported for the urban heat island effect (Figure 2).

This finding supports anecdotal subjective evidence from long term residents of Kuala Lumpur who claim city living is becoming more and more uncomfortable compared to the rural areas. An objective measure of heat stress imposed by the outdoor Malaysian environment during different periods of the year has been calculated from the Test Reference Year in a novel Thermal Discomfort index (Figure 3).

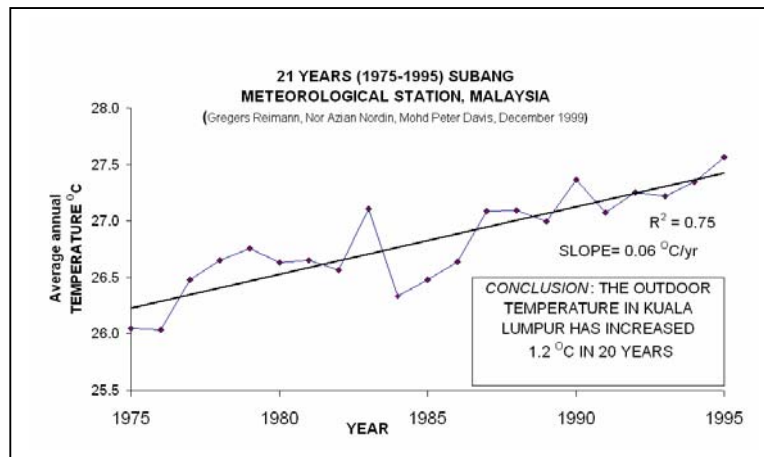


Figure 1 Average temperature vs year

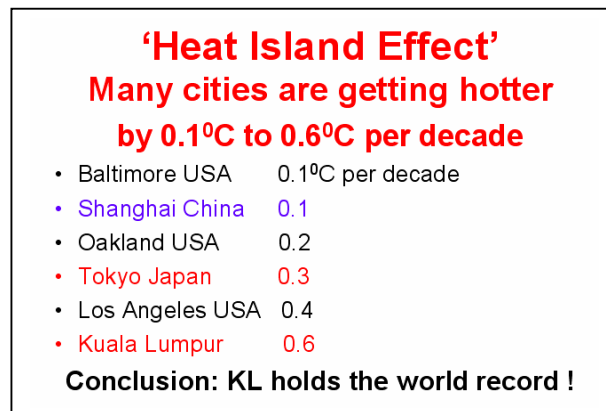


Figure 2. Heat island effect

One unit of thermal discomfort is defined here as the heat stress suffered by a person wearing light tropical clothing whilst resting outdoors for one hour in the shade with no wind whilst the average ambient temperature is 1°C above the upper thermal comfort level (estimated to be 28°C for the Malaysian humid tropics, Davis *et al* 2000). For example, a person under these conditions when the average ambient temperature between 1pm and 2 pm is 33°C suffers, by definition, 5 units of thermal discomfort. These units per hour, summed over 24 hours, provide a quantitative measure of human heat stress for that particular day.

The results reveal that the population of Malaysia suffers outdoor heat stress throughout the year; there is no cool season (Figure 3). Whilst Malaysia, being close to the equator, is hot every day of the year, this index reveals for the first time the true but rather hidden seasonality as felt by humans. Two

heat-waves, imposing 40 units of thermal discomfort per day, occur regularly in March and May whilst the 4 months from September to December are much more pleasant, imposing only 15 units of thermal discomfort per day.

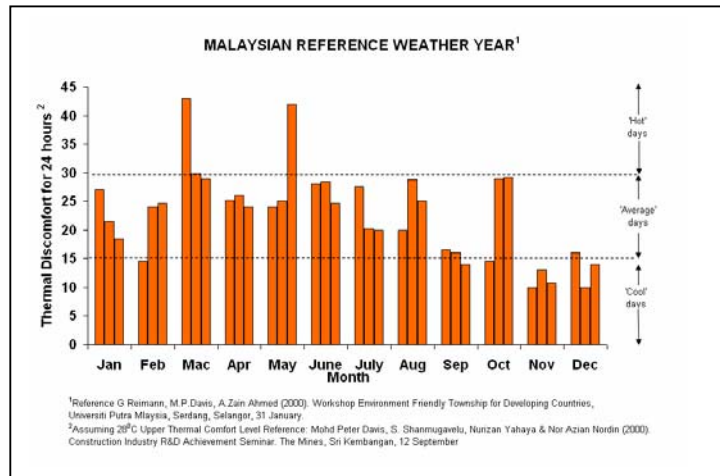


Figure 3. Malaysian reference weather year

2.2 Indoor Heat Stress

The indoor temperature of residential houses in Malaysia has been extensively studied over the last ten years by researchers at the Centre for Thermal Comfort Studies at Universiti Putra Malaysia (Davis *et al*/ 1995, 1997, 2002, 2003). Whilst the traditional well ventilated wooden houses in the rural areas are near ambient houses, closely following the outdoor temperature, all of the modern concrete houses built over the last 50 years in Malaysia are grossly overheated (Figure 4).

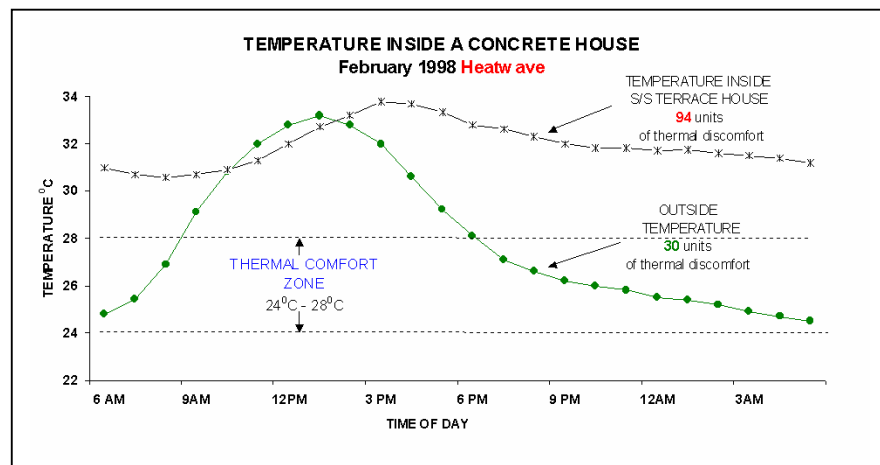


Figure 4. Temperature inside a concrete house

In this example a single story concrete terrace house during a heat-wave is way above the upper thermal comfort level every minute of the night and day. However, the outdoor environment is perfectly comfortable for 14 hours per day. Experiments such as this during different times of the year, using a miniature temperature data-logging technique (Davis *et al*, 1995), has established that all 2 million modern concrete houses cause two to three times more thermal discomfort (heat stress) than the outdoor environment (Table 1).

Our general, though rather sad, conclusion is that the Malaysian urban population would be far more thermally comfortable if, they abandoned their houses and lived under trees.

Table 1. Thermal discomfort

Thermal Discomfort during Feb 1998 heat-wave	
	<i>Discomfort units per 24 hours</i>
Outdoors (under a tree)	30
Single Storey link- Serdang	94
Long house- Balakong	72
Double Storey link- Balakong	70
5 Storey Flats (Top Floor)- Serdang	70
d/s bungalow- Bangi	47

This absurd situation has provided the motivation to design thermally comfortable houses without the high electricity cost of air-conditioning which has been estimated by computer simulation to be more than the house construction cost over a 30 year period (Davis *et al*, 2003).

The general problem of gross overheating in Malaysian urban houses is illustrated (Figure 5). The closed attic space becomes up to 14°C hotter than outdoor ambient temperature. This excessive heat is transmitted through the bedroom ceilings and becomes stored in the concrete walls and floor slabs. Unlike wooden houses, Malaysia's concrete houses therefore heat up like ovens during the day and barely cool down at night. The term 'sweat boxes' is aptly applied to Malaysia's 1.7 million terrace houses. The principle source of the problem is the absorption of solar radiation by the concrete roof tiles and the transmission of the heat into the non-ventilated attic space. Over the years, Malaysian attics have become less and less ventilated, to prevent the spread of fire and to keep out rain, birds and vermin. However, replacing the concrete tiles with a metal roof and insulating the roofs with glass wool or rockwool has proved highly effective in reducing the sealed attic space temperature to outdoor ambient (Davis & Nordin, 2003). This is illustrated (Figure 6). Renovating a double storey house in this way reduced the thermal discomfort in the bedrooms and living areas by 80% (Figure 7).

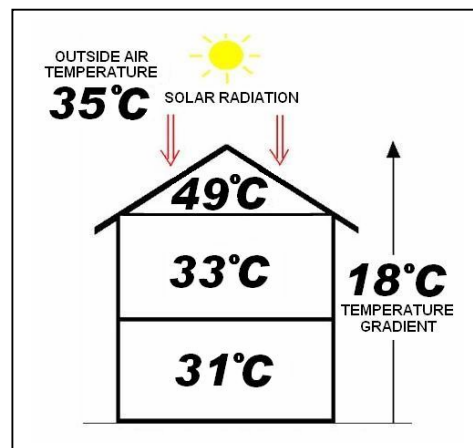


Figure 5. Indoor temperature vs outdoor ambient temperature

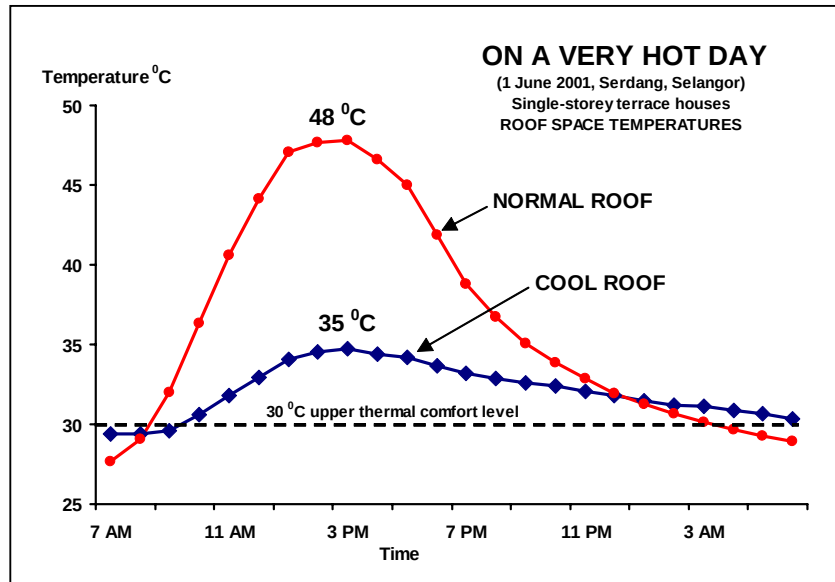


Figure 6. Thermal comfort level for very hot day temperature

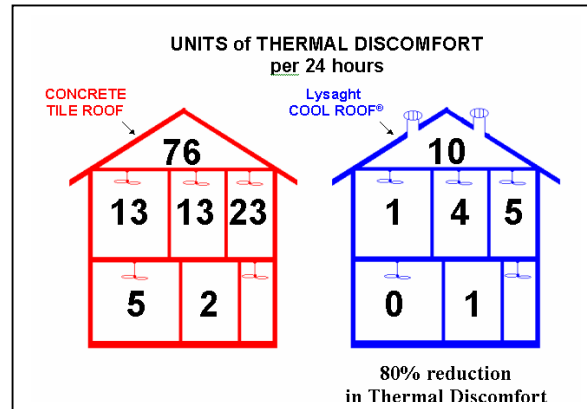


Figure 7. Thermal discomfort per 24 hours

Computer simulation, using BSim software linked to the Malaysian climatic test reference year, has demonstrated that further improvements in thermal comfort can be achieved by shading the walls, to reduce solar heat gain, and by mechanically ventilating buildings at night, to expel hot air and introduce cool night time air. Thus bungalows (Figure 8) and apartments (Figure 9) have been designed which, according to computer simulation, will stay within the thermal comfort zone without the need for air-conditioning, even on the hottest day of the year.

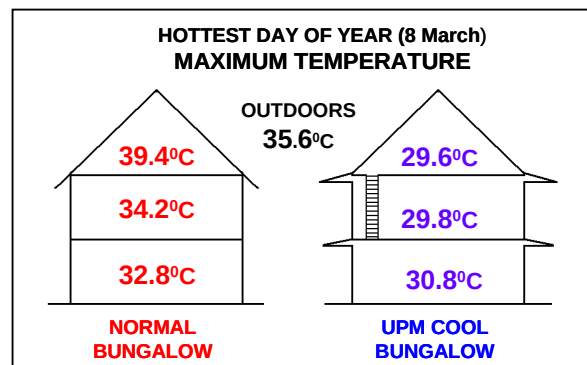


Figure 8 Maximum temperature for hottest day of the year

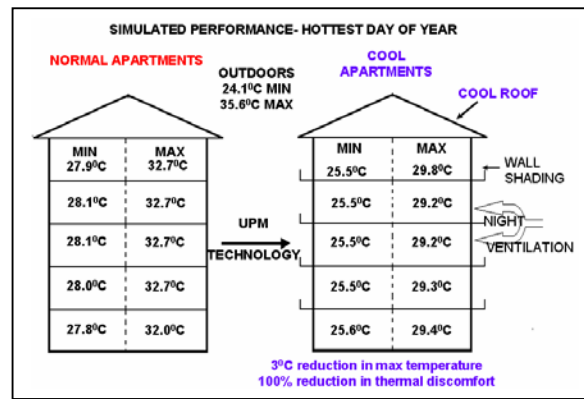


Figure 9. Simulated performance on hottest day of year

3. Honeycomb Housing

Honeycomb Housing is a new patent pending invention for subdividing land discovered in 2003 by one of the present authors, architect Mazlin Ghazali. Instead of building rows of monotonous houses on rectangular plots of land, houses are built on triangular land within larger hexagonal-shaped land. Each hexagon is a cul-de-sac containing 5 to 14 houses all surrounding a small community park with large trees shading the road (see Figure 10).

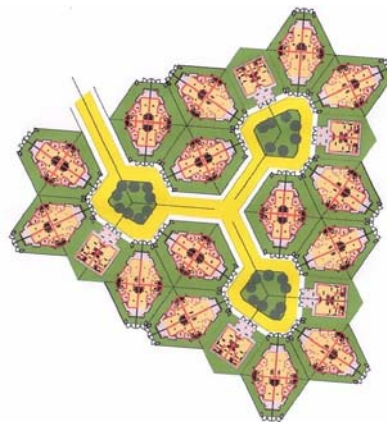


Figure 10. Honeycomb Housing

The novel, wide frontage houses currently being designed include bungalows, back to back semi-detached, quarter-detached, triplexes and sextuplets.

Honeycomb housing creates small, friendly neighbourhood communities with 'defensible space'. The hexagons efficiently interlock to form a 'honeycomb', interconnected with looping roads that are safe for children, pedestrians and cyclists. Since the roads are internal rather than around the perimeter of houses, the road area can be substantially reduced compared to terrace housing.

For example a honeycomb township containing 258 houses was compared, using our Honeycomb mathematical software, with a conventional terrace house township also contain 258 houses (Table 2). The land saved by reduced roads, including the socially useless back lanes, was 23% in the honeycomb layout. This allowed for 100% bigger gardens for the consumer and 20% more saleable land for the developer. The Honeycomb layout, 16.5 houses per acre achieved an 8% higher housing density, compared to only 15.2 houses per acre for terrace row housing. Honeycomb layouts have other inherent advantages. Since the houses are not built in rows they do not require a level building site, only a level footprint for each housing block. This is far more environment friendly than terrace housing and causes minimal disturbance to the top soil and the natural water run off.

Honeycomb roads are shorter and winding which creates slow moving traffic, safer for children, cyclists and pedestrians.

4. Reducing Heat Island effect

Kuala Lumpur is getting hotter, faster than any other recorded city in the world. New townships in Malaysia are repeating this mistake. Townships are being created from virgin jungle or plantations by totally clearing all trees and ground cover and cutting the hills and filling the valleys for easy terrace house construction. The high density of housing with token gardens and excessive road areas and back lanes leaves almost no suitable land to restore tree cover and green environment. Urban areas have become concrete jungles and heat islands, perhaps 4°C hotter than the surrounding rural areas. This is particularly noticeable in Selangor with a population density of 526 persons per square kilometre compared to only 35 in Sabah and 17 in Sarawak.

Honeycomb housing layouts can permit a very lush urban landscape in the gardens and neighbourhood parks. The winding roads can also be tree lined to provide shade. The aim is to recreate a rainforest type canopy over the township as the trees mature over a 5 to 10 year period to reduce the heat island effect. From our Honeycomb mathematical model, we have estimated the potential tree canopy area of the above honeycomb township to be 46%, compared to only 15% for a row housing, typical of a Malaysian terrace house township (Table 2)

Table 2 Comparison between terrace and honeycomb housing

Mathematical Comparison		
% of site	Terrace housing	Honeycomb housing
Road area	46%	37%
Saleable land	43%	52%
Houses per acre	15.0	16.5
Private gardens	6%	12%
Public green	10%	10%
Potential tree shade	15%	46%

Discussion

The successful urbanisation of Malaysia from a rural agricultural economy in two generations has become an inspiration to other developing countries. However, in the rush to modernise and alleviate poverty, serious mistakes in urban development have been made, albeit unwittingly. Evidence presented in this paper establishes that Kuala Lumpur is getting hotter faster than any other recorded city in the world. Random household surveys conducted by Universiti Putra Malaysia have also established that terrace houses, the major housing form in urban Malaysia, are considered by residents to be too hot on about half the days of the year (Davis and Nordin, 2002).

These problems should be seen as mistakes that Malaysia has made, rather than the inevitable consequences of urbanisation. Other developing countries can avoid these mistakes with a sensible application of the technologies outlined in this paper.

The Cool House technology developed at Universiti Putra Malaysia and reviewed here has the potential to solve the general problem of overheating in Malaysia's urban housing. The insulation, ventilation and shading technology is not really novel. However, the use of indoor climate computer simulation programs linked to an accurate weather year for Malaysia provides a powerful tool for combining and optimising these separate technologies. As demonstrated in an earlier paper regarding energy efficient housing for China and Arab countries (Davis *et al* 2003), this method can be extended to any other climate, allowing energy efficient buildings to be perfected at the design stage, rather than expensively modifying houses after construction.

Renovation of existing houses using this technology and the construction of the new designs of thermal comfort houses and apartments can have an enormous impact on air-conditioning electricity consumption, potentially saving Malaysia RM200 billion (USD 52 billion) over the next 30 years (Davis *et al* 2003). No country who wishes to rapidly urbanise can afford to ignore electricity savings on this scale, particularly other developing countries with far higher populations than Malaysia such as China, India and Indonesia.

Modifying the indoor climate is clearly achievable with existing technology, correctly applied for any particular climate and culture. Preventing the thermal mass of buildings from heating up during the

daytime is a very effective strategy for passively achieving indoor thermal comfort in hot climates and also lowers the radiation from the buildings to the outdoor environment, helping to reduce the heat island effect.

However, the urban roads in Malaysia are also a major contributor to the heat island effect. The roads are surfaced in black bitumen and fully exposed to direct sunlight which optimises the absorption of solar radiation, grossly overheats the roads and the subsurface layer of hardcore. Roads also comprise almost half the of the land area of Malaysian terrace house townships. Urban roads are therefore an enormous heat sink in Malaysia and need to be shaded from direct sunlight by canopy trees. This is not possible in the grid land subdivision typified by terrace housing.

Only very small trees can grow since their roots are blocked by drains at the front and sewer pipes at the back lanes and offer virtually no shade to the roads. New Malaysian townships are becoming increasingly like desert townships, too hot and devoid of nature. Honeycomb townships offer a sensible and environmentally friendly strategy for preventing the roads from overheating. The large central parks in front of the houses allows very large trees to grow in land undisturbed by drains or sewage pipes, providing almost complete shade to the courtyard roads as they mature to 12 to 18 meters in height. The short winding roads can also accommodate shade trees on both sides, providing a tunnel of tree which filters most of the sunlight. The design of Honeycomb townships has led to the emergence of Urban Wildlife technology at Universiti Putra Malaysia, a well established agricultural based university with a full complement of biological faculties. A collection of some 600 species of fruit and berry bearing trees and bushes collected from the rainforests are now being propagated in polybags in a commercial nursery of over 1 million trees in Tanjung Malim run by James Kingham, a collaborator in this project. Each species of tree will provide food for a range of insects and bird life. By selecting and planting a variety of these trees and bushes in honeycomb townships, a rich food chain and diverse microhabitats can be established in urban areas, supporting large populations of semi-domesticated but free ranging birds and non-aggressive small native animals such as squirrels and mouse deer as well as visiting migratory birds. This natural food chain can be supplemented with food supplied by residents to achieve higher densities of wildlife, cared for particularly by knowledgeable school children and retired residents.

Conclusions

Thermal comfort honeycomb townships provide a blueprint for cooler, environmentally friendly and energy efficient houses, towns and cities of the future, potentially overcoming the heat island effect suffered by many of the world's cities. The thermal comfort technology, combined with Honeycomb land subdivision and the emerging urban wildlife technology, is now at the commercially ready stage and is beginning to attract the serious attention of Housing Developers and Government Housing Ministries in Malaysia. The technology can be applied particularly to new towns and cities worldwide, in any climate. Nature and wildlife can become an intimate part of all urban areas, even desert cities, using a sensible and sensitive application of this technology to improve human welfare.

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Environmental Conditions of Air-Conditioned and Non Air-Conditioned Bedrooms: A Comparative Analysis

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Abstract

Most air conditioned households in Malaysia have their air-conditioning units installed in the bedrooms. A monitoring study was conducted to investigate the internal thermal conditions of these bedrooms. For comparison purposes, the internal conditions of non air-conditioned bedrooms were monitored first. The results are charted onto psychrometric charts and discussed with reference to comfort zones established by ASHRAE 55 Szokolay and Abdulshukor. The result shows that in most non air-conditioned cases, the thermal zone does not fall within the comfort zone stipulated by ASHRAE and Abdulshukor. However they do fall within Szokolays higher air movement comfort zone. In the air conditioned cases, most of the units are used during the night to bring the internal temperature down close to the external condition. The resulting conditions do fall within the comfort zone proposed by Abdulshukor, albeit on the colder and drier side.

Keywords : Thermal Comfort, Domestic Air conditioning, Monitoring.

1.0 Introduction

Most air conditioned households in Malaysia have their air-conditioning units installed in the bedrooms. A monitoring study was conducted to investigate the internal thermal conditions of these bedrooms. For comparison purposes, the internal conditions of non air-conditioned bedrooms were also monitored.

2.0 Thermal Comfort in Malaysia

For the purpose of this study, ASHRAE standard 55[1] and Comfort Zone for Malaysian developed by Abdulshukor & Young[2] will be used. The possible comfort zone developed by Szokolay[3] by means of higher air velocity will also be included for comparison. The results will be charted onto psychrometric chart. Table 1 below shows the summary of the comfort zones used in this study.

Table 1. Summary of comfort zone used in this study

	Temperature (Celcius)		Humidity (%)		Air movement (m/s)
	Min	Max	Min	Max	
Abdulshukor	25.0	31.4	45	90	0.1
Szokolay	23.0	36.0	10	90	1.0-1.5
ASHRAE 55	19.5	24.5	30	70	-

3.0 Monitoring of non air conditioned houses

Monitoring of non air-conditioned houses were conducted first to establish 'background case' for the analysis. Four houses of different types were chosen.

3.1 Methodology

Hobo dataloggers are placed in the bedroom at 5' above floor level. The parameters are measured at 5 minutes interval for 24 hours. The parameters measured are air temperature and humidity level.

Two of the houses (C01 & C02) chosen for this study are located in Selangor and within 20km of the main capital Kuala Lumpur, the main capital (3°08'N, 101°44'E).

Two houses are located in Melaka, 160km South of Kuala Lumpur. The two houses are situated next to each other and monitored concurrently. The distinguishing characteristic is the construction material. C03 is of masonry construction and C04 is of timber construction.

The data are then fed into excel and drawn into time series profile charts and psychometric charts. The results are compared with comfort zone as suggested by ASHRAE 55[1] standard and Comfort Zone for Malaysian developed by Abdulshukor & Young[2]. The possible comfort zone developed by Szokolay[3] by means of higher air velocity will also be included for comparison

Table 2 below shows the summary the houses monitored in this study.

Table 2. Summary of houses monitored

Case name	Location	House type	Construction type	Date of monitoring
C01	No 8, Jln Kemuning Kelang	Single storey terraced	Masonry	11-12/01/ 2003
C02	Taman Bangi	Two storey terraced	Masonry	2-3/01/03
C03	Kampung sri tanjung	Single storey Bungalow	Masonry	27-28/1/03
C04	Kampung sri tanjung	Single storey Bungalow	Timber	27-28/1/03

3.2 Procedure

The houses chosen were lived in houses. For every house, one data logger was placed outside while another was placed in the main bedroom. A 24 hour of monitoring was conducted for every house. The monitoring period ran from Mid December 2002 to February 2003. Over the monitoring period, the weather is characterized by rain in the evening, typically from 5pm to 7pm.

3.3 Results and analysis

The maximum daytime temperature and the minimum night time temperature for each case is shown in Table 3.

Table 3. Results for monitoring of non air-conditioned houses

			C01		C02		C03		C04	
			Internal	external	Internal	external	Internal	external	Internal	external
Temperature (°C)	Daytime	Max	29.5	29.5	29.9	31.9	32.8	31.9	33.2	31.9
		Average	28.2	27.4	29.2	29.1	30	29	29.2	29
	Night time	Min	27.5	25.6	28.7	26.3	27.5	24.8	24.8	25.2
		Average	28.5	27.1	29.2	27.4	29.5	27.4	27.6	27.5
Relative Humidity (%)	Daytime	Max	79.7	88.2	80	88	72	76	74	76
		Average	76.9	77.4	74	72	60	57	54	57
	Night time	Min	73.5	71.5	72	81	56	53	48	53
		Average	77.4	78.7	75	84	67	69	65	68

In the single storey terrace house (C01), it is found that during day peak temperature, the internal condition is similar to the external condition but 1.9°C higher during the night. In the double storey house (C02) the internal condition is 2°C lower than the external condition during mid-day. During the night, however, the minimum temperature is 2.4 °C higher than minimum external temperature. In the

masonry bungalow house (C03) the maximum internal condition is 0.9°C higher than the external condition during mid day. During the night, however, the minimum temperature is 2.7 °C higher than minimum external temperature. In the timber house (C04) the internal condition is 1.3°C higher than the external condition during mid day. During the night, however, the minimum temperature is 0.4 °C lower than minimum external temperature.

Comparing the result between masonry and timber construction in C03 and C04, it is found that the thermal mass of masonry construction has the effect of maintaining high temperature during night time when external condition cools. The data from the timber house shows that the internal condition follows the external condition very closely. This is the only case where the minimum internal condition is actually lower than that of external during the night. The relative humidity data shows that in all cases, the peak time is during the morning while it gets lowest during the afternoon. Apart from the timber house, all the other houses shows the effect of reduced internal humidity fluctuation compared to that of the external.

Fig.1 to Fig.4 show the psychrometric results of all the studies. In general the internal conditions of all the houses were consistently high temperature and high humidity. Apart from the timber house, it is found from the study of all houses that the internal condition of the bedrooms were higher than the external condition especially during the night time. In general the thermal mass of masonry construction has the effect of reducing temperature fluctuation.

In cases C01 and C02, when the external condition does not fall within the comfort zone as suggested by Abdulshukor, the internal condition of the bedrooms too does not fall within the comfort zone. However, when the effect of the use of ceiling fan is taken into account, the conditions largely fall within the zone suggested by Szokolay for air velocities of 1m/s and 1.5m/s. Comfort is achieved by the occupants by forced convection by the use of ceiling fan. It can be concluded that the use of ceiling fan is vital in achieving comfort in Malaysian houses.

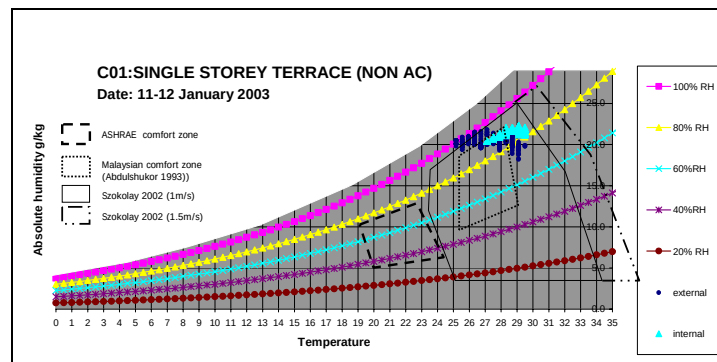


Fig.1 Absolute humidity variation with temperatures for case C01

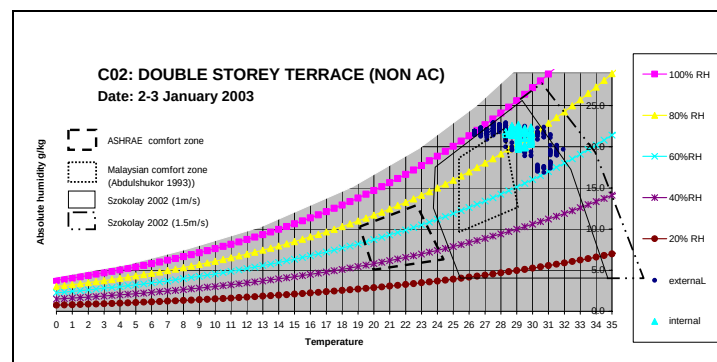


Fig.2 Absolute humidity variation with temperatures for case C02

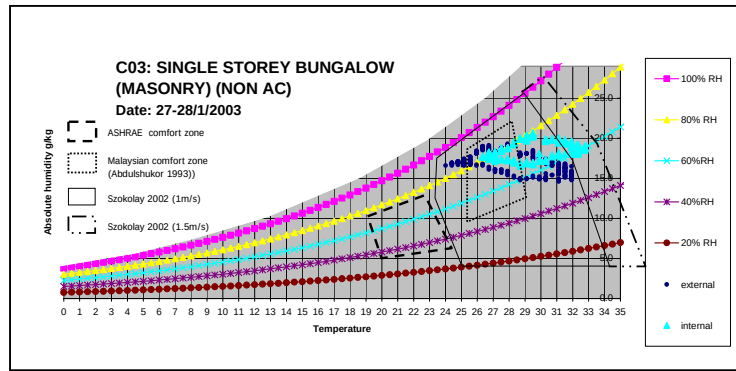


Fig.3 Absolute humidity variation with temperatures for case C03

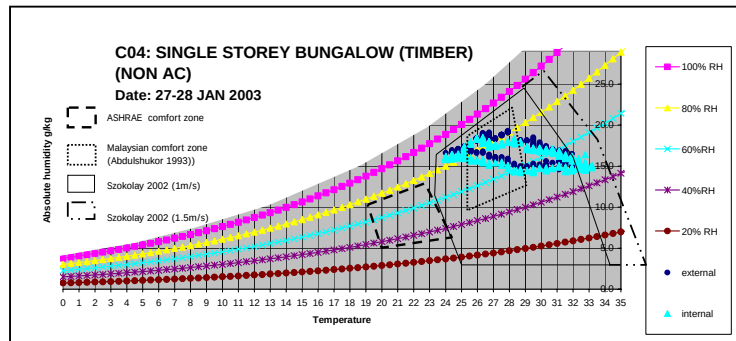


Fig.4 Absolute humidity variation with temperatures for case C04

4.0 Monitoring of Air conditioned bedrooms

4.1 Methodology

Hobo dataloggers were placed in the bedroom at 5' above floor level. The parameters measured were air temperature and humidity level, measured at 5 minutes interval. Another datalogger was placed outside to log simultaneous external condition. At the beginning of the monitoring, the occupants of the monitored room were given a log sheet which they have to fill in everyday to record thermal sensation, room occupancy, switching on or off, temperature setting and fan setting at quarterly intervals.

The data are then fed into excel and drawn into time series profile charts and psychrometric charts. The results are compared with the comfort zones suggested by ASHRAE 55 standard and Comfort Zone for Malaysian developed by Abdulshukor & Young.

4.2 Results

Following the analysis of the monitoring, the period between 10.00pm 28/11/03 and 4.00am 29/11/03 is selected for average condition data. During this period all the houses use their air conditioning units. The data during this period are also charted onto psychrometric charts.

4.3 Findings and Analysis

shows the summary of the results of the monitoring for all houses. It is found that in all cases, there is a mismatch between set temperature and the minimum temperature.

Table 4. Summary of monitored houses

Case no:	M001	m002	m003	m004	m005	m006	m007
Owner	Amri	Mr Low	Rizal	M Hatta	Melon	Anuar	Suzairi
Room	Master bedroom	Master bedroom	Master bedroom	Master bedroom	Master bedroom	Living room	Master bedroom
House category:	Low cost single storey	Medium Cost Single Storey	Medium cost double storey	Low cost single storey	Medium cost single storey	Medium cost single storey	Medium cost single storey
Power of unit	1	1	1	1	1	1	1
Temperature setting	19C	26C	17C	22C	18C	20C	25C
Fan Setting	medium	Low			Medium	Low	Medium
Satisfaction	yes	Yes	yes		Yes	yes	yes
Ceiling fan	no	No	no	no	no	often	no
Temp vote	Slightly Cold (-1)	Ok(0)	Ok(0)	Slightly Cold (-1)	Ok(0)	Slightly Cold (-1)	Ok(0)
humidity vote	Ok(0)	Dry (1)	Ok(0)	Ok(0)	Ok(0)	Ok(0)	Dry (1)
Min Temp	26.3	26.3	26.3	22.9	26.0	27.1	27.5
Max Temp	28.7	27.9	29.1	30.3	29.9	29.9	29.9
Ave Temp	27.2	26.8	27.5	24.8	27.0	28.2	28.3
Min Humidity	78.8	59.3	46.4	42.7	34.5	65.8	45.9
Max Humid	91.7	78.2	71.9	68.2	55.4	79.8	71.2
Ave Humid	86.9	71.7	57.4	45.3	37.7	70.3	53.0
Design Discrepancies between set temperature and actual condition							
	7.3	0.3	9.3	0.9	8.0	7.1	2.5

Fig.5 to Fig.11 shows the average condition zone of all houses charted on Psychometrics chart. It is found that the average condition falls largely within the comfort zone (approx 85%).

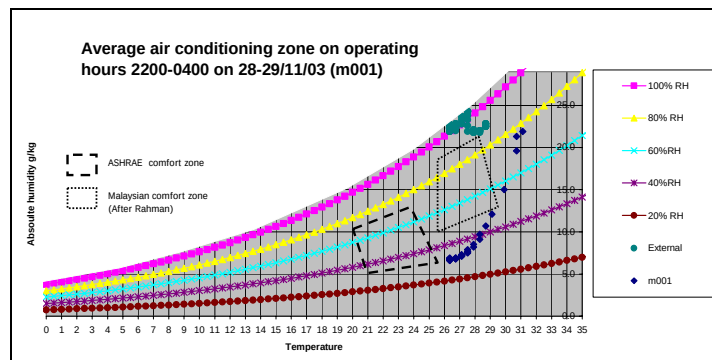


Fig.5 Average air conditioning zone on operating hours 2200-0400 on 28-29/11/03 (m001)

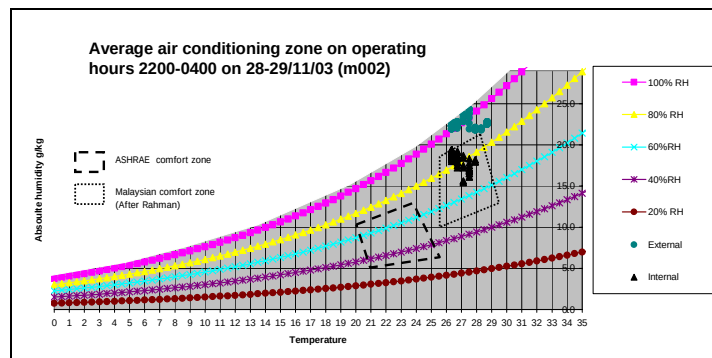


Fig.6 Average air conditioning zone on operating hours 2200-0400 on 28-29/11/03 (m002)

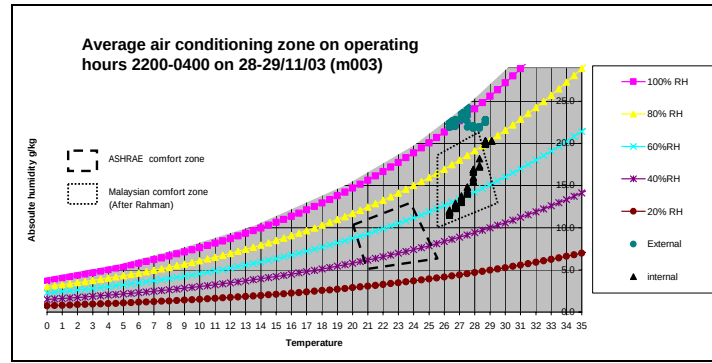


Fig.7 Average air conditioning zone on operating hours 2200-0400 on 28-29/11/03 (m003)

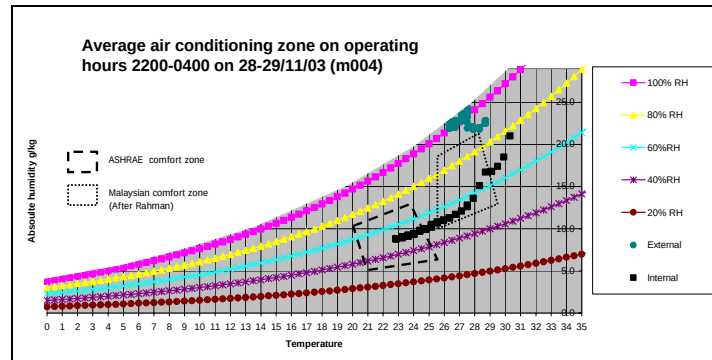


Fig.8 Average air conditioning zone on operating hours 2200-0400 on 28-29/11/03 (m004)

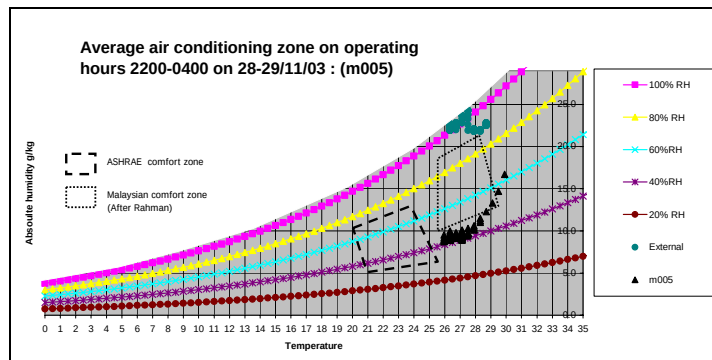


Fig.9 Average air conditioning zone on operating hours 2200-0400 on 28-29/11/03 (m005)

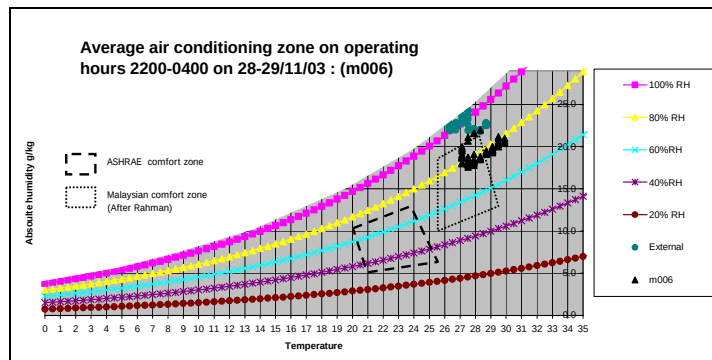


Fig.10 Average air conditioning zone on operating hours 2200-0400 on 28-29/11/03 (m006)

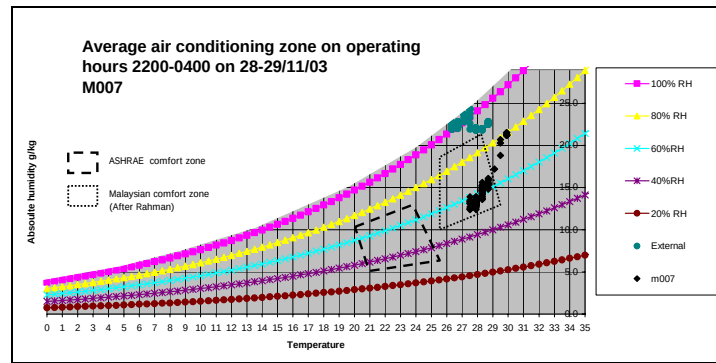


Fig.11 Average air conditioning zone on operating hours 2200-0400 on 28-29/11/03 (m007)

Table 5 below shows the percentage of condition that fall within the comfort zone suggested by Abdulshukor.

Table 5. Percentage of internal condition falling within comfort zone by Shukor

House	m001	m002	m003	m004	m005	m006	m007
Condition within Comfort Zone	< 1%	100%	%90	%45	%10	%60	60%
Extreme conditions	Too dry Too cold			Too dry Too cold	Too dry Too cold		
Temperature Vote	Slightly Cold	Ok	Ok	Slightly Cold	Ok	Slightly Cold	Ok
Humidity Vote	Ok	Dry	Ok	Ok	Ok	Ok	Dry

The results shows that three houses have less than 50% condition within the comfort zone. House m001 has the most problems with less than 1% of its condition match that of the comfort zone. In all three cases the resulting condition is too cold and too dry. The general comfort votes reveal that 43% of the occupant think the condition is slightly cold and 29% think the condition is dry.

Table 6 shows the average of the overall condition during the analysis. While the air temperature does not differ very much from the outside temperature, the most significant impact of the use of air conditioning is the removal of moisture. The internal humidity is around 30% lower than the external humidity.

Table 6. Average Conditions for monitored condition between 10pm 28Nov and 4am 29Nov

	OVERALL AVERAGES					
	Temperature			Humidity		
	Min	Max	Ave	Min	Max	average
External	26.3	28.7	27.2	78.8	91.7	86.9
Internal	25.8	29.7	27.1	45.9	70.3	54.4

4.4 Conclusion of Monitoring study of Air-Conditioned bedrooms

The results shows that the internal conditions of air conditioned rooms monitored in this study do not fall within the comfort Zone suggested by ASHRAE. However when the comfort zone for Malaysian suggested by Abdulshukor is used, the condition shows approximately 85% match, indicating satisfactory design performance.

There is a tendency for the internal condition to be on the colder and drier side of the zone. There is a potential for energy efficiency for the design condition to achieve higher temperature and humidity.

Comparison between temperature setting and actual air temperature shows a mismatch with the actual temperature higher than the setting by on average of 5°C. The operative temperature do fluctuate with external condition. This can be attributed to two problems: (i) the inadequacy of the design of the unit to achieve the target temperature and (ii) the leakiness of the room.

The findings from this study can be used to speculate the energy issues and occupant behaviour. The inability of the unit to achieve set temperature results in the setting chosen by occupants does not reflex the actual preferred temperature. As the temperature profile decrease following the external condition in the early morning, the air temperature can get below the preferred temperature. There result from household survey confirm this hypotheses, that there is a need for the occupants to alter controls during sleeping hour, and to use comforter (thick blanket) to achieve comfort.

5.0 Conclusions

Without air conditioning, the internal condition of bedrooms in Malaysia hardly fall into the comfort zone proposed by Abdulshukor. However, when the use of ceiling fan is taken into account, they do fall within the larger comfort zone proposed by Szokolay for higher air movement. The thermal mass of masonry construction cause the reduction of day peak temperature while keeping the internal condition higher than outside during night time. The internal condition of timber house follows closely the external condition due to the lightweight nature of the construction, hence, low thermal mass. The problem for timber house can be the day peak temperature which can be as high as 33.5°C revealed by this case study. This suggests that, without air conditioning, the use of ceiling fan is indispensable in achieving thermal comfort in a Malaysian house.

The internal condition of air-conditioned houses shows that on average, the internal condition do fall within the comfort zone suggested by Absulshukor. However, in some cases the condition can either be too cold and too dry.

A interesting finding is the amount of latent cooling involved when using air conditioning (AC) units. As much as 30% of moisture was removed in air-conditioned bedroom, while air temperature does not get much lower than that of the external during the night time. This suggest that a proper humidity control might be necessary in providing comfort in Malaysian homes.

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THE VENTILATION PERFORMANCE OF A SOLAR-POWERED ATTIC FAN IN MALAYSIAN CLIMATE

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Abstract

A study was conducted to investigate the effectiveness of a ventilation system, in providing thermal comfort to the interior space of a building in hot and humid climates. The system consists of a solar powered attic fan with lightweight fan blades powered by photovoltaic (PV) panels. The system is widely used in temperate climate countries to improve interior environments during daytime in the summer, since it is purely solar radiation dependent. The ventilator functions as a heat extractor, extracting out warm air and moisture trapped between the ceiling and roof, thus reducing the heat radiating effect on the living spaces. As a result, the temperature in the occupied space is reduced. The hot air trapped in attic during the daytime becomes a major source of heat. In this study, the temperature, air movement, and humidity inside a room and the attic in which the ventilation system has been installed, were monitored continuously over a certain period of time. Comparisons on the measured values were then made for cases with and without the ventilation system, thus giving an analysis of the overall performance and effectiveness of the system for humid climates. The results of this study could be used for further improvisation of the systems to accommodate the requirements of hot and humid climates.

Keywords : Natural ventilation, PV panels, Air movement, Thermal comfort.

1. Introduction

Air trapped in between the ceiling and roof is a major problem for hot climates. The hot air trapped during the daytime becomes a major source of heat (Abdul Rahman, S. et al., 2004). Insufficient ventilation and attic air exchange are claimed to be among the main causes that contribute to these phenomena. The hot air eventually transfers into the living spaces, sending both utility bills and temperatures soaring. For hot and humid climates, achieving thermal comfort without the use of active energy consuming measures is a great challenge. Studies have indicated that there is a need for both ventilation and dehumidification for regions of these climatic conditions (Abdul Rahman, S. et al., 2004, Zain_Ahmed, A. and Abdul Rahman, S., 2000). Humidity levels play a significant role in the evaporative capacity of the air. When the humidity is high, the high vapor pressure will prevent evaporation thus restricting the cooling effect unless higher air velocities are introduced (Abdul Rahman, S., 1999).

A solar-powered attic fan (Fig.2) is a passive ventilation system mainly designed for the purpose of extracting out the hot air trapped inside the attic of a building while simultaneously drawing in air from outside through the openings at the lower intake vents of roofs (Fig.1). The system consists of lightweight fan blades powered by PV panels. The system was developed for temperate climate countries where the outdoor and indoor temperature difference is substantial but was never tested in hot humid climatic conditions. The attic fan runs best when the solar panel is in direct sunlight. Being dependent on solar panels, it only operates during daytime. However, if it works, the system can provide potential energy and cost savings. Theoretically, by extracting the heat and moisture out of attic spaces, the system consequently reduce the heat radiating effect on living spaces while fighting against mold and control humidity levels like shown in Fig.1.

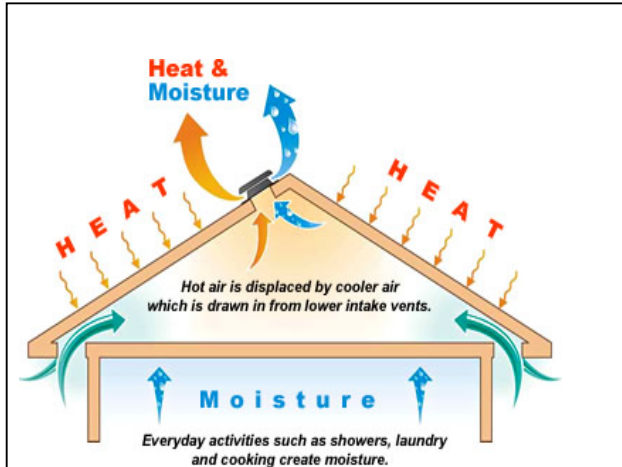


Fig.1 A Solar Powered Attic Fan on operation.
(<http://www.solatubeskylight.com/solarstar.html>)



Fig.2 Solar-Powered Attic Fan
(<http://www.solatubeskylight.com/solarstar.html>)

The objective of this paper is to report on the effectiveness of the system in improving the interior conditions of building spaces in hot humid climates by ventilating the attic spaces of the building. The results of this study can be used for further improvisation of systems of similar functions that is currently being developed.

2. Methodology

The solar-powered attic fan was installed in a test room of floor size 4.5 m x 4.5 m and height 3.05 m. The room, which was painted white has one door and two windows on adjacent walls with opening area equivalent to 10% of the floor area as required by the Malaysian Uniform Buildings By Law. The test room has a steel roof with asbestos ceiling. The door was closed during the whole duration of the experiment. The attic fan was located at approximately the center of the room, facing West.

The experimental work was divided into two major parts; measurements in the attic and in the occupied space of the test room for cases with and without the system. However measurements in the occupied spaces included two additional cases of with and without opening. In order to take measurements without the system, the solar panels were temporarily covered with a piece of black plastic disk to block the light from striking it. For cases of without openings, the windows were shut and covered. Since all the experimental works were carried out in the same test room, taking temperature or humidity for different cases simultaneously was not possible. However, the temperature and humidity were always measured simultaneously for every case.

Measurements were taken using Lastem Sensors connected to a data logger which is able to record data automatically over a period of time. The data was then transferred to a computer using a software called Dewesoft. All calculation was done using Microsoft Excell Software. The outdoor climatic parameters were measured and recorded continuously using Symphonie data logger. The sensors for measuring the outdoor data were placed at a height of one meter above the rooftop whereas for the indoor, all sensors were placed at work level, that is 0.75 m above the floor. Interior measurements were taken every minute, while outdoor measurement every 10 minutes for the period between 8:00 am and 6:00 pm. For each case the experiment was repeated twice.

3. Results and Discussions

3.1 Attic Measurements

Tables 1 and 2 show the results for airspeed, humidity, and temperature outdoors and inside the attic for cases without and with the system installed respectively.

Table 1: Outdoor and Indoor Measurement For The Attic Without The System

Time	Attic Humidity (%RH)	Outdoor Humidity (%RH)	Diff in Humidity (%RH)	Attic Temp (DegC)	Outdoor Temp. (DegC)	Temp. Diff. $T_{\text{Outdoor}} - T_{\text{Attic}}$ (DegC)
8:00:00a.m.	72.648	69.5	-3.148	26.25	25.8	-0.45
10:00:00a.m.	74.671	60.7	-13.971	27.72	29.3	1.58
12:00:00noon	62.274	58.7	-3.574	30.71	33.3	2.59
2:00:00p.m.	60.550	60.0	-0.550	32.62	31.8	-0.82
4:00:00p.m.	60.930	60.5	-0.430	31.73	29.0	-2.73
6:00:00p.m.	66.800	62.4	-4.400	29.65	26.6	-3.05

Table 2: Outdoor and Indoor Measurement For The Attic With The System Installed

Time	Attic Humidity (%RH)	Outdoor Humidity (%RH)	Diff in Humidity (%RH)	Attic Temp (DegC)	Outdoor Temp. (DegC)	Temp. Diff. $T_{\text{Outdoor}} - T_{\text{Attic}}$ (DegC)
8:00:00a.m.	70.631	58.8	-11.831	31.61	31.61	0.00
10:00:00a.m.	63.417	62.7	-0.717	28.75	32.71	3.96
12:00:00noon	51.418	55.9	4.482	32.93	34.37	1.44
2:00:00p.m.	46.189	57.8	11.611	34.42	34.51	0.09
4:00:00p.m.	46.184	58.8	12.616	32.89	32.58	-0.31
6:00:00p.m.	49.465	61.5	12.035	31.43	32.00	0.57

The results show that there appears to be relative reductions in attic temperature and humidity when the solar attic fan was used as shown in Tables 1 and 2. This is portrayed graphically in Fig.3, Fig.4, Fig.6 and Fig.7. Reduction of attic temperature and humidity is a clear indication that ventilation in the attic has improved. In the morning, the temperature difference was not very significant. However, it appears to increase as the day progresses especially after 12:00 o'clock in the afternoon. This is expected as the PV panels of the system faces West, thus increasing the efficiency of the fans during and consequently the ventilation performance of the system towards the later part of the afternoon. This would be a great advantage as attic temperatures get higher as the day progresses due to the heat being trapped in the attic as the roof is increasingly being exposed to the hot sun.

The results also showed that with the system installed, the attic temperature never went higher than the outdoors. Without the system, the attic temperature was found to be after 2:00 pm (Fig.3 and Fig.4)

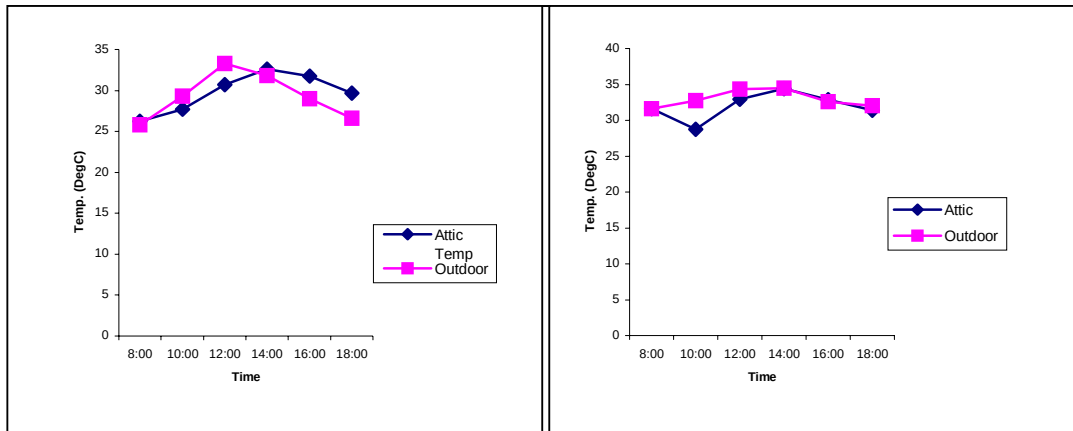


Fig.3 Graph of Temperature Vs. Time For the Attic Without the System

Fig.4 Graph of Temperature Vs. Time For the Attic With the System Installed

Since the measurements were taken on different days, it is also meaningful to observe the temperature differences rather than the true temperature. Fig.5 shows that the temperature differences is positive for all cases except one, when the system was installed, indicating that the attic temperature was lower than the outdoor temperature for most of the time.

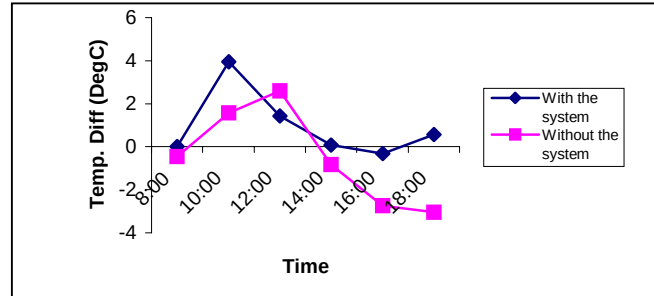


Fig.6 and Fig.7 show a significant decrease in humidity inside the attic compared to humidity outside when the attic fan was used. This is a very positive effect of the system as moisture in the attic can promote mold, fungal decay and plywood delamination.

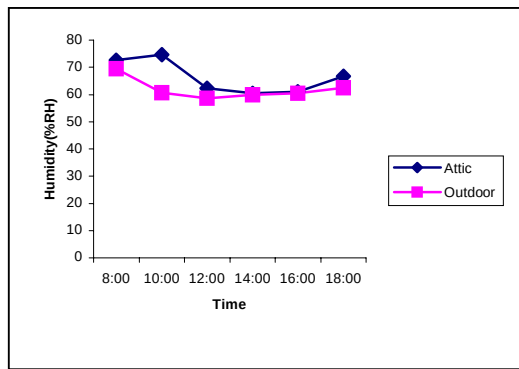


Fig.6 Graph of Humidity Vs. Time in the Attic (Without The System)

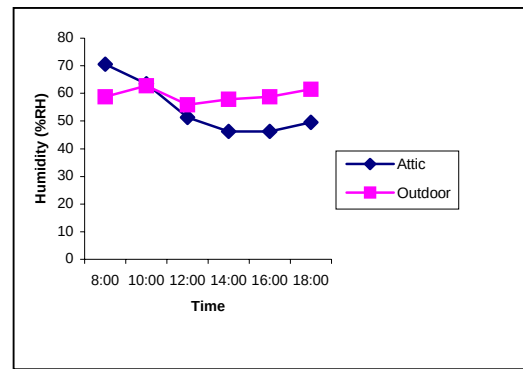


Fig.7 Graph of Humidity Vs. Time in the Attic (With The System)

Although results have shown significant changes in temperature and humidity, the airspeed in the attic was found to be very minimal. Table 3 below shows the average solar radiation and the average relative airspeed in the attic with and without the system taken from 12:00 o'clock in the afternoon until 6:00 p.m. With solar radiation as low as 4.97 W/m², there appears to be no significant difference in the performance of the attic fan when compared to when the solar radiation was 18.87 W/m², indicating that the PV panels have a high efficiency.

Table 3: Airspeed in The Attic Compared to The Solar Radiation

Cases	Average Solar Radiation (W/m ²)	Average Airspeed in Attic (m/s)
Without Attic Fan	18.87	2.507×10^{-4}
With Attic Fan	4.97	2.42×10^{-4}

3.2 Occupied Space

Tables 3 and 4 show the results of measurement inside the occupied space. It can be seen that the system does give a significant impact on the indoor temperature and humidity. The decrease in the indoor air temperature can be clearly seen Fig. 8 to Fig.10.

Table 3: Outdoor and Indoor Measurement For The Occupied Space Without The System (Without Opening)

Time	Humidity (Occ space) (%RH)	Outdoor (%RH)	Diff in Humidity	Temp. (Occ space) (DegC)	Outdoor (DegC)	Diff in Temp (DegC)
8:00a.m.	70.99	61.8	9.19	27.85	27.6	-0.25
10:00a.m.	57.74	59.4	-1.66	27.76	31.3	3.54
12:00noon	46.36	58.3	-11.94	27.96	33.5	5.54
2:00p.m.	48.30	59.1	-10.80	28.08	30.8	2.72
4:00p.m.	58.03	59.0	-0.97	28.59	30.1	1.51
6:00p.m.	64.67	60.7	3.97	28.60	28.7	0.10

Table 4: Outdoor and Indoor Measurement For The Occupied Space With The System Installed (Without Opening)

Time	Humidity (Occ space) (%RH)	Outdoor (%RH)	Diff in Humidity	Temp (Occ space) (DegC)	Outdoor (DegC)	Diff in Temp (DegC)
8:00	51.32	61.9	10.58	26.82	26.9	0.08
10:00	44.79	60.6	15.81	26.86	30.4	3.54
12:00	41.45	59.3	17.85	27.1	31.4	4.30
2:00	47.52	59.5	11.98	27.6	30.5	2.90
4:00	49.52	58.9	9.38	28.29	31.7	3.41
6:00	48.94	61.5	12.56	28.36	26.6	-1.76

Fig.8 and Fig.9 are the results for the cases of no opening whereas in Fig.10 and Fig.11, windows were opened to provide openings on the adjacent walls. It can be observed from Fig.9 that using the solar attic fan without opening gave the best result in reducing the air temperature inside the occupied space relative to the outside conditions. It is interesting to note that despite the outdoor air temperature that fluctuated drastically due to the change of weather, the indoor temperature changed only gradually indicating that the building enclosure were able to provide relatively good protection against temperature fluctuations.

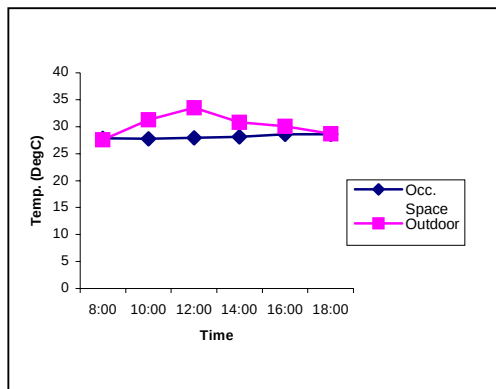


Fig.8 Graph of Temperature Vs. Time For the Occupied Space Without the System (Without Opening).

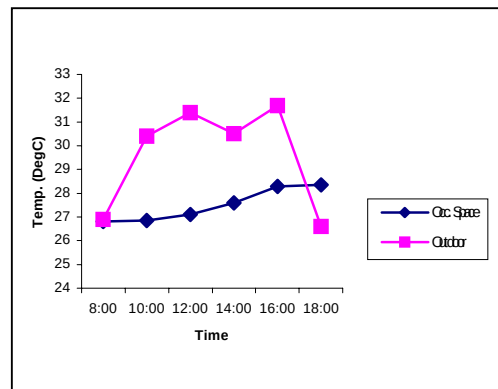


Fig.9 Graph of Temperature Vs. Time For the Occupied Space With the System (Without Opening).

As shown in Fig.9 and Fig.11, the temperature differences between the outdoor and the occupied space decreases when there is opening in the occupied space. This shows that the presence of openings presents an avenue for heat entry, thereby increasing the temperature of the interior space.

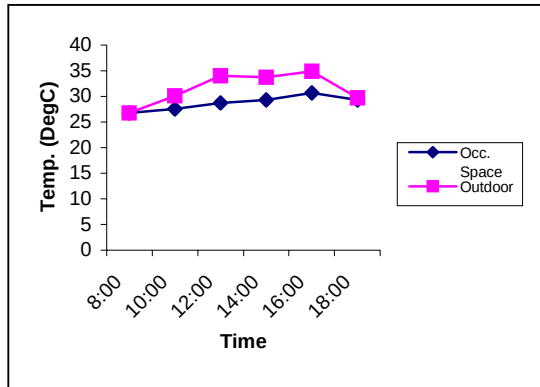


Fig.10 Graph of Temperature Vs. Time For the Occupied Space Without the System (With Opening)

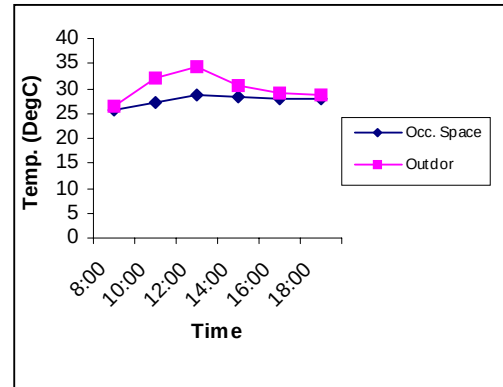


Fig.11 Graph of Temperature Vs. Time For the Occupied Space With the System (With Opening).

Fig.12 is the results for the case of the occupied space without the Attic Fan. As could be seen in Fig.13, the presence of the attic fan really reduced the humidity levels inside the occupied space. In order to achieve thermal comfort, reducing the humidity level is essential. Air temperature and humidity are two major factors that influence thermal comfort. The accepted humidity level for buildings occupants to stay thermally comfortable is 40 – 70%RH (<http://www.acc.co.nz>). However, in high temperature regions like Malaysia, a lower humidity is definitely more favorable as this would translate to withstanding higher temperatures.

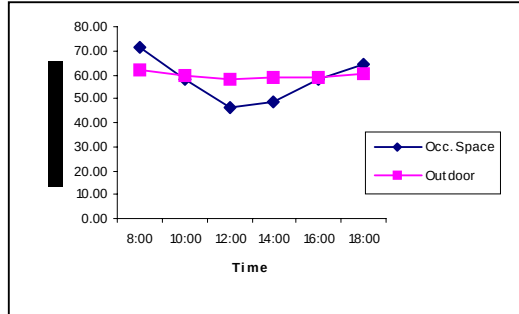


Fig.12 Graph of Humidity Vs. Time For The Occupied Space Without The Attic Fan

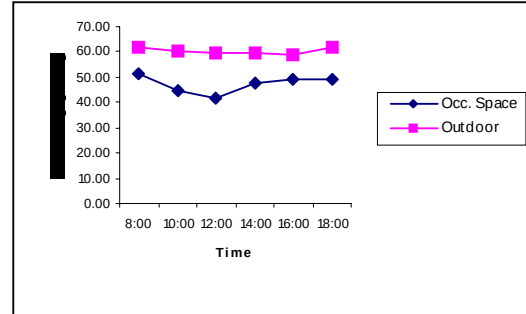


Fig.13 Graph of Humidity Vs. Time For The Occupied Space With The Attic Fan Installed

4. Conclusions

From this study, it can be concluded that introducing good ventilation in the attic could be one effective way of reducing air temperature and humidity in buildings. It was also shown that the presence of openings can cause a relatively significant increase in interior temperatures. In general, the use of solar-powered attic fan in Malaysian climate has shown positive effects towards achieving thermal comfort. The results show that the system does succeed in reducing the air temperature and humidity levels inside a building. When humidity level is low, human body could compromise a higher temperature to stay comfortable compared to a more humid environment. The application of this fan would be optimum if additional outlets were provided for in the ceiling for the warm air in the interior space to escape while creating air movement. The application of the system can be a good potential energy and money savings strategy in a long-term as it requires no maintenance and no cost of operation, besides being environmentally friendly. However, being solar radiation dependent, the

function is limited during daytime only. In addition, the use of solar panels makes the system expensive and unaffordable to all levels of consumers although it is a worthy investment.

Acknowledgements

The authors would like to acknowledge MOSTI for granting the IRPA grant (IRPA Code : 02-02-01-0016-EA0016), Institute of Research, Development and Commercialization, and the Faculty of Applied Sciences, University Teknologi MARA for supporting the research. The authors also appreciate the involvement of Nik Aryusman Fitri Abd Razak, Wan Mohd Khairi Wan Yahya and Mohd Afzan Abdul Halim in the project.

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ECO HOUSE: AFFORDABLE AND SUSTAINABLE SOLUTION FOR POST-EARTHQUAKE RECONSTRUCTION

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Abstract

This paper examines a recent sustainable design project, Eco House, in Taipei, Taiwan. The Eco House was conceived as a response to the Chi-Chi Earthquake that struck central Taiwan in 1999. The earthquake, measured 7.8 on the Richter scale, took 2,400 lives and destroyed more than 100,000 homes, leaving many surviving victims living in temporary metal shacks in remote mountainous disaster areas. Two years after the earthquake, the Tai Yuen-Hui Cultural Educational Foundation, a non-profit organization, built a demonstration house in Taipei County that aimed to provide a feasible, affordable and self-sufficient solution for the reconstruction as well as a model for sustainable building design. The Eco House addresses the above issues through both the construction and operation of the project. Its simple lightweight metal-frame structure and utilization of different recycled materials allowed the on-site construction to be completed in 20 days with a budget of under \$26,000 USD. The project met the two imperative challenges, time and money, in the context of post disaster reconstruction. Its operation is to provide a feasible demonstration in order to promote sustainable technologies, such as water recycling and renewable energy, to the government authority and the public. The project features a gray water system that is fully self-supported using a renewable energy system with two wind turbines and four photovoltaic panels. The Eco House can be considered as an experimental project that has succeeded in providing a sustainable solution for post disaster reconstruction. Since South East Asia is prone to frequent natural disasters, the project can provide some valuable experience and lessons for the region, particularly in terms of cost-effective sustainable technologies.

Keywords : Sustainable buildings, Post disaster reconstruction, Cost-effectiveness, Taiwan.

1. Introduction

Every year Taiwan has to face the risks of typhoons, floods, earthquakes and landslides, which pose great threats to human lives and property. The most recent major disaster was an earthquake that struck central Taiwan on September 21, 1999. The earthquake, measuring 7.8 on the Richter scale, has been referred to as *Chi-Chi Earthquake*. It took approximately 2,400 lives and injured 11,300 people. It also left behind 51,000 collapsed houses and another 53,000 semi-collapsed (921 Earthquake Post-Disaster Recovery Commission, 2001). Ever since the occurrence of the disaster, the reconstruction work has been carried out with abundant resources; however, the wide range of the disaster area covering from urban to remote created a variety of challenges for reconstruction efforts. Among the most devastated communities in the disaster area are those of aboriginal tribes. The epicenter of the earthquake was situated at the Chi-Chi region of the Central Mountain Range, where aborigines were already struggling for a basic living before the earthquake. The lack of infrastructure and the socioeconomic disadvantages in the area have resulted in a slow pace of reconstruction, leaving victims continuing to struggle. The Eco House project is primarily designed to serve as a single family-housing prototype that aims to address imperative issues in post-earthquake reconstruction as well as develop off-grid energy through a sustainable approach.

2. Methodology

In this case study, the detailed construction process was documented based on participant observations. The data were gathered from field investigations and interviews with participants engaged in project in the duration from the planning to the completion of construction. A comparison of the studied project with other prefabricated temporary shelters constructed by the government was provided through the post-occupancy evaluations and literature review of related research papers. The

comparison focus on financial affordability and feasibility of the structural system and construction process. The purpose of this case study was to analyze the feasibility of integrating sustainable design into post-reconstruction housing projects.

3. Challenges in Post-Earthquake Reconstruction

In the context of post-disaster reconstruction, challenges presented in various scales from different aspects. The foremost are the constraints of time and finance for both government and individual in the processes of reconstructing infrastructure and housing projects. In physical built environment, the seismic safety has become the first priority in technological concern and the revitalization of the disaster area in both regional economic and mental aspect of surviving victims are the ones even pressing for a long term perspective of reconstruction.

3.1 Financial and time constraints.

Time and money are the most important imperatives in the context of post-disaster reconstruction. The immediate rescue efforts often undertaken with the first phase of reconstruction including removing debris, repairing infrastructure and searching for (or building or converting) temporary shelters for surviving victims. The second phase of reconstruction can be considered as the transition from demolishing temporary shelters to reconstructing permanent housing, which may take anywhere from weeks to years depending on individual circumstances. The temporary shelters often consist of shacks using metal panels without proper insulation, leaving the occupants to bear the chill in winter and heat in summer. Unfortunately, the fact that many victims had to live in such conditions for years reveals the problems underlying temporary housing strategies and financial crisis for disadvantaged victim household. The first goal for the Eco House was therefore to explore the possibility of shortening or even removing the transition period by offering a fast construction housing module at an affordable cost at first place.

3.2 Seismic Safety.

Seismic safety has become a key priority for the reconstruction since what the population have experienced through the disaster and post-disaster rescue effort were imprinted in their mind. The heavy weight reinforce concrete construction that is commonly used in house construction has been proven fragile in seismic resistance and had lost credibility among surviving victims. For the remote area where the dwellings are mostly single family housing that is no more than two-stories, searching for an alternative, cost-effective structure system had become one of the goals in the design of Eco House.

3.3 Revitalization.

Although the physical reconstruction was demanding, the psychological revitalization was even more pressing since what the earthquake left behind were not only the collapsed buildings but also lost families, and severe financial challenges. There is no denying that issues of regional recession and unemployment involve effort from many different aspects at different scales; however, as the smallest scale of the built environment, housing reconstruction is also obligated to find a way to contribute to such aspect. A possible methodology was therefore suggested in the Eco House; by simplify the construction process in order to engage the victims in rebuilding their own homes.

4. Design & Construction of the Eco House

The intentions of the project Eco House was twofold: first, through media coverage and public exhibition, the house has become a physical implementation of different sustainable technologies that the foundation has been advocating for years; second, the low-tech, low cost and easy-construction house with self-sufficient power system is an ideal solution for reconstruction in earthquake disaster areas particularly for those remote mountainous regions that are lacking in basic infrastructure but rich in natural resources.

4.1 Site and Structure.

A site located in She-Men village (Fig.1) in a seashore community of Taipei County was made available by one of the foundation members, the site was occupied by a ruined one story concrete vacation villa, which made it ideal for an experimental project, because it was possible to start from site demolition. The Eco House project employed a steel metal frame structure instead of reinforced concrete (RC). The RC construction is the most common construction method in Taiwan, both for the urban high-rise apartment and countryside row house. However, the overall behavior of reinforced concrete buildings in earthquake showed that the most critical and weak elements are the first floor RC columns that support upper floors. It was evident in the earthquake that most two or three-story row houses collapsed at the points of support between first floor column and its upper loads, resulting in a smashed first floor while the upper parts remained intact (Fig.2). This behavior indicated a lack of lateral resistance. The heavy weight of the upper floors and roof system may have been the major causes for the collapsing, and hence a lightweight metal frame structure was employed in the project to improve the seismic performance. The house was constructed with three modules of lightweight steel frames, supplemented by lateral structure members for shear resistance. The module (Fig.3) allows the structure to be connected as whole, providing resistance in both directions and successfully reduces the weight of the floor by replacing concrete slabs with a lightweight metal floor system.

In addition to seismic concerns, the lightweight structure also has advantages in cost efficiency and construction time. During reconstruction, it is important to spend money and time precisely and efficiently. \$26,000 USD is the rough figure available for a victim household from government recovery funds and other charity sources. The primary goals of the project were therefore to control the total cost within this budget and finish the construction in a short time frame. In order to lower the cost and shorten construction time, the design of the floor plan has taken structure and construction methods into consideration to attain a combination of simplicity and feasibility (Fig.5). The two-story house has a simple layout, leaving spaces open to provide flexibility to accommodate different needs according to individual circumstances. The module structure system and its simple construction process allowed on-site construction to be finished in 20 days. A straightforward process that replaced welding with screwing further indicated the possibility for employing non experts with short-term training in construction. This suggested a way to engage victims in rebuilding their own houses.



Fig.1 Site

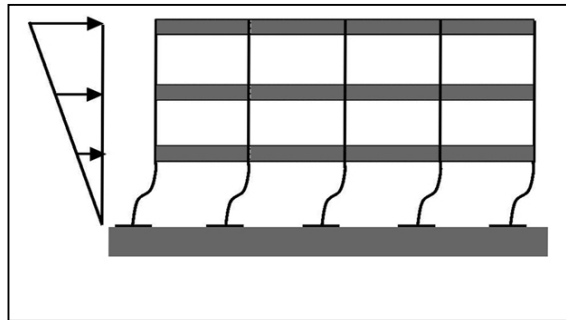


Fig.2 Diagram of RC building distortion by shear force

After the lightweight steel frames were elected, panels made of recycled plastic were used to construct the walls with proper openings for natural lighting and ventilation. The low-cost recycled plastic wall materials (Fig.4) were easy to install as well and provided good insulation and further enhanced the building's seismic resistance to shear force.



Fig.3 Structure module



Fig.4 Wall material



Fig.5 Floor system

The selection of the roofing tile materials was also based on the same criteria as for wall: lightweight, easy and fast installation and better seismic performance. The unique interlocking design of the tiles, achieved during installation, provides fortification of edges and protects against rainfall, wind, and earthquakes. Only 12 pieces of tile are required per square meter, thereby allowing time savings of approximately 20% on installation and handling. The interlocking design provides for quick and easy alignment and adjustment and therefore speeds up the construction. The envelope of the house was further finished with wood sidings, recycled from demolished house, to provide another layer of insulation and an aesthetic look (Fig.6-Fig.8).



Fig.6 Front view before wood siding



Fig.7 Front view after completion Site



Fig.8 Back view

4.2 Renewable Energy.

One of the intentions for this experimental project was to provide a practical example of renewable energy applications (Fig.9) that has been advocated by the foundation for years. The dedication came from the goal of creating a "Nuclear free home" which is now supported by the current Taiwanese government. There are three nuclear power plants in operation generating 20% of annual power consumption in Taiwan, while renewable energy contributes less than 1%. With the incoming Kyoto Protocol that impacts traditional methods of electricity production and the environmental issues of nuclear power, renewable energy has emerged as an attractive alternative for the Taiwanese government. The government is willing to support the local implementation of renewable energy by funding NT 150,000 (USD \$ 5000) for each Photovoltaic Panel that generates 1 KWH with the limit up to 50 % of total system cost. The Eco House employed renewable energy as its only electricity source. The site for the project is located on the seashore where it receives ample sunlight as well as strong shore wind. The house employed a hybrid electrical system that integrates solar photovoltaic panels and wind turbines. The system consists of two wind turbines utilizing the east wind and four photovoltaic panels installed on the roof facing south. The whole system generates sufficient power for the off-grid project. Table 1 shows the energy production from different renewable systems.



Fig.9 Renewable energy system

Table 1. Energy production from renewable system
(Data provided by China Electric MFG. Corporation)

PV panel	Max 17.6 KWH/Month Avg 13.9 KWH/Month Min 9.6 KWH/Month
Wind turbine	Max 20.1 KWH/Month Avg 10.0 KWH/Month Min 5.2 KWH/Month
Hybrid system PV panel x4 and Wind turbine x2	Max 110.6 KWH/Month Avg 75.6 KWH/Month Min 48.8 KWH/Month

4.3 Water recycling and paving.

The earthquake uncovered problems of soil and water conservation underlying rapid but careless economic development in Taiwan as evident in the fact that hill sliding was one of the main causes of death in the earthquake. The issues were even worse after the earthquake damage reduced the durability of hillside in coping with natural hazards. In urban areas, with majority of surfaces covered by concrete, the city drainage system often fails to discharge water brought by heavy rain, and resulted in frequent flooding. In addition, the reduced capability to retain water in its ecological cycle also results in water shortages. Although these environmental problems require comprehensive solutions at a national scale, in the small scale built environment such as a single house, the contribution to ecological design is also essential. The Eco house was intended to incorporate sustainable technology in this aspect, employing a penetrable paving and water recycling system. The pavement around the house employed 90% water penetrable bricks, allowing natural water recycling to continue without interruption and preserving the foundation soil in a secure condition. The house also features a water recycling system that collects the rain through the roof into a tank, and reuses it for grey water.

5. Discussions

5.1 Temporary Shelter and Permanent Housing.

The initial options for victims whose houses were completely collapsed following the earthquake included: "applying for public housing at 70% discount," "receiving rent allowance NT \$3000 (USD \$100) per month per family member" or "living in free prefabricated temporary shelter" (*Enforcement Rules of Housing policy for 921 Post-Reconstruction Areas*. Republic of China, 921 Earthquake Post-Disaster Recovery Commission, Executive Yuan.). Most people chose to receive a monthly rent allowance and about one third decided to live in temporary shelters. To rebuild their home, there were also options including: "urban regeneration", "same-site, same scale" and "relocating rebuilding" (*Enforcement Rules of Housing policy for 921 Post-Reconstruction Areas*. Republic of China, 921 Earthquake Post-Disaster Recovery Commission, Executive Yuan.). The Eco House was targeted on the "same-site same-scale" option which is more suitable for those who intend to rebuild their single house on the existing site. The reconstruction works are different from case to case and region to region, unlike group housing in urban areas, their reconstruction is often slowed by the external factors such as the negotiation for consent from all unit owners. For the remote village that property issue is relatively simple; the main cause of slowing is then the individual financial problem. Considering that the victims in remote areas were struggle to earn basic living before the quake, the recession of the regional economy and following unemployment forced the victim to live in the temporary shelter without the ability to move out.

Although the temporary shelter was offered free initially, the cost of renting land will become the burden as time goes by. The example of Da-Ai temporary shelter village in Puli County illustrates the problem. The site was rented from the Taiwan Sugar Corporation at 10% proclaimed land value for yearly rate, which is NT \$60,000,000 (around USD \$2,000,000) to distribute to its 700 unit owners,

about NT \$100,000 (around USD \$3,000) per year for the land rental. This number goes up when one unit moves out, since there is one less unit owner to share the total land rental. The demolition of temporary shelters also revealed another issue of its inefficiency in economic terms: As the metal shack was constructed in a way that made recycling difficult, the temporary shelter are demolished without considering reusing. There are two possible ways to address the above issues: the first is to redesign the short-term emergent shelter with the capability of making it possible to reassemble and restock them for future reuse. Another is to improve the quality of the temporary shelter, transforming them into an emergent permanent housing, which is one of the goals of the project Eco House. In fact the intention was to formulate a feasible option that could move some of the budget of temporary shelter toward the cost effective and fast construction of permanent housing that serve the same purpose for serving victims in the emergency context. The Eco House proved through its low cost and short-timeframe construction that emergency permanent housing is a possibility in the post-reconstruction context. With research on availability of material on-site and incorporating passive design of regional micro climate to further enhance building performance and reduce the cost, the Eco House can be considered as a prototype to formulate regional sustainable housing reconstruction option in emergency context.

5.2 Revitalizing the disaster area.

The simplified structural system and construction process not only shortened the time frame of construction but also indicated possibilities for incorporating collaborative-build methods in reconstruction work. The collaborative-build method is a type of practice that combines community revitalization and reconstruction work. Typically, experienced staff would lead community members to participate in the project from the initial design phase to the completion of construction. This method of design and construction is ideal for remote disaster areas, where affordability and resident participation is much needed. Cost is without doubt the primary concern for the victim households since the earthquake not only took away lives and properties, but also led to collective unemployment in the disaster area. However, as we learned from the reconstruction process, real recovery should include physical as well as psychological aspects, and in some cases the latter is even more crucial. High suicide rates in disaster areas indicate that distress and depression have exceeded the threshold for some surviving victims and hence revitalizing the region has become a very pressing task. The collaborative-build method employed is an ideal solution in this regard. The great deal of coordinated work involving victims will restore the vitality for the community and help them look forward and move on to new lives. In addition, it also lowers the cost and temporarily solves the unemployment problem.

5.3 Off-grid energy policy.

The aborigines are the most disadvantaged ethnic group in Taiwan's socioeconomic structure. Most of them live in mountainous rural areas and make their livings through traditional ways: farming, hunting and fishing, all of which rely directly on natural resources. Traditionally, they managed their territory and natural environment in sustainable ways. However, as a result of industrialization, their territories are being isolated and their communities marginalized, which forces them to earn a basic living from the touring industry. The earthquake also means the recession of the touring industry, leaving the surviving victims in financial crisis. Considering the sustainable life style that demand minimum electricity use and the fact that the traditional electric grid may not be cost effective in such remote areas, an integration of renewable energy in housing reconstruction seems a feasible solution. As demonstrated in Eco House, a simple hybrid system can provide sufficient electricity for the minimum use of a single family house, if complete with an bidirectional network that provides the capability to store extra generated power and perhaps an supplemental power generator such as motor to provide peak power demand, a simple hybrid system in a community scale may supply the needed electricity all year round for a small scale off-grid village. As suggested in the operation of Eco House, the integration of alternative energy system is ideal way to incorporate the sustainable life patterns of the aborigines and reduce their living costs. For the government it is also an efficient way to provide electricity in remote areas, and hence could be a win-win situation for both ends.

6. Conclusions

The project of Eco House is significant at different scales. At the scale of a single housing project, it provides a practical stage in promoting sustainable technologies such as recycled material, renewable energy and water recycling implementation. The physical demonstration has led to direct success in promoting such sustainable technologies. Through the media coverage and field visits, the project has received praises from government and public for making contributions in sustainable development. At the scale of policy making, the low cost and fast construction as well as the application of renewable energy demonstrated in its operation indicates collaborative solutions for housing reconstruction and off-grid energy restoration in the context of remote disadvantaged communities. The problems emerged from the prefabricated temporary shelter along with the pre-existing social and economic problem for those aboriginal disaster areas indicates an imperative in providing an alternative in housing reconstruction that address their need for the present and future. The Eco House Project successfully incorporates dwellings into their sustainable life style, focusing on reducing the burden for both its inhabitants and the environment. This can be further developed into a more reconstruction prototype for other similar contexts in preparation for frequent natural disasters.

Acknowledgements

The authors are grateful for having opportunities to observe and participate in the process of construction and post-occupancy of project Eco House. The authors would also like to extend their deepest gratitude to Ms. Mei-Huei Chou, General Secretary of Tai Yuen-Huei Cultural Education Foundation, for her full support in preparing this paper.

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CAN NEW CONSTRUCTION TECHNOLOGIES DRIVE A SUSTAINABLE HOUSING INDUSTRY IN RURAL THAILAND?

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Abstract

There are grave fears for the future of Thailand's forests as the construction industry continues to consume forest reserves. With the region's timber harvesting at unsustainable levels, it is the poorest communities that are denied the capacity to build with traditional methods. What effect does this deforestation have on the housing systems used in the rural regions of Thailand? What can be done to improve the sustainability of the new housing types in the region? This paper compares traditional and contemporary Thai housing practices before identifying two research teams working to create sustainable prototypes with either earth or soil/cement walls.

Experimentation with new housing technologies is to be encouraged. However this paper argues that whilst these innovative prototypes offer a technical 'solution' there may be alternatives that offer greater prospects for sustainable development. Masonry construction technologies do not inherently suit tropical climates and further consideration should be given to systems centered on lightweight materials and relevant design principles.

Keyword : Construction technology, Housing, Sustainability, Deforestation, Thailand.

1. Deforestation and the Need for New Construction Technologies

Forests continue to be threatened by industrialization, overpopulation and corruption and the warnings of long-term indiscriminant logging have been ignored (Dauvergne, 1997; Global Witness, 2002). Unsustainable management of forest resources is often justified as a byproduct of national development, but it appears to result in personal fortunes for those in power at the expense of the poor (Global Witness, 2002). Warnings of the long-term effects of indiscriminant logging, slash and burn cultivation and the devastating effects of wildfires have failed to initiate significant change in forestry practice.

The Food and Agriculture Organization of the United Nations (FAO) prepares the biannual *State of the World's Forests* report. They recently reported that forests cover nearly half of Southeast Asia's landmass but decreased at an alarming rate over the ten-year period between 1990-2000. Indonesia and Malaysia were losing forest cover at six times the global average. Burma was worse at seven times, whilst Thailand and Cambodia lost forest cover at three times the global average.

Respected international newspapers continue to highlight the destruction of Asia's forests. Australian newspapers have reported that a retired Thai Prime Minister has been implicated along with the Cambodian Government in the illegal logging trade (*The Age*, 24 January 1997). Another suggested that the Cambodian forests would be commercially exhausted within five years and there was little hope for sustainable forest industries (*The Australian*, 9 June 1999). Not all of this activity is legal and newspapers claim that a retired prime minister has been implicated in the illegal logging trade (Baker, 1997). The *Bangkok Post* has reported that the illegal logging industry continues despite the government's moratorium put in place in 1989 (*Bangkok Post*, 1 October 1998).

More recently there has been some discussion that the Thai government might resume logging as a way to reduce debt. In 2001 the state-owned Forest Industry Organization (FIO) prepared to harvest timber from reserves set aside in 1967. Over 30000 hectares of forests were classified as 'economic forests' and made available for harvesting. Furthermore the FIO wants the existing regulations changed to harvest an additional 105000 hectares (*The Nation*, 30 July 2001).

Attempts to regulate the timber trade have failed to make Southeast Asia's timber industry sustainable. This poses a significant problem for the huge numbers of communities, particularly those in rural areas, which have traditionally used timber for construction. Thai government policies recognize that stable rural communities are an important way to reduce migration to the overstretched cities. However it is clear that the demand for new housing in rural areas must be met and must be supported with access to new construction materials. What are these construction materials likely to be and can they be used to build low-cost houses in a sustainable manner?

This paper compares the applicability of various construction materials and bundles together concrete, earth and soil/cement bricks as mass or *masonry* technologies and timber or fibre-cement panel or partitions systems as *lightweight* systems.

2. From Lightweight to Masonry Construction: A New Vernacular Emerges

As part of a larger research program the author has selected a village in northeastern Thailand for closer analysis. *Ban Rai Kok* (the village on the small hill) is typical of the rural villages in northeastern Thailand and shares many similarities with the region's common rural housing typologies. This research was conducted between 1998 and 2003 and has allowed the author to undertake a detailed analysis of the ways vernacular housing responds to the effects of globalization – in particular the changes brought on by the introduction of new construction materials.

Timber has long been the preferred construction technology for housing in Southeast Asia as subsistence lifestyles required communities to build with materials freely gathered in the forest. These traditional housing types developed in response to local materials, conditions and expertise. No design or construction professionals were employed to build houses and the owner coordinated production with assistance from neighbours and family. This system ensured that the cost of housing was measured in terms of labour rather than the purchase of materials (Charernsupkul, 1996; Srisuro, 1997; Sutthitham, 1997). Nowadays, as rural villages respond to external influences, housing production has been transformed. Industrialized construction materials play a larger role in the housing process and specialist builders are required to complete production.

Ban Rai Kok village illustrates how this transition may occur. The most obvious of these changes can be seen in the following two examples, one house is nearly fifty years old and built from timber, and the other is only five years old and built from concrete.

Fig.1 shows the house of the 'head man' in the village. The walls have been built with sawn timber, the roof is made with corrugated iron, the windows are unglazed and the house is unpainted. The house retains a spatial pattern typical of the traditional houses in this region. It has been built on stilts so that the family can spend the daytime under the house where it is much cooler. The enclosed space on the level above is the private space where the family sleeps. This upper floor cross-ventilates particularly well and the cooling breezes can pass easily through the house.



Fig.1. A traditional lightweight timber house in Ban Rai Kok village

The house shown in Fig.2 has been built with concrete block and a type of fibre-cement roof sheeting common in Bangkok. The window frames, shutters and front door have been mass-produced and purchased from a shop rather than made by the owners on-site. Its industrialized construction technology marks this house as one of the newest in Ban Rai Kok and the house works in a different way to the traditional houses in the village. There is no cool sitting space below the house and the internal walls reduce the potential for cross-ventilation. The community recognizes these newer houses as being much less comfortable to live in than traditional types. However cost constraints, and the fact they are seen as be 'modern', makes them a desirable commodity.



Fig.2 A contemporary masonry house in Ban Rai Kok village

Concrete has become the mainstay of new rural housing production, not just in this village but also throughout many developing regions in Southeast Asia. But there are drawbacks to the use of concrete. It is the belief of Population and Community Development Association (PDA), a Thai non-government organization, that concrete houses are too expensive for rural communities and that low-cost and sustainable alternatives must be found. Professor Bernard Lefebvre at the Asian Institute of Technology (AIT) in Bangkok shares a similar concern, and he too aims to develop low-cost prototypes. These teams are working independently to test alternate construction technologies and both have identified the region of northeastern Thailand on the Khorat Plateau as the place to build prototypes.

3. Housing with Earth

The CBIRD (Community Based Integrated Rural Development) village is located 350 kilometers northeast of Bangkok and close to Cambodia's northern border with Thailand. This village, in the poorest region of Thailand, was initiated by PDA in the 1990's with funds from international aid agencies. PDA's administrators are in the process of developing a range of low-cost prototype houses. To reduce timber use they have begun to develop houses with walls made from rammed earth and their research has been informed by 'appropriate technology' theory and practice as proposed by Schumacher in his seminal text 'Small is Beautiful' (1973). The value of appropriate technology is its 'emphasis on low capital costs, local materials, grassroots decision making, collective rather than individual efforts, user control, community empowerment and economic self sufficiency' (Hamdi, 1991).

Earth walling systems are virtually unknown in Southeast Asia but are popular in parts of Africa, the Middle East, Mexico, The United States, and Australia. In these places people place a high value on the wall's ability to insulate the interior of the house from the heat and cold outside. The main advantage of this system is that soil is almost free and therefore there is no need for the homeowner to spend money purchasing timber or concrete blocks. The labour component is higher than concrete construction but this cost increase is negligible when the wage costs are low in developing nations. Once the earth walls have been constructed the rest of the house then can follow the styles of the concrete houses common in urban areas (Fig.3).

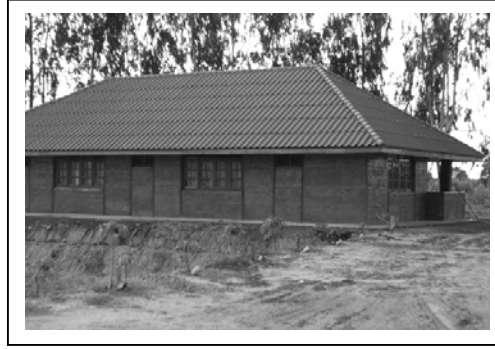


Fig.3 A rammed earth prototype house built at CBIRD village

The PDA research team has found that their rammed earth prototype houses have proven to cost more than conventional concrete houses. This should come as no surprise since prototypes tend always to be more expensive than mass-produced items. Despite this it appears likely that streamlining alone will not be enough to reduce costs. Rammed earth walls are thicker and heavier than concrete walls and require stronger footings. In an attempt to be more efficient the construction team used earthmoving equipment, tip trucks and compressors to compact the soil into the formwork. There are high costs associated with this machinery and the advantages of low wage costs dissipate with mechanization. Furthermore formwork is costly to maintain because the compaction disfigures the panels.

4. Housing with Soil/Cement

A research team from the Asian Institute of Technology (AIT) in Thailand has also been working to construct low-cost houses. They have built prototypes in Thailand, Indonesia, the Philippines and Laos – arguing that new construction technologies hold the key to sustainable production. Walls are made from soil/cement blocks similar in size to a common house brick. Window and door frames, roof tiles and structural members are made from concrete poured into a series of specially designed moulds. Only the doors and windows use timber (Fig.4).



Fig.4 A soil/cement prototype house built at the Asian Institute of Technology in Bangkok

In some respects the AIT prototypes offer a more sympathetic package than the CBIRD alternative. Unlike the prototype at CBIRD village the AIT models are double storey and based on a simple square plan in the manner of the traditional houses in the region. The project leader, Professor Bernard Lefebvre, claims that costs are up to one quarter less than concrete block construction and are significantly cheaper than the rammed earth system. Soil/cement blocks 'work' in a similar way to the common concrete block are a similar size, modular, easily transportable and do not require specialist machinery. The similarities with conventional concrete block construction means that rural communities see this system as less confronting than rammed earth.

5. Reviewing Masonry Construction Technologies

5.1 Problems with Masonry Construction.

Easton (2000) suggests that the only factor limiting the widespread acceptance of rammed earth construction is the perception that it is not 'modern' enough. This may well be an important factor to consider – however it does not acknowledge the limitations brought on by the climate, nor the way the community operates on a social level and the way the local housing culture operates. This section outlines a series of problems associated with the use of masonry construction. Four reasons against the use of masonry construction have been identified. Firstly, the liveability of these houses is compromised by the way these prototypes retain their heat. Secondly, the masonry houses generally require air-conditioning to remain comfortable and there is a range of problems associated with this. Thirdly, traditional living patterns must change, as people don't have any semi-outdoor living space under masonry houses. The remainder of this section will review these problems in further detail.

5.2 The Problem of Heat Retention.

In tropical climates, such as those on the Khorat Plateau, the high heat loads generated during the daytime must be addressed in order to make these houses liveable. Masonry walls built from 'mass' construction systems, whether they are soil/cement blocks, rammed earth or the ubiquitous concrete block, have the capacity to absorb heat and then radiate it again. This is a benefit in many parts of the world, in particular the regions with high daytime temperatures and cold nights such as the desert regions. However the Khorat Plateau, reaching from northern Cambodia, through northeastern Thailand into Laos, is known for some of the hottest temperatures in Southeast Asia. For most of the year, and particularly between March and May, daytime temperatures regularly exceed 35 degrees and overnight temperatures remain above 30 degrees. The cooler seasons are humid, hot and wet with temperatures rarely dipping below 30 degrees.

In critiquing these prototypes a significant factor to consider is the *diurnal* variation of the temperature inside the house. The diurnal variation measures the difference between daytime and night-time temperatures. A low figure (less than 5 K or 5°C) indicates that there is little temperature difference between day and night. This is typically the case in tropical climates, such as on the Khorat Plateau, where the diurnal variation of temperature is low. On the other hand a high diurnal variation occurs in climates where daytime temperatures are high but the nights are cold – such as in desert regions.

Fig.5 shows that the temperature inside both masonry and timber houses on the Khorat Plateau share a similar peak temperature but that this occurs at different times of day. Whereas the peak temperature for timber houses occurs early in the afternoon it occurs later in the day for masonry houses. This discrepancy is due to the time it takes for the different wall types to absorb heat. Masonry walls absorb heat at a greater capacity than timber walls and this heat stored and then radiated back into the house in the latter part of the day. This capacity to retain heat sets the masonry houses apart from the timber houses that lack the ability to trap and then radiate heat.

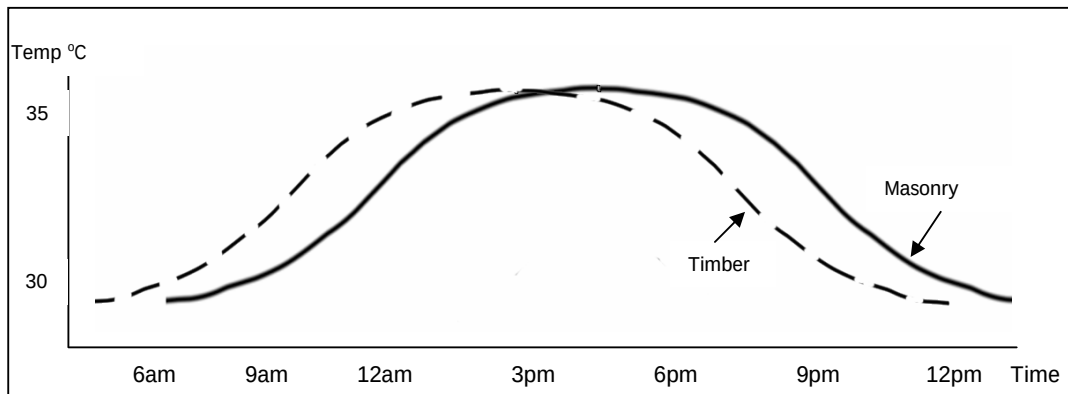


Fig.5 Temperature measured against time for the interior of masonry and timber houses

However retaining the daytime heat is not an advantage in tropical climates. With a low diurnal variation in temperature (the night-time temperature is only slightly less than the day) there is no advantage in having additional heat from the walls radiate into the house. This is particularly so as this radiant heat is retained in the house whilst it is occupied – typically later in the day as the residents are eating and sleeping. On the other hand an advantage for timber houses is that the highest heat loads occur earlier in the day when the residents are either at work or in the well-shaded and ventilated space below the house.

The bottom line is that lightweight houses are ideal for climates with a low diurnal variation and have been developed over many generations specifically to address the tropical climate on the Khorat Plateau. Timber and bamboo walls can't absorb heat to any significant degree and cross-ventilation proves to be an effective method to cool the houses in the evening. By contrast masonry houses – and rammed earth and soil/cement prototypes fit in this category – are less well suited to this climate and their 'bungalow' style design typically makes them stifling hot.

5.3 People Respond to Poor Design with Air-Conditioning.

Without good cross-ventilation the effects of these high heat loads are further magnified. The internal walls make the masonry houses work in a contemporary sense and support the roof. However these walls obstruct cooling breezes from flowing through a house and diminish the effects of cross-ventilation. Furthermore the windows used in these masonry houses are particularly expensive and must be purchased from a shop rather than made by the owner. In most cases it is cheaper to continue building the wall rather than punctuating it with windows, and again this further reduces possibilities for cross-ventilation.

In the urban areas the wealthy and middle classes address the heat with air-conditioners. In Thailand's status driven culture a consumptive and technologically driven system of modernization tends to prevail. But there are ramifications should this attitude remain unchecked. A reliance on air-conditioning has widespread implications for any region's energy consumption, not to mention significant social and environmental costs. One example of this concerns a venture by the Electric Generating Authority of Thailand (EGAT) and the Petroleum Authority of Thailand (PTT) to purchase gas from offshore platforms in the Andaman Sea. This gas is pumped across Burma in pipelines to Thailand and fuel electricity turbines (Unocal, 2002).

Although Unocal claims that production brings benefits to those along the pipeline, non-government organizations remain critical of the process. Gas is pumped through a network of pipes built by slave labour – people classified by Burma's regime as dissidents (Asian Human Rights Commission, 2001). The pipeline cuts through pristine rainforests and threatens wild elephants, tigers and rhinoceros. The Burmese military, subcontracted to provide security, has forcibly relocated many thousands of indigenous people (Asian Human Rights Commission, 2001; EarthRights International, 2000, 2002; Environmental News Network, 2002). The winners in these types of deals are typically multinational companies (Total, Texaco, Nippon and Premier) and well-connected middlemen. Precious little, or none, of the profits ever make their way to fund local projects such as schools or hospitals.

The nation's other sources of power are also problematic with many subject to public outrage and international criticism. Further expansion of these facilities has political, economic, environmental and social consequences. Unchecked consumption is unsustainable. The bottom line to consider here is the devastating impact that would occur if the whole Thai population was to live in air-conditioned houses.

5.4 Living Patterns are Forced to Change.

Traditional timber technologies suited the living patterns developed by the residents. Typically residents sat between the posts under their timber house during the hotter parts of the day and only moved upstairs at night-time. This pattern allowed them to shield themselves from the sun by remaining under the house during the day and to take advantage of the cooling breezes flowing through the house during the night. This housing culture evolved over many generations and, until recently, has been a sustainable way for these communities to develop (Sutthitham, 1997).

The introduction of masonry construction technologies requires new types of living patterns. It is particularly expensive and difficult to support masonry walls on columns, and therefore it is impractical to maintain this semi-outdoor living space below the masonry house. The result of this technological change is that living patterns are also forced to adapt and change. However the disadvantage for residents is that they no longer

have a cool place to sit during the heat of the day. The residents of new masonry houses tend to find it too uncomfortable to stay inside their houses during the day and are more likely to go and visit friends and relatives living in traditional houses. Others build lightweight pavilions to use during the day – but it is rare to see anyone living inside masonry houses during the day.

6. In Support of Lightweight Construction

6.1 The Advantages of Lightweight Construction.

The majority of residents at Ban Rai Kok understand the clear advantages of lightweight houses (O'Brien, 2004). Lightweight systems have some key advantages over masonry alternatives and this section identifies these in further detail. The first recognizes that lightweight systems can closely follow traditional formats and are more in line with the regional housing culture as it has been developed by previous generations of builders and designers. They assist the community to maintain its social fabric by providing comfortable and recognizable places for the residents and their family and friends to gather. Secondly there is an increased capacity for lightweight houses to remain comfortable because they do not absorb heat to the same degree as the masonry alternative. The final advantage for lightweight systems is that they are designed in such a way that they can more easily cross-ventilate and remain comfortable without the need for air-conditioning systems.

6.2 Build the Community a Cool Place to Gather.

Access to a cool place to sit during the day enables residents on the Khorat Plateau to remain comfortable without resorting to air-conditioning. When houses are built on stilts, as the lightweight types are, they retain a semi-outdoor living space under the house that is ideal for this purpose. However if the houses are built on a concrete slab with masonry walls built from the ground level up there is no capacity for this semi-outdoor living space below the house. These residents are either forced to endure the heat inside the house (and they rarely see this as a viable alternative) or they go elsewhere (typically to a friend or family member's timber house). In many other cases they choose to build their own separate pavilion from lightweight materials – scrap timber or bamboo and thatch – close by their house. This pavilion comes at an additional cost and further strains the resources of these poorest communities. The cheapest option is for the one house to include both spaces for day and night-time living, rather than forcing the residents to have separate buildings for each part of the day.

6.3 Increase Comfort Levels By Using Materials with Low 'R' ratings.

Table 1 compares the 'R' rating for various types of construction materials. The 'R' rating measures the ability of a construction material to resist the transmission of heat. Materials with a higher capacity to resist heat transfer, including rammed earth, soil/cement blocks and concrete block, are less suited to tropical climates. Alternatively the materials with lower 'R' ratings transfer heat quickly – cooling quickly in the evening when the resident is sleeping. In this case enhanced liveability occurs when materials with lower 'R' ratings are used. Table 1 shows that lightweight materials (hardwood timber boards, pine weatherboards and fibre cement sheet) are the most applicable construction materials for non air-conditioned buildings on the Khorat Plateau.

Although pine weatherboards are not used in this region they have been included in this study because they should be recognized as a potential alternative to the status quo. Sustainable timber industries are becoming commonplace in the developed world and the potential for this type of industry to be introduced into Thailand should not be discounted. Pine plantations grow quickly and the timber can be used to make houses that suit the climate. On the other hand fibre cement sheets are already available in Thailand. Although this material is not popular, perhaps as it is not seen as a high status alternative, it should not be discounted as a long-term prospect. It has an excellent 'R' rating for this climate and is an inexpensive alternative. Further research should be conducted to identify the barriers that exclude these materials from widespread use.

Table 1. 'R' ratings for wall construction materials

Material	'R' rating	Comfort rating
Concrete block (90mm)	0.14	low
(190mm)	0.19	low
Rammed earth (300mm)	0.40	poor
Soil/cement (100mm)	0.25 (av.)	poor
Timber boards (19mm hardwood)	0.10	acceptable
(19mm softwood)	0.17	low
(12mm pine weatherboard)	0.09	acceptable
Fibre cement sheet (6mm)	0.02	high

Adapted from *Australian Standard 2627 – Thermal Insulation of Dwellings* and
CSIRO – Building Innovation and Construction Technology Notes No. 11 June 2000

6.4 Good Design Takes Advantage of Cross-Ventilation.

Traditional timber houses on the Khorat Plateau were the result of many generations of builders knowing exactly how to make houses to suit the climate. The cooling effects of cross-ventilation were recognized and employed to make the houses liveable. The semi-outdoor living room used during the day and the open plan enclosed parts of the house emerged as a direct response to the social needs, available construction materials and climate. From this a sophisticated housing culture emerged.

Now that the external forces detailed earlier in this paper have shattered this housing culture another needs to be created. Many of the traditional patterns of building need to be retained, as a wholesale adoption of imported technologies and patterns is problematic. A primary factor to consider is the need to formulate a design approach in such a way as to take advantage of cross-ventilation since it is easier to cross-ventilate a lightweight house – particularly one without internal walls.

7. Conclusions

This paper has investigated two attempts to build low-cost housing prototypes on Thailand's Khorat Plateau. These attempts are based on the premise that timber construction is unviable due to the effects of deforestation and that there is a shortage of low-cost housing. For this reason alone experimentation with new housing technologies is to be encouraged and new construction technologies must be developed to address the shortfalls that occur when natural resources are depleted.

However there are a number of complications that emerge when this experimentation takes place. New construction technologies cut across traditional modes of production and consequently raise questions over housing affordability. Traditional methods for keeping houses cool have been compromised and new methods of building reduce the liveability of houses. New masonry technologies, whether they are concrete, rammed earth or soil/cement, are ill suited to the tropical climate. Attempts to make these houses comfortable with air-conditioning places the region's resources under further pressure. The energy required to power air-conditioners has serious environmental and social implications. The poor cannot afford to buy air-conditioners and they cannot afford running costs. Furthermore, the traditional patterns of living that shape these rural communities are threatened by these strategies, and there is evidence that this is not a desirable outcome. This paper argues that lightweight construction systems hold the key to sustainable housing systems. Coupled with careful design strategies – informed by particular traditional practices – new types of low-cost housing can be developed to enhance liveability without further exacerbating the environmental costs.

Acknowledgements

The author would like to acknowledge the assistance of Population and Community Development Association and Professor Bernard Lefebvre from the Asian Institute of Technology. Funding for this project has come from the Sir Edward Weary Dunlop Fellowship administered through Asialink.

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PUBLIC HOUSING SCHEMES FOR THE POOR IN KERALA: RECOMMENDATIONS FOR SUSTAINABLE HOUSING.

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Abstract

The housing situation in Kerala is quite different from other parts of India. The public housing schemes in Kerala were showing greater performance in terms of magnitude in investment and physical achievements, thus considerably reducing the housing gap. Official estimates also predict that if the present trend in house construction continues, by the year 2006 all people in Kerala will have their own houses, although closer inspection of the current housing scenario in Kerala reveals another side to this overall picture. Despite many positive advances, visible slum-like areas still occur in human settlements in rural parts of the state and many inhabitants are deprived of basic facilities like drinking water and sanitation. The efficient supply of housing is closely associated with policies and delivery systems, infrastructure services and the availability of affordable building materials. This paper reviews the present housing situation of the poor in Kerala with an analysis of the success and failure factors of public intervention in housing. The paper also gives some recommendations to create affordable and sustainable habitat through community participation and cost effective, environment friendly construction techniques.

Keywords : Sustainable habitat, CEEF technology, Conceptual framework, Low- income housing.

1. Introduction

The inadequate housing conditions of an estimated one billion people in the world urges the need for scaling up housing supply and as such become a main focus of policy debate (UNCHS, GSS 2000). Developing countries suffer the most acute housing problems. Rapid population growth, increased urbanization, relatively low investment in housing and widespread poverty has created serious shelter problems in India. Based on the tenth five-yea plan (2002 – 07) estimates, India has a shortage of forty one million housing units. The housing situation in Kerala, situated on the south- west coast of the Indian sub continent differs from the other states. Official estimates predict that if the present trend in house construction continues, by the year 2006 all people in Kerala will have their own houses (The Government of Kerala, Economic Review 2003).

A closer inspection of the current housing situation in Kerala reveals another side to this picture. The housing gap (figure1) is calculated as the difference in number between households and housing units. The number of housing units includes temporary houses, requiring changes to be suitable for permanent occupation. The housing gap also does not take into account those people living in un-habitable houses. Hence the actual housing problem is much bigger than that projected by the official reports. The huge magnitude of private and public investments and Governmental assistance so far provided in the housing sector would have been sufficient enough to solve the housing problems of all the socio- economic groups of the State. Despite many positive advances, visible slum like areas occur in human settlements in rural parts of the state with many inhabitants still deprived of basic facilities

like drinking water and sanitation (Gopikuttan, G 2002). This contradictory situation urges the need for a closer evaluation of the various factors preventing the rural poor from satisfying their housing needs even in the midst of increased public interventions and an apparently favourable environment.

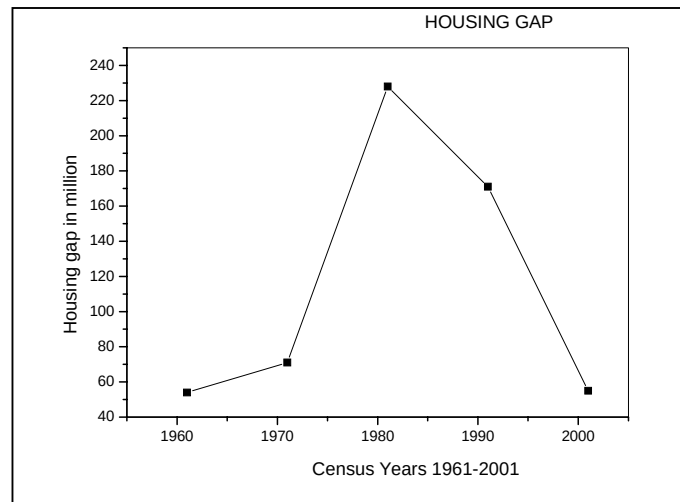


Figure 1

The ensuing text presents a conceptual framework and review of the present housing scenario of Kerala. This paper also discusses the four major public housing schemes for low-income households in Kerala: One *Lakh Housing Scheme (OLHS), Subsidized Aided Self - Help Housing Scheme (SASH), Indira Awaas Yojana (IAY) and Maithri Housing Scheme on the basis of this framework. The discussions and analysis are based on personal interviews with the beneficiaries of the different housing schemes, other low-income households, officials engaged in housing activities and available literature.

2. The Conceptual Framework

Sustainable-affordable habitat can be seen as a conceptual framework achieving and maintaining sustainability through housing development by balancing the needs of social progress, economic growth and technology along with conserving and protecting the environment and natural resources. At a strategic level, sustainable development principles and approaches should be integrated into policy development and planning processes.

The proposed framework consists of two equally important phases. The first phase; Sustainable – affordable housing, analyses the housing issues based on various criteria that correspond to the different aspects of sustainability. The second phase; Strategies for Sustainable - Affordable Housing, is intended to assist in formulating policy recommendations supporting sustainable- affordable habitat utilising the criteria set out in phase one as guidelines. The efficient supply of housing is closely associated with policies, land delivery systems, infrastructure services, finance, construction industry and building material supply. The existence of inappropriate regulations and an inefficient planning system can wreck havoc with housing supply for the poor majority (UNCHS- GSS 2000). Therefore an efficient policy framework is essential to consummate the concept of sustainable – affordable habitat. Sustainable habitat embraces four closely inter-dependant aspects; socio-cultural, economic, technological and environmental. The social and cultural factors determine the primary requirements for housing. The financial capacity or affordability to an individual is decisive in changing a concept into a sound reality. Technology acts as a catalyst to help in realizing this concept by providing affordable options suiting the individual requirements and changing circumstances. Besides accomplishing present demands, the needs and wishes of future generations should also be taken into account. Environmental sustainability takes care of this aspect. Protecting the environment is the basis for sustainable development.

* Lakh- 100,000

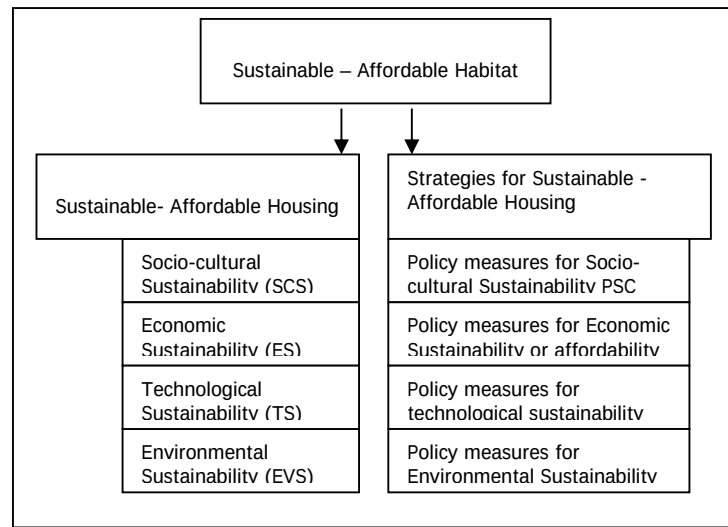


Fig.2 The Conceptual Framework for Sustainable Habitat

Socio-cultural Sustainability and Policy Measures - An adequate shelter is not only a human right, but also forms a base for human relationships. It helps in the free development of the individual creating a platform to play an active role in the social and cultural life of a community (Springer.S, 2000). Socio- cultural sustainability in housing is focused on housing development that promotes social interaction of individuals and cultural enrichment of a community. The location and type of houses often reflect basic social inequalities. People do not want to live in a house, which stigmatises them as belonging to a low-income class, even if it is all that is affordable to them. Socio- cultural sustainability also aims to reduce the inequality of housing between social classes (Islam. N, 1996). This also affects social relationships, day-to-day living and ultimately opportunities for future generations. The following criteria are identified to analyse housing issues and recommend guidelines to develop socio- cultural sustainability in housing.

Flexibility: The concept of shelter differs from individual to individual depending on culture, tradition, profession and way of living. The flexibility to fulfil the varying needs is thus an important criterion, which requires serious consideration in planning housing development. The design and materials used for a house should correspond to the user's way of living and local building traditions (Christel Ebsen and Bjarke Ramboll, 2000).

Stigmatisation: Housing developments should be able to promote equality among individuals and should not cause segregation of a community based on income, religion or other social criteria. The design, type of building materials used and the location of the houses should not stigmatise the inhabitants but instead facilitate them to take part in community activities, improving social relations and intermingling with others.

Integration of amenities & Services: - Sustainable shelter requires the integration of amenities such as privacy, security, lighting and other basic infrastructure facilities (UNCHS, Habitat II, 1996). At community level, social amenities like schools, libraries, recreation centres, medical facilities and other primary facilities need to be integrated into settlements.

Self-help and community involvement: Community participation should be ensured in the sustainable housing development processes to speed up the growth of sustainable residential neighbourhoods. Self-help housing and the involvement of households in the building process develop a sense of ownership or pride among the inhabitants improving their self- reliance. The users build houses to suit their needs and hence self-help or a participatory approach in housing brings desirable changes that lead to sustainable housing (Eldemery, I. M. 2002). Turner' laws on housing are also important in this context. According to Turner's second law, when dwellers control the major decisions and are free to make personal contributions to the design, construction, or management of their own house, both the

process and the environment produced stimulate individual and social well-being. When people have no control over, or responsibility for, key decisions in the housing process the dwelling environment becomes a barrier to personal fulfilment and burden to the economy (Turner, J, F, C and Fitchereds, R 1972).

Economic Sustainability and Policy Measures - Improvements and developments in society are directly related to economic development, making socio-cultural sustainability closely linked to economic sustainability. They often meet at various points of poverty alleviation. Affordable housing can be said to be economically sustainable only if it satisfies minimum housing requirements without compromising quality. The poor often cannot afford to accept public housing assistance due to the lack of economic sustainability or affordability of the schemes. It should be embedded in an economic development strategy, which strengthens the economic self-reliance of household members. The housing sector is employment intensive; it generates employment during the construction period and also during its life for proper maintenance providing employment opportunities for skilled as well as unskilled labour (Glaeser, B 1995 and Tiwari, P 2001). Policy measures for economic sustainability should be formulated by considering the following criteria for economic sustainability in housing.

Affordability: - The affordability to the individual household must be given prime priority before planning any housing development programme. The most important financial resources are the actual and potential savings of the inhabitants out of their income. This probably represents between 10 to 15% of all personal incomes (Turner, J, F, C 1976). Housing programmes can be linked to employment or income generation programmes enabling the poor to afford and maintain their own houses (Bhattacharya, K, P 1994).

Pre-requisites or Basic requirements: - Access to land with infrastructure is a pre- condition for adequate housing and should be given due importance (Bhattacharya, K, P 1994). Houses cannot be built and managed or maintained without resources, infrastructure and land to build on. The economic sustainability of housing is, of course, a function of the value of these resources and the resulting costs in the way, which they are employed (Turner, J, F, C 1976).

Minimum housing needs: - Affordable housing can be said to be economically sustainable only if it satisfies minimum housing requirements without compromising quality. It should be able to provide basic facilities and amenities essential for the well being of the inhabitants demanding minimum operational and maintenance costs in the long run.

Technological Sustainability and Policy Measures - Access to affordable building materials is one of the main constraints on the poor to provide adequate housing for themselves. Besides the escalation of building materials costs, crucial environmental concerns due to the intensive exploitation of natural resources for general construction and other housing development activities, urges the need for alternative technological options. Alternative materials, methods and techniques of construction replacing conventional building technology can reduce the depletion of natural resources and simultaneously offer considerable energy savings. This framework identifies technological sustainability as a combination of sustainable – affordable building materials and cost effective and environmental friendly technology (CEEFF). Sustainable-affordable building materials are those, which are environment friendly, less energy intensive, traditionally used, locally available, and in plenty. The technology needed for the development and application of these building materials can be referred to as CEEFF technology. It should be capable of being produced locally, using unskilled labour, using available materials, and should not require heavy initial investment. Policy measures for technological sustainability should be formulated based on the guidelines derived from the analysis using the following criteria.

Sustainable construction: Environmental friendly construction techniques should address resource limits of our environment through the efficient consumption of non-renewable resources, minimizing the impact of waste materials and pollution by utilizing appropriate technologies. The primary objective is the development of alternative technological options satisfying the requirements of sustainability.

Technological feasibility and flexibility: Technological innovations should be simple and accessible to the poor. It should primarily make use of locally available and reusable materials utilizing a local work force.

Social acceptance: Technology should satisfy the needs and requirements of inhabitants as well as strength and durability criteria. It should be socially acceptable and economically affordable also.

Environmental Sustainability and Policy Measures - The main aim of sustainable development is to focus attention to social development and its consequences for the environment. Environmental sustainability is the most important concept of sustainability; it takes care of the demands of future generations. If development along with the use of natural resources is not sustainability oriented, changes in the environment and ecology will eventually outstrip technological developments. In order to be sustainable, economic development and social change should retain ecology and improve potential resources for future generations. Many environmental problems often originate from lack of development and environmental degradation hence ultimately leading to poverty. Overall, the concept of sustainable development suggests a potentially positive relationship between socio-economic development and environmental sustainability (Veron, R 2001). Positive environmental changes generate economic empowerment, enhance social capital and build institutional capacity. The construction industry is involved in activities, which adversely affect the environment through the over exploitation of non-renewable resources. According to the World watch Institute, building construction consumes 40 % of raw stone, gravel and sand; 25 % of virgin wood; 40% of energy; and 16% of water used annually worldwide (Dimson.B, 1996). Construction activities have stripped topsoil; destructing natural topography resulting in problems like erosion, land slides also causing detrimental effects to local hydrology. It also contributes to the depletion of natural resources and pollution of the environment by the emission of dust, debris and toxic gases as by products of the building process. Good environmental performance is important to mitigate the effects on climate change and the depletion of resources. Policy measures for environmental sustainability should give priority to achieve the following objectives.

Conservation of resources: Sustainable habitat should integrate alternative solutions for renewable energy, reuse of water and land conservation.

Infrastructure facilities: The development of an adequate infrastructure base is a requisite for sustainable habitat. Infrastructure can be divided into two components, social infrastructure and physical infrastructure. Social infrastructure refers to; educational and health care facilities. Physical infrastructure includes; water supply, sanitation, drainage, transportation, and solid waste management and land management. The provision of physical infrastructure must be seen as a prerequisite to achieve sustainable human settlements and to meet the basic human needs (Choguill, C, 1996).

Waste management: Strategies should include measures for the proper management of household as well as construction wastes polluting the environment. The processes involved in the provision and use of housing have a significant role in the contribution of solid waste. Reducing material wastage has several benefits. It reduces global material consumption and in the long term, the amount of demolition waste. It also reduces construction costs, making houses more affordable. When properly done, recycling waste as building materials is a convenient way to reduce the environmental impact of the construction industry (Agenda 21 for Sustainable construction in developing countries).

The succeeding literature will be analysing the public intervention in housing and reviewing the housing scenario of Kerala based on this conceptual framework.

2.1 Socio- cultural Sustainability

The public housing schemes of Kerala are based on the National housing policy. Even though the schemes allow flexibility to accommodate regional requirements, this is not reflected very much in the state schemes. The One Lakh Housing scheme-OLHS (1972) was the first scheme implemented by the state government. It was designed uniformly for the whole state without taking specific geographic or climatic considerations and varying requirements of the proposed inhabitants in different regions into account. IAY (1985), a centrally sponsored scheme, was without a prescribed type design. The plinth area of the houses was restricted to be around 20 square meters. The beneficiaries were able to design their houses according to their preferences keeping in view of the climatic conditions, community perceptions and cultural attitudes. Even though it provided flexibility in planning for the beneficiaries, it was not able to consider local material and wage structures making it unsustainable and less affordable. The Mythri scheme (1996) recently implemented by the State Government also provided flexibility in planning. But the beneficiaries were not able to take advantage of this criterion due to limited access to affordable technology and present strategies for public housing schemes. SASH (1983), showed a better example by providing flexibility in design and at the same time controlling beneficiaries by involving voluntary agencies in the building process. Type designs for this scheme were prepared

considering the socio- economic and climatic conditions of Kerala, the requirements of target groups, and facilities for future expansion etc. The beneficiaries were also given freedom to alter the designs or adopt new designs to suit their needs with prior approval.

Even though, the OLHS could create a massive movement within the context of low income housing in Kerala involving the entire state, it failed to create a sense of pride and ownership among the beneficiaries, as they were not directly involved in the building process. Even after thirty years, the beneficiaries of this scheme still do not own the houses mentally and are of the strong belief that the Government should do timely repair and maintenance. This indicates their increased dependence on the government rather than improved self-reliance. Socio-cultural sustainability in housing also urges the need for equal participation of different groups of people within the society. In OLHS, houses were constructed in a clustered manner by acquiring land in all the panchayats throughout the state. The type designs and the grouping of houses practiced for this scheme, later proved a failure as it stigmatises the beneficiaries as those who belonging to 'One lakh-housing colony'. The other three schemes were able to overcome this problem by involving the beneficiaries in the building process. The interviewed households belonging to SASH, IAY and Mythri showed more personal attachment to their houses than those of OLHS due to their involvement.

The integration of amenities and services is an important aspect of sustainability, which should be treated with sufficient priority along with the provision of shelter. But it seems that the public housing schemes do not give the deserving importance to this criterion. Most of the housing schemes in Kerala consider the financial assistance given as equivalent to the provision of shelter; proper priority is missing in ensuring the basic facilities. In majority of cases, the poor are unable to complete their houses within the limited assistance and give priority to providing a roof over their heads rather than sanitation and water. All these reveal that the present strategies of housing assistance and housing policies are insufficient in realising a sustainable habitat or a healthy living environment.

2.2 Economic Sustainability

The majority of the present housing schemes for the poor in Kerala are either partially or fully subsidized schemes. Even though the housing problems arise mainly as a product of poverty, mere financial assistance is not sufficient to help the poor. A household, who spends nearly all their income for food, often does not have savings. Therefore they find it difficult to build a liveable house with the partial assistance alone. The affordability to a household must be given due consideration before planning any housing development programme. Most of the present public housing schemes (IAY, Mythri, SASH) in Kerala insist in having the ownership of a minimum land parcel (80m²) to get the housing assistance as a criterion for selection. In some of the schemes like Mythri, the beneficiaries also need to pay an initial amount as their contribution and as a pre-requisite. It also insists that the beneficiaries finish the construction of their houses to the plinth level, before getting their first instalment of financial assistance. Thus they need to have some initial money to fulfil the pre-conditions and for starting up. The most deserving households belonging to the lowest strata of society are unable to meet these requirements and hence screened away from receiving assistance. They build small temporary structures or huts adjacent to their parental houses to satisfy their shelter needs. Thus resulting in the clustering of poor quality houses devoid of basic facilities.

A mismatch in perceptions is also evident between the Government and the beneficiary. Although the Government has changed its role to that of 'facilitator', the poor still like to perceive the Government as 'provider'. The partial financial assistance provided by the government is with a view to create an urge in the beneficiaries to construct their houses with minimum basic facilities. On the other hand, the beneficiaries expect complete financial assistance enabling them to construct their houses according to their aspirations using modern materials. It seems that the public housing schemes in the present form is an economic drain or waste of resources. Only through modifications to suit the socio- economic and cultural requirements of rural Kerala, they would contribute to positive development (G.Gopikuttan, 2002).

2.3 Environmental Sustainability

Changes in land use patterns, the exploitation of paddy fields and haphazard growth of housing development activities have created severe problems such as water logging, non availability of drinking water and ultimately the degradation of the natural resources and changes in the micro climate of Kerala. Conserving and protecting the resources need crucial attention for achieving environmental sustainability. Annually more than two million residential buildings are constructed in India apart from the construction of commercial and industrial buildings. Bulk annual consumption of materials like cement (more than 75 million tones), steel (more than 10 million tones) and bricks (more than 70 billion) for these construction activities contribute to the emission of green house gases to the atmosphere (Reddy, B, V, V and Jagadish, K, S 2001). The houses built under OLHS were using locally developed materials like sun dried mud blocks. But none of the housing schemes other than the SASH scheme were able to utilize the innovative materials and cost effective construction techniques. The development of an adequate infrastructure base is inevitable for sustainable habitat. Based on a recent census report of India (2001) 14% of the total population in Kerala has no access to drinking water and 16% has no toilet facilities. None of the public housing schemes have given these criteria their deserving importance. In the case of OLHS, the houses were constructed in a clustered manner fixing a density of 20-houses to an acre of land with 20 % of area utilized for roads and open spaces. Even in this case, the government intervention failed to provide the essential infrastructure facilities sanitary latrines or drinking water. SASH, also failed to integrate the provision of basic facilities with housing. Even though, the construction of sanitary latrine and smokeless chula forms integral parts of the IAY housing schemes, it was observed that in a large number of cases, either the sanitary latrines or the Chula were not constructed due to lack of sufficient funding. The case of Mythri beneficiaries is also not different. Even though the type design prescribed by this scheme includes the provision of a toilet, most of the houses visited were devoid of toilets. All these show the need for improving the strategies for housing provision based on an integrated approach.

2.4 Technological Sustainability

Traditional housing activity for the poor in Kerala was mainly through self- help or on mutual help basis using indigenous materials and local resources. The indigenous adoption of the available raw materials was the dominant feature of traditional constructions in Kerala. But in the early seventies, the intrusion of energy intensive modern materials like concrete, cement, and bricks started replacing these materials and building methods. This generated changes in the employment sector and wage structures making self-help and mutual help construction obsolete and impracticable. Intermediate agents came in between the owner and the builder for all building activities. The poor beneficiaries were also forced to depend on these intermediaries to meet their housing needs. Even though the Government propagated cost effective technologies to overcome the problems of modern construction techniques in providing affordable shelter, the poor households were not able to take advantage of them. This proves the inaccessibility of innovative technology to poor beneficiaries. The houses constructed under OLHS are built with locally developed materials utilizing cost reduction techniques. Even after thirty years they are still liveable, though exhibiting small problems like roof leak, cracked walls, poor flooring which could have been avoided by doing timely maintenance and repair. But it failed in gaining the acceptance of public by creating an inferior appearance. In SASH, type designs were finalized from the result of a real project competition conducted among the building experts and architects all over India. It integrated cost reduction techniques at various stages of the building process. IAY and Mythri on the other hand failed to integrate any policy measures for technological affordability and in this respect both were merely degraded to housing finance schemes.

The rural housing strategy of India is formulated on the observation that housing activity in rural areas is based on land rights and access to resources and not to the cash economy (National Housing & Habitat policy). But the decreasing accessibility to common property resources and indigenous materials is a severe problem in rural areas. With the limited financial assistance, the poor beneficiaries are not able to purchase conventional materials. At the same time they are unable access common property resources due to present changes in the social and economic scenario. Commercial exploitation by various industries has aggravated this situation. Even though the technologies are available to make local materials to suit their needs, the majority of the interviewed beneficiaries are hardly aware of these technology innovations and when aware are doubtful of strength and durability aspects. Besides

lack of money, poor- accessibility to available sustainable resources and lack of awareness of affordable cost effective technology have also become serious obstacles in the path of public assistance to the poor in providing shelter. The following table gives some options for sustainable construction for each phase in the building process.

Table 1. Materials for different phases of construction

Types	Traditional materials	Conventional materials	Sustainable options	Remarks
Foundation	Laterite, Rubble	Laterite, Rubble Concrete	Laterite, Rubble	Laterite, locally available on most parts of Kerala and rubble in highlands only
Building blocks or superstructure	Laterite Rubble Wood Mud	Bricks Concrete blocks	Stabilized mud blocks, Ferro cement, Hollow concrete blocks Building blocks from agricultural and industrial wastes, Straw bale techniques.	Less energy intensive Utilization of waste materials Renewable option
Binder	Mud or clay Lime, Gypsum Cow dung	Cement Lime	Clay or Mud, Lime Pozzolanas from rice husk saw dust, fly ash.	Less energy intensive binders Locally developed, replacing cement in low strength applications
Roofing	Palm leaves, Thatch, Tiles	Concrete, Tiles, AC sheets	Shell roofing, Ferro cement, Filler slab, Micro concrete roofing tiles	Less energy intensive

3. Conclusions and Recommendations

This study reveals a totally different side of the housing scenario of Kerala than projected by the official documents. It proves that the real housing situation can not be evaluated based on numerical data alone. Instead, it requires the viewpoints of beneficiaries also. Hence, a holistic perspective based on several concepts of sustainability, should be established to provide a thorough and comprehensive framework for analysing and evaluating housing issues. This analysis shows that the poor and lower segments in the society very often do not get the necessary assistance for the actual construction and completion of houses. Though the poor manage to get support, projects often fail. None of the government programmes succeeded in fully utilizing the capacities of beneficiaries. The difficulties in feasibility, acceptability and non- awareness of affordable technological options aggravates the housing problem along with other aspects of sustainability. All these factors, clearly point towards the need for an alternate approach based on appropriate technology innovations with improved implementation strategies for realizing the dream of "Housing for All" along with the development of a sustainable Habitat.

Housing schemes should adopt a bottom-up approach instead of a top-down approach to make it as a pulling process rather than pushing. Participatory housing including community building and self-help, infrastructure development like the provision of public services and basic infrastructure facilities can be considered as essential requisites for sustainable- affordable housing. Technology promotion activities, awareness programmes, skill up gradation or training programmes should be promoted through policy initiatives for affordable housing. The formal housing sector finance institutions are not able to reach the poor. Therefore access to housing finance is an important criterion for affordable housing. Strategies and housing policies should facilitate the provision of easy loans, subsidies and income generating activities, which accelerate the repaying ability of the households.

Acknowledgements

When promoting sustainability, and degree to which it is achieved, we must realise that today lies in the past, and tomorrow lies in today." Prof.dr.ir.Ch.F.Hendriks (Sustainable Construction)

The authors would like to pay special tribute to Prof Hendriks and deepest condolences on his sudden passing away and acknowledge his contributions for this research.

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PERSONALIZATION AS A SUSTAINABLE APPROACH TO MASS HOUSING: THE FUNDAMENTAL THEORY

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Abstract

Standardised house design is commonly employed in current mass housing in Malaysia. Although all completed houses are assumed to have met the building and planning regulations, the current renovation works indicate the 'failure' of the design to meet the expectation of users of different backgrounds. This paper propagates "personalization" as a sustainable means of achieving sustainable living environment. Personalization is an act of marking and changing in order to impose control on one's territory. The act ranges from furniture rearrangement, putting up displays to structural modification of living units. "Personalization" is essential and a continuous process in housing because people's physical and psychological needs are ever changing. In mass housing personalization, user participation is central because home environment is an extension of man's existence and personality, hence man is an agent of environmental change and not merely a recipient of environmental influences. Man should be able to manipulate, shape and alter the environment to meet their needs. Instinctively man is directed by his goals in which to achieve this, he has to interact with his physical and non-physical environments. Cultural influences, particularly the multi-ethnic user values are seen as determinant to selecting and changing housing unit's attributes. Although renovation works have been in practice in this country for a long time, there is no proper framework established to accommodate the potentially viable approach for a better sustainable and quality home making. This paper suggests a possible framework of personalization that is prerequisite to developing future house design prototypes.

Keywords : Personalization, User values, Housing units attributes, Personalizable housing design, User participation.

1. Introduction

Sustainable development as defined by World Commission on Environment and Development (Lee 2004) are those that meet the needs of the present without compromising the ability of future generations to meet their own needs. It embraces a long term perspective that looks beyond current problems, searching for durable solutions. It seeks the equitable distribution of goods and services, and addresses the present and future well being of the people. It also posits an environmental perspective, aiming at maintaining and enhancing the natural resource base. Lee (2004) further suggests that sustainable housing is an issue of the long term well being of families that live in it: how it affect their health and welfare; whether the housing encourages or discourages social interaction; or is it managed in a way that combat social exclusion. Sustainability is not only about natural resources, although we must be rational with the use of water and energy (Lee 2004). Generally, studies on housing are addressing a wide range of sustainable issues on housing, such as environmental sustainability, economic sustainability, social sustainability etc.

In the context of this study (Malaysian Urban mass housing), it is suggested that the post occupancy modifications of houses (termed as "personalization") be recognized as an approach for housing sustainability. Personalization is a continuous process to ensure the houses are in the state of "person-environment congruent", a concept that is vital in living environment (Barker, 1968) without which arousal, overload, reactance, and other responses will occur. This approach allows the users to be involved in the design or improvement of their living environment, where public participation is one of the fundamental prerequisites towards achieving sustainable development (UN, 1992:23.2).

Personalization in housing provision may be considered as a "self-provision housing", an approach described by Duncan and Rowe (1992) and Clapham et.al (1992) as the hidden housing arms of the developed countries. In the same token Gosling et.al (1992) posit that house extension is a form of housing development. "Self-provision" concept of housing is a kind of self-help, and these two terms have been used interchangeably by various authors. Self-help is very much referring to Turner's (1978) works in Latin America where the users involved in all aspects of house construction (even in design process) with or without the helps of professionals. In the developed country, self-help (self-provided) housing by moderate and low-income group is commonly found in the form of house improvement rather than new housing construction (Carmon and Gavrieli 1993). Centrality of personalization remains the same in both self-provided new housing and self-provided house modification.

Personalization is about quality home making within the "standard" set by the households themselves. Cost saving is also proven in this method of housing provision (Duncan and Rowe, 1992). Therefore, personalization is a sustainable housing approach that enables users to have an affordable quality houses.

The emphasis of this paper is on personalization in the context of Malaysian urban mass housing, particularly the ready-built houses developed by private developers using the formal mode of provision. Personalization in the context of residential neighbourhood, self-provided new houses in urban or rural areas will not be included in the discussion, though the authors realize the relevance of personalization in these housing aspects. The paper will be divided into two parts. In the first part, suggestions will be made to modify and expand the existing theory of personalization. This theory forms a theoretical framework from which the development of personalization framework for urban mass housing is formulated. Part two is dedicated to suggestions on the fundamental aspects of the proposed personalization framework. The suggestions are based on the authors' ongoing studies on the renovated houses in Johor Bahru, Malaysia.

2. The expanded theory of personalization

2.1 What is Personalization?

Personalization is an act of marking one's territory (Becker and Coniglio 1975; Lang 1987; Bechtel 1997), which is a mechanism to achieve privacy, hence user control of his environment (Lang 1987). Personalization, as discussed by many authors (Rapoport 1982, 1990, Bechtel 1997, Lang 1987, Bentley 1986) seems to refer to non-structural modification such houses' interior layout, finishes and decoration that involve movable items. However, the basic theory of personalization may also relate to structural modification of the houses, although attempts must be made to reduce cost implications. In many studies, this modification process is known by many terms such as house extension, renovation, modification, transformation and house remodeling. This practice is well known in various Asian countries including India, Egypt, Bangladesh, Kumasi, Harare and also Malaysia (Tippie, 2000). The authors also suggest that moving is an act of personalization because the theory that led to moving from or modify the place is the same (see Fig.1). The decision is generally influenced by constraints such as housing market situation, regulations, financial situation, accessibility to housing information etc. (Priemus 1986, Rapoport 2001, Sinai 1998, Speare 1975),

2.2 The Significance of Personalization

(i) Personalization is a way to establish user meaning of built environment (Rapoport, 1982). It is also a process of generating environmental meaning that lead towards achieving one's values and goals.

Values came from culture that creates and determines needs, which is significant in determining users' housing choices.

(ii) Personalization is particularly essential in housing because of the wide differences between users' and designers' values, and the difficulty to meet the precise needs of the users by the designer (Brierly, 1993). In housing, user values and meanings are more important (Rapoport, 1982; Rapoport, 2000). The current scale of adaptation and renovation is a testimony to this fact.

(iii) Personalization is a continuous process where the individual characteristics and values are emerging with the times and new needs. Building houses is a natural human activity. A Chinese proverb says "the day the man stops building his house is the day that he dies" (Keyes, drawing from Ahmed 2003). This suggests that even if the existing living environments are properly designed, personalization will continue due to naturally changing needs and behavior of human being. What is required is the implementation of a systematic personalization framework to avoid unnecessary high costs in home making.

(iv) Personalization demands users to participate in their home making. The environment is an extension of man's being and personality, hence man is an agent of environmental change and not merely a recipient of environment influences. He should be able to manipulate, shape and alter his environment (Altman 1976). Being directed by his goals as man's instinct and to achieve this, he has to involve and exchange with his physical environments Proshansky et.al (1974). Involvement of users has the potential for producing environments, which are not only safer and cared for, but also tailored to the needs of users due to the fact that the residents were involved in making decision relating to their house and their immediate residential environment (Wilkinson, 1999). Therefore the personalization framework must include a proper approaches or programmes for user involvements. There is a belief that today we shape the environment and tomorrow the environment will shape us. Therefore, the users must have a say in their future.

2.3 Theoretical Model of Personalization

The theoretical model of personalization that the authors developed depicts the above theory (Fig.1). Built environment is defined by its attributes (Rapoport 2000). Since most of us work and live in environment designed by others (Bentley 1986), the given environment will be first filtered and evaluated by the person's filtration system. Culture is suggested as the main agent of this filtration process, which in a broad term encompasses the measurable variables such as values, ideals, norms, standards, needs, characteristics etc. (Rapoport, 2000). The consequence of this filtration or evaluation process is whether or not the user finds the house as suitable (person-environment congruent). There are two ways to cope with conflicting situation (person-environment incongruent). One is to adapt by changing family norms or standards (Sinai 1998, Bell et.al 1996) and remain in stresses, while another option is to personalize. Personalization however is constrained by several factors such as financial availability, market situation, social ties, planning and building regulations etc. These constrains are determinants to whether the users move or modify. This process will be repeated in which ever decision the user made. An important point is that, although the users have reached some satisfaction, the situation will not last. Due to changing needs during their life, they would later find their houses to be inadequate (person-environment incongruent).

2.4 Value as Environmental Filter and Evaluation

Values are expression and understanding of culture (Rapoport's 2000, Rokeach 1973). Culture is defined as a shared organization of ideas that includes the intellectual, moral, and aesthetic standards prevalent in a community and the meanings of communicative actions (LeVine 1984). Culture defines and distinguishes among groups i.e. pseudo-species (Rapoport's 2000, 2001), where in the context of man-environment relationship, it is the man made part of the environment (Herskovits 1948). This definition is expanded by Triandis (1980) to include physical culture (physical objects: roads, buildings and tools) and subjective culture (subjective responses to what is man-made: myth, roles, values and attitudes) In living environment groups differences has led to culture-housing relationships which can be realized by the different forms and styles especially with the vernacular design (Rapoport 2001). Values are at the core of a culture and influence the perception of symbols and rituals among others. When used to characterize and distinguish between cultures, it represents socially shared abstract ideas

about what is good, right and desirable (Hofstede, 1994). For example, in product promotions, understanding a country's core values is of paramount importance, without which miscommunication in advertising is likely to occur (Watson et.al. 2002). Due to its influences on a country's characteristic and consumer behaviour, values serve as the criteria where its members use to determine what behaviour is appropriate; to guide self presentation and to justify their choice to others (Watson et. al. 2002, drawing from Rokeach 1973). In housing, values help define groups and make housing particularly important, because dwellings play an important role in acculturation and, hence the survival of groups through the transmission of values, linking values to family (Rapoport 1982, 1990). In Singapore, religious values of three groups (Malay Chinese and Indian) lead to different problems in standardized housing, and the more severe problems being linked to activities rather than symbols (Chua, 1988). Therefore, values influence preferences and choice (Rapoport 2001, Coolen and hoekstra 2001).

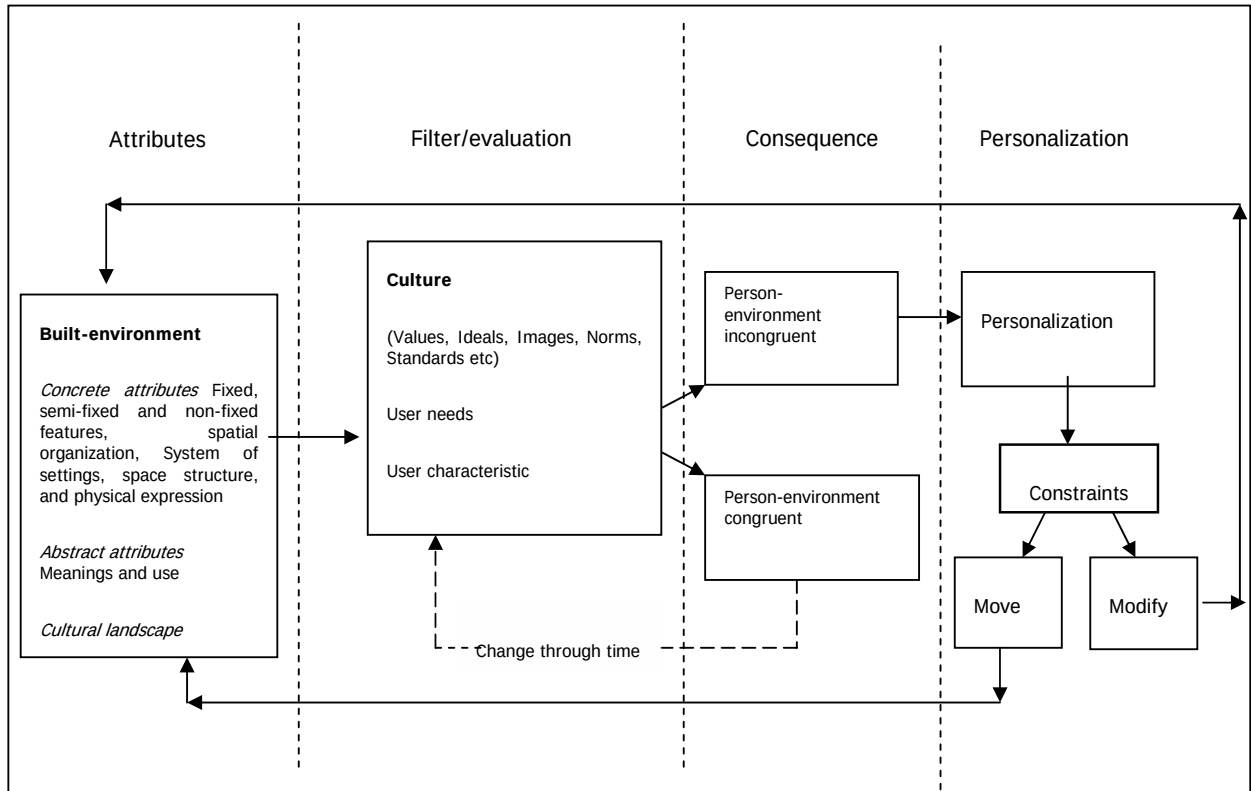


Fig.1 Theoretical model of personalization in built environment. Source; the authors

Values are often expressed through ideals, images, schemata, meanings etc (Rapoport 2001). For example, a caption "turn your home into paradise" is used to describe a façade with roof pediment, window pediments and columns (Rapoport 2001). How people perceived environments depends on his/her values. Unfortunately the importance of user values in decision-making in the design of built environment has seldom been emphasized, although in products' marketing it has been widely applied. It is suggested that value must be included as an important design consideration in order to achieve sustainable housing through personalization framework.

2.5 Conclusive Remarks

This article therefore suggests to conceptualise personalization in two ways: -

(i) Personalization as an essential and continuous process of achieving users' goals in built environment through physical and non-physical modification of their environment. This includes decoration, display, rearrangement of movable items, altering family norms and composition, and structural modification of the houses.

(ii) Moving is another activity to meet users' goals and is influenced by the same factors as for non-moving.

The authors also advocate that personalization is a potential housing development arm in providing quality and sustainable living environments that suites users' income streams. Tipple (2000) in his book "Extending Themselves" lists down several practical advantages from house transformation activities (the authors of this article consider transformation as an act of personalization). Together with his suggestions, the benefits of personalization may be summarized as follows: -

- Housing consumers become producers of housing
- Personalization saves money and other resources
- Personalization allows users to modify in order to establish their meanings and use of homes
- Personalization is an effective housing production arm at affordable cost for low and higher income groups.
- Personalization improves the social, economic and environmental quality of the living environment
- Personalization increases the productivity of housing
- Personalization enriches the use and function of homes
- Personalization adds value to an area and increases the potential property tax base
- Personalization makes efficient use of existing social resources
- Personalization promotes better social integrations.
- Personalization produces variety out of uniformity
- Personalizable housing concept is a potentially attractive housing option for housing buyers.

3. The Need for a Personalization Framework

The authors (2003) highlighted the 'popularity' of renovation practices in almost all urban mass housing schemes in Malaysia, and urge the housing actors to establish some kind of framework to facilitate this act of personalization. It is suggested that any personalization for living environment in this country should (i) address the varying and changing needs of the multiethnic users, (ii) allow the architects and the developers at the earlier stage of the design process to consider the possibility of user personalization to take place during occupancy, (iii) minimize structural modification of the houses when personalization takes place, (iv) defining the extents of the flexibility, open endedness, and adaptability of the original design in order to strike a balance between individual freedom of choice and planning control which is essential to ensure the sense of unity of the environment, and (v) minimize financial burden to the users, developers and the nation.

It is suggested that the key characteristics of a living environment that allows personalization is flexible and open-ended. The term 'personalizable' is introduced by the authors to describe the criteria of a living environment that is flexible, open-ended, and modifiable (FOM) to meet the user's expectations. Therefore 'Personalizable house' means a house that is flexible, open ended and modifiable for the above-mentioned purposes. With these key characteristics, a 'personalizable houses' enable the multiethnic users of this nation to establish their meanings of homes. The extent of 'flexibility', 'open-endedness', and 'modifiability' (FOM) is assumed to be defined by several factors including housing policies, planning and urban design control, construction and structural systems, building regulations, and user's characteristics. Planning and building regulations are necessary to define the extent of personalization 'freedom' that is given to the users. This is particularly vital to ensure users' personalization practices will not adversely affect the environmental sense of unity, neighbourhood character, structural soundness of the building, and other technical aspect of the house and the locality.

Modification without affecting the fixed features of the houses (wall, columns, roof, etc) is considered as an ideal situation. As posited by Rapoport (1982), modifications should affect only the semi-fixed features (such as demountable partitions, furniture, picture frames, etc). In the contexts of economy, this notion may directly be related to minimising financial implications on the users in personalizing their houses, and eventually the nation's spending on 'housing developments'. However the authors suggest that allowing the users to modify the fixed-features may increase the level of personalizability hence users' freedom to achieve their design expectations. This level of flexibility and modifiability would immediately implicate the need for the appropriate architectural design and construction systems.

Personalization must be considered at the design stage, in which the architects must be fully aware that the houses they designed will be subjected to future alterations. Architects should be working towards helping and supporting the users to establish their dream homes.

It is observed from an ongoing study on house renovation that the current practice of personalization in this country apart from being a financial burden, it is unorganized, uncontrolled, unsystematic, and often led to unexpected and chaotic neighborhood character. Professional helps acquired by the users are mostly due to municipality's requirements rather than to suggest good design. Cases where users wrongly appointed inexperience contractors, and being cheated by the contractors are common. Therefore in order to optimize the benefits from personalization, a framework is needed to be established.

The authors suggest that the personalization framework should consist of (i) Design, (ii) Construction Technology, and (iii) Enabling strategies.

4. Design

There are 3 major design aspects introduced that differentiate between personalizable house design and the commonly practiced design approaches in Malaysian urban mass housing, namely (i) Identification of users' values – housing attributes relationship (UVHAR), (ii) User participation, and (iii) personalizable house design

4.1. Identification of UVHAR

The personal goals and values are the motivational factors that help users to make decision in choosing the kind of houses they wish to possess, and the attributes are the means through which they may achieve those goals or values (Mahmud 2004, Mahmud and Ahmad Bashri 2004). The nature of user values-housing unit attributes relationship will provide important cues in defining the extent of flexibility and open endedness of the design.

The immediate concern is the use of the existing building standards and regulations. Building standards or building regulations such as number of room, sizes, opening, etc. are found to be only about adequacy, not quality (Brierly, 1993). It is insufficient to ensures user's satisfaction or achieve users housing goals. The authors suggest that for urban mass housing in this country, the multiethnic values about home must be first recognized in all sectors in housing production in order to turn housing into user centered architecture. The authors consider this as an essential component in the design process that will support housing sustainability.

The ongoing study on modified houses using Means-End Chain Model (Mahmud and Ahmad Bashri, 2004) have shown that user values have significant influence on the housing unit's attributes (spaces, furniture, decorations etc). This has been reflected by the way the users changed the original design of their houses. The study also found that there are three important points about the implication of user values in relation to house attributes: -

(i) Users perceive house attributes differently.

Different users perceive House attributes differently. For example, kitchen is perceived by some as a place for family gathering, children upbringing, space for ladies etc. Likewise living room is regarded as a place for family gathering, self-expression and to certain extent as an alternative sleeping room. There are users who emphasized on furniture where home making were based on their types such as collapsible, self-made, antiques, etc. As a result modification of the existing structures were minimal. Several other users have altered the existing spatial layout, changing the existing function, adding new spaces, adding new finishes and decorative elements to the floor and walls, changing the façade design, putting up religious icons, personal identities etc. Structural modifications in these cases are more significant.

(ii) Users prioritise house attributes differently

The study found that users emphasise spaces in their house differently. Kitchen, forecourt including front gate, and living room have been repeatedly mentioned as users' main concern in personalizing

their houses. When the users were asked to arrange the spaces according to priority, the responses were varied, although kitchen and forecourt seem to be of popular concern.

(iii) Intention for future modifications

Several respondents have intention to alter their houses in the future, despite the fact that many of them have done house modification for more than once. This may be seen as an irony in the theory of personalization. Although the earlier modifications of the houses were done by the involvement of the users, they still intend to change the design in the future. This may be attributed to changing values, needs and even life goals.

Therefore it is necessary to identify UVHAR in the design process that may be established by carrying out post occupancy interviews using Means-End Chain model (MEC). It is suggested that the findings of MEC interviews will be able to show the links between user values and house attributes. The findings will be useful as a reference for the designer to identify and evaluate housing unit attributes beyond the dimensioning requirements as normally expressed in the building by-laws. MEC interviews may also be carried out on the potential buyers of the house.

4.2 User participation

As highlighted earlier, user participation is one of the main components in personalization. The question now is how the users would effectively participate in the future improvement of their home. Participation means 'having a share in' (Damer and Hague, 1971-Drawing from Ahmed 2003), and also suggests 'empowerment of users' (Johnson, 1984 – drawing from Ahmed 2003). To be socio-culturally appropriate, an environment should have, as a primary element, the contribution from its future residents (Bhatt and Navarret 1991). Wulz (1986) suggests seven stages of user participation in the design decision-making process between the two extremes of 'representation' of the users by the designers (expert autonomous architecture) and 'self-decision' by the users themselves (user autonomous architecture). The stages are (i) Representation, (ii) Questionary, (iii) Regionalism, (iv) Dialogue, (v) Alternatives, (vi) Co-decision, and (vii) Self-decision.

User-participation particularly the self-help concept, have been regarded as a viable housing alternative for the low-income group in the developing nations. However the concept have also been applied in housing provision for the middle-income group in the developed countries mostly for house improvement rather than for building new ones (Carmon and Gavrieli, 1993). Another term is 'Self-build', that is a user participation approach used by the middle-income group to provide a better quality homes (Ward, 1982). In this concept the user are taking the role of developer or contractor, or even to build themselves on new or half-finished house units. 'Self-provided housing', the term used by Clapham (1993) on the other hand is for individuals or groups who managed the provisions or modifications of their homes, especially detached family houses.

From the study on alteration works in the urban housing schemes, it is found that users were involved in the design and also the construction process of the alteration, ranging from consulting architects/designers, material procurement, selection and appointment of contractors, managing payments, supervising construction works, and some of the users also involved in the construction of the houses. However, it is noticed that user participation in the design process of the alterations were not optimised. In many cases design participation were only in the form of describing to the designers or the contractors their requirements. Very few of the users commented on the drawing provided by the designers. Some of them did not even know what have been drawn by the designers. Despite the minimum user involvement in the design process, most of them were satisfied, and even exited with the outcomes of their personalized houses.

4.2.1 User participation methods for personalization The application of the widely accepted professional-led participation approach may be suggested for housing unit's personalization in urban mass housing. However some modifications will need to be introduced to ensure it's viability in Malaysian context.

(i) Co-decision approach.

It is recommended to let the users involve in the design of the housing schemes, as has been practiced in the develop countries, such as Millgate, Newark in Nottinghamshire, United Kingdom (Moughtin et.al

1999, page 107-122). However there are several technical, cultural, and bureaucratic problems to consider before the approach can be viably applied. Ahmed (2003) highlighted from several authors that getting user representation is extremely difficult, particularly in large-scale housing projects. Wide gaps between the professionals and the users has led the professional's preconceived ideas to dominate the decision-making. Bureaucracy and developer's management strategies also influence the decision making process and some other user participation models that were implemented, experiences several shortcomings.

(ii) Passive participation using statistical and UVHAR surveys.

The approach allows the configuration of the urban spaces with regards to housing layout and the design of the house units, being controlled by the professionals. User participation may be in the form of statistical surveys and UVHAR interviews from the potential/actual users. The information may be fed into the design process. The neighborhood character or identity building of the housing schemes may be developed by the professionals by using, for example, regionalism participation approach. In this approach, active user participations may be introduced in the design of the individual house units (not the overall layouts). This may be done by providing various personalizable alternatives of housing units for the users to choose.

(iii) Programmed user participation

It is suggested that user full participation starts when the houses are handed over to them. Therefore, appropriate personalization programmes are needed for the users to carry out personalization works according to their financial capacity, income, and time scheduling. Options should be as flexible as possible where it should allow options, ranging from the users as a developer or designer to the users constructing the building themselves. Two main options to be considered are *Developer Assisted Personalization Programme (DAPP)*. and *Post-Occupancy User Managed Personalization Programme (POUMPP)*.

Developer Assisted Personalization Programme (DAPP) integrates the personalization process as part of the formal housing production. In this case the production process will be divided into two main stages. Stage one is for the developers to produce the Personalizable housing unit prototype (PHUP) where passive participation would be appropriate. Stage two is where the actual users will be involved in personalizing their houses. The developer will be providing assistance in terms of design ideas, time schedules, and construction work force. The advantage of this option would be for the developers to benefit from a complete package of housing provisions. Also the personalization programmes may be tailor suited to developers' provision programmes. For the users, the process will be more systematic and timely. Personalization works would be more efficient because they are carried out by the agencies that are familiar with the original units. The disadvantages would be that this programme may not be able to facilitate self-help concept, long term personalization programmes, low-income users who wish to personalize according to their income streams, and users who wish to erect the building themselves. This programme has some similarities with the concept of 'customization' that has been practiced by housing developers in the United Kingdom (Barlow 1999). The developers allow users to customise their house design during the construction process of their houses, as part of sales attraction. Developers allow users' input in various techniques and scales. Some allows users' inputs on the external facades and some of the non-load bearing walls. Many are limited only to customisations of fixtures and fittings. Some other large-scale housing developers are reluctant to allow customisation for some other practical reasons such as difficulties in time allocations and so on.

Post-Occupancy User Managed Personalization Programme (POUMPP) is where developers' housing provision programmes end when the PHUP are handed over to the users. The users will have more freedom in carrying out the personalization works according to their time and income streams. Users who are interested in the self-help approach are accommodated for. Another significant advantage is for national interest, in which new jobs may be created. The programme may be monitored by the related government housing agencies, and offer the programmes to practitioners (designers, contractors, suppliers etc) who may be interested to specialise in personalization programmes. However, all practitioners will have to undergo proper personalization trainings before licensed to carry out the works. Special training programmes must also be provided for the users particularly from the low-income group who are interested to build their houses themselves.

4.3 Personalizable House Design

Architects must avoid treating house design as finish items, instead they must realize that they are providing means for other 'designers' to explore. Therefore, the houses design that the architects produced must be flexible, open-ended and modifiable (FOM). For mass housing schemes where standardisation is inevitable the following design considerations are suggested: -

- (i) Avoid the rigid standardised, and predetermined housing unit design that do not take into consideration future modifications, as is commonly done. But planning regulation must be observed to ensure the environmental unity or the neighbourhood characters are not adversely affected.
- (ii) Identify which part of the structure are fixed or changeable
- (iii) Plot sizing, house shape and layout shall support personalization. Davidson and Payne (1983) suggest that rectangular shape building in terrace house with 12 meters façade is considered as the most flexible unit. 6 meters width façade is the minimum dimensions for being flexible.
- (iv) Consider developing a "FOM core design" strategy that have the same basic principle with the widely used core house concept. The core should be designed by taking into consideration the personalization patterns that will take place later. The core design may have two options namely *extendable core design* (Fig.2), and *open plan house design* (Fig.3).

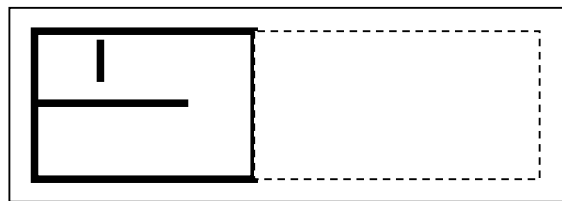


Fig.2 Extendable core design

In extendable core design, the houses are designed with possible modes of future extension where the design will be started with a basic set of housing attributes. The design may be in modular form, meaning that extension will also be in modular pattern. The main advantage is the optimum flexibility for extensions and modification of the interior or exterior parts of the houses. This option may pose difficulties in monitoring the façade design hence the environmental unity (neighbourhood character) of the locality. This may be overcome by designing a proper mode of extension, standardised construction technologies and a proper personalization programmes. It means that the extensions are not left to the users entirely.

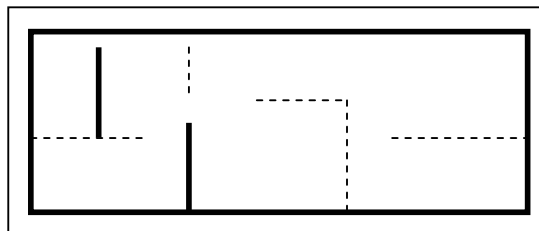


Fig.3 Open plan house

The concept of open plan office is borrowed in the open plan house design concept (Fig.3). Wu (1999) proposed a similar house design concept in China by using a structural system that relies on long span panels. In each unit only the kitchen and the bathroom are fixed. No wall has been constructed between the kitchen and the service balcony in order to give residents flexibility in its use. In the context of Malaysian urban mass housing, The housing unit will be designed as a box, providing the basic attributes and leaving the interior layout open for personalization. The main advantage of this option is the ease of control of the façade design thus ensures environmental unity. Illegal extensions

practices may also be minimised. However, appropriate construction techniques must be developed, together with proper programmes.

An important flexibility issue is enlargement of houses' size. Currently, the extensions are taking place on the empty space where the building lines have not reach the development limits. There are some users in the study area, extended their houses vertically by occupying the attic areas, without increasing the original height of the building. In this way they managed to get more spaces compared to the horizontal expansion. However this practice is illegal.

5. Construction Technology

The construction technology for personalizable housing prototypes must support the design and user participation approach. The techniques have yet to be explored. Some of the existing techniques may be considered for their potentials and suitability. Skeletal structure such as reinforced concrete frames offers modification flexibility to certain degree, due to the nature of the wall being non-load bearing. Load bearing structures (brickwork and blockwork) have the advantage of being a dry construction, but the application is unpopular and the know-how of this technology is lacking in this country. Also, the use of too many structural walls will make modification more difficult. Concrete panel construction that is commonly used in the prefabricated housing schemes on the other hand is too rigid for alteration. Currently, most of the conventional construction techniques are still expensive and difficult for personalization. It is suggested that the construction techniques for personalizable housing units, should have the following attributes: -

- (i) The construction systems minimise demolition when the buildings are modified
- (ii) Building components have a high degree of moveability and reusability.
- (iii) Minimum structural walls
- (iv) Minimum wet construction
- (v) Building components/materials are small in size, lightweight, easy to handle and transport.
- (vi) High degree of standardization.
- (vii) Modular coordinated construction system.
- (viii) Using locally available components and materials.
- (ix) 'Easy to fit' jointing systems

One of the interesting construction systems to be explored is the use of demountable partitions concepts, using materials with properties suitable for privacy. The 'lego' concept is a highly flexible systems and a potential concept in the personalizable housing unit prototype, because of the 'inter-locking' jointing systems, using small size units, dry construction, and lightweight.

6. Enabling strategies

Tipple (2000) expresses that government enabling strategies is vital in supporting personalization approaches. He posits that the first stage in enabling is to discover what drives and what hinders the personalization process. The "what drive" factors of personalization have been discussed earlier that can be summarised as a viable housing arm for a quality housing at affordable costs. What hinders the application of personalization framework is many. Government policies such as Planning and building regulations are indicated as major disabling or enabling factors. The current 'hindering' outcomes from the completed renovation works in the housing scheme that is being studied has several similarities as what was explained by Tipple (2000). Uncontrolled and unplanned transformation, unpredictable demographic and neighbourhood character, creating rooms without proper ventilation and lighting, crude construction system employed, unconformities to building regulations, encroaching outside boundaries, low-quality contractors employed, are some of the examples of planning and building control problems. Other hindering elements are the bureaucratic procedures including the time taken to process the applications for carrying out alteration works, building and planning requirements that are rigid. The requirements for architectural drawing to have "architect's signature" seems to be questionable. Many of the users found this as a mere formality but yet costly that lead to many did not bother to comment on the drawings.

There are so much that the government would gain from personalization practices. But it is of paramount importance to review government's housing approaches in order to allow the practical implementation of personalization. The current planning and building regulations must be modified in order to allow extensions rather than to outlaw the practice, and thus leave them uncontrolled (Tipple 2000). Some of the enabling steps that promote and at the same time control the practice are suggested as follows: -

- (i) Allow flexibility in terms of room types, number, and size. If possible allow vertical extensions with some degree of control.
- (ii) Relaxation of set-backs and building lines to allow development close to side and rear boundaries (Tipple 2000)
- (iii) Introduction of classes of permitted development within which planning permission is not needed (Tipple 2000).
- (iv) Introduction of classes of permitted developments that do not require professionals' involvement for approval.
- (v) Recognize *Personalization Programmes* (as discussed earlier) as part of housing development policy, so that the establishment of the programmes are to be controlled by the related government bodies.

Financial enabling strategies are vital to ensure viability of the framework. The study suggests that the users were able to manage the alteration works out of their family savings. Some managed to obtain financial helps from their Employees Providence Funds (EPF), and also loans from commercial banks. With the suggested personalization programmes, modifications to the current standard procedures in getting bank or government loans will have to be modified. For example, allow application for buying new houses together with personalization works in a single package. Users who personalize using their family savings sometimes faced difficulties of getting sufficient fund on time. This may delay the works on the contractors, thus the completion of the project. Bridging loans for contractors for personalization projects may be considered (Tipple 2000). In a systematic personalization works, the authors assume that the contractor may have several renovation projects in different locations. Allowing them for bridging loans would lead to a more efficient and timely completed works.

7. Conclusions

In conclusion, personalization is a viable housing provision arms for a better quality houses at affordable costs. It is a way to achieve sustainable living environments because the users are involved in the making of their living environments. This paper highlights the great potential of housing personalization approach to be systematically applied in the urban mass housing in this country. This is a new attempt in housing development that is different from the commonly known user-participated housing. This approach is applicable for the normally employed formal mode of housing delivery for the low and the higher income groups. The concept will benefit the government in providing a viable housing arm that saves unnecessary spending on housing. It may create more jobs by creating new areas that the professionals and builders may venture. The scheme would be more attractive to the potential housing consumers, hence the developers. However Government's recognition on this approach and commitment from all sectors of housing development are necessary before the system could be practiced.

The ideas presented in this paper are still conceptual and subjected to further elaborations and studies. The suggestions are based on observations from the authors' study on renovated houses in a housing scheme in Johor Bahru, using Means-End Chain (MEC) laddering techniques. It is not possible to provide any statistical data because the study is still at an early stage. It is strongly recommended that several researches on the design, construction technology, and enabling strategies to be carried out to ensure a viable personalization framework to be effectively implemented.

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A CASE STUDY OF THE LOW ENVIRONMENTAL IMPACT CRITERIA ON THE ECONOMICS OF HOUSING CONSTRUCTION.

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Abstract

The Social, human and technical actions as well as economic decision of construction will affect the environmental performance of buildings. Bioclimatic design, adequate system for the supplies of energy and water for heating and cooling, or selection of construction materials will involve a non-conventional way of construction therefore with unknown initial costs. An approach focused on the economical influence of these criteria upon the environment would enable owners and other public and private sectors to put these products into services and markets.

The paper presents a case study which includes a cost evaluation for sustainable construction criteria introduced into the projects. The case study is based on an example of a project located in the city of Valladolid, Spain. The study showed that the environmental benefits both for tenants and community for exceeded the economic values. Other important environmental benefits include better comfort and health care however, this could not be economically verified. In conclusion, promoting the collaboration between the environmental benefits and business opportunities is important in order to definitely change the myth that "green buildings" are more expensive to construct.

Keywords : Economic evaluation, Housing, Bioclimatic design.

1. Introduction

1.1. Background.

The construction of a building composing of three recently completed houses in Valladolid has been used to study the environmental aspects of sustainable construction. Two research have been undertaken.

The first, focused on the reduction of carbon dioxide (CO₂) emissions during the design project and the construction process, through a careful selection of low environmental impact materials (González et al, 2004). The target of this research has been to reach theoretical considerations to be used with the environmental and planning authorities.

The second research that was carried out provided a cost evaluation of all processes and items related to sustainable criteria and its economic implications (González et al, 2004). The aim of this second research was to obtain and convey information during the operational period for the commercial property, the organization and economic agents. It provides economic data for the various construction stakeholders, such as owners, architects, engineers, developers, technicians and tenants too.

This paper summarizes those two previous analysis and the later experiences, to provide further research with the aim of achieving a deeper knowledge on sustainable construction.

1.2 Recent experience

There is no doubt about the environmental benefit of buildings constructed in a sustainable way. Specifically, in this case, a great amount of CO₂ emissions has been reduced through the careful selection of construction materials (González et al, 2004). Other criteria to reduce the consumption of conventional energy, such the passive solar system and the bioclimatic design, appear to be the most efficient way to save energy (Kisilewicz, 2002). There is a great amount of research about the topic, but there is not much investigation about the impacts that it will produce.

On the other hand, and from the owner's point of view, the most important issue is the study of the preliminary budget, and more precisely the economic references and evaluations. The daily practices show how difficult it is to develop specific researches about the economic data and inputs of sustainable building construction. The main difficulty when developing this non conventional construction type is its unknown cost which results in a major obstacle for private owners and developers.

Both theoretical and economical aspects of the studies were undertaken and its results disseminated. However, the experience obtained from sharing this information has shown the importance of reaching a reasonable compromise between theoretical and economical aspects, especially in private performances in order to obtain the collaboration of tenants. (Beaudoin et. al, 2002)

1.3 Objectives

This paper attempts to define those economical, as well as environmental aspects which lead to important benefits. Those aspects are linked to durability and social acceptance, and developed through sustainable construction. They are like the two faces of the same coin. (Deilman, 2004). Self-adjustments of those factors are necessary to develop a general eco-efficiency outline. (Tattari et al, 2002) The economic results must be linked to other ranges, such as:

- economic data
- the relative cost related to the final consumer price
- economic and environmental profit for tenants
- environmental profits for the community

1.4 Methodology

The case study of this paper analyzes a compound building comprise of three houses, which have been constructed using low environmental impact criteria; including the use of alternative energies and considering the following maintenance of the building. The research were carried out by comparing this compound building with a building of similar characteristics, but constructed in a conventional way, with no sustainable criteria at all. The latter is called a reference building.

As the conclusions greatly vary depending on the circumstances --place, social and economic levels, typology, use and size of buildings, etc-- the development of the present research work starts by describing the specific circumstances and hypothesis of this case study.

The results of joining together these four ranges are summarized in Table 1

Table 1

column 1	column 2	column 3	column 4	column 5	column 6
three low environmental impact houses	reference building of conventional construction	% construct budget	%final budget	profit for tenants	profit for community
CHAPTER A. BIOCLIMATIC DESIGN					
SIZE AND SHAPE	CONVENTIONAL SIZE AND SHAPE	0.00		25% saving heat energy	reduction pollution
SOUTH-NORTH ORIENTATION	ORIENTATION ON SITE	0.00		no refrigeration system	saving no renew energy
CROSS VENTILATION	NO CROSS VENTILATION	0.74		high level comfort	reduction CO2
TRÔMBE WALL	CONVENTIONAL WALL	1.44		sensitive comfort	
GREEN HOUSE	NO GREEN HOUSE	1.83			
SHADING DEVICES	NO SHADING DEVICES	0.22			
SUM. CHAPTER A		4.23	1.77		
CHAPTER B. LOW ENVIRONMENTAL IMPACT MATERIALS					
WOOD FRAME	CONCRET STRUCTURE	4.41		sensitive comfort	27% reduction CO2
WOOD FRAME WINDOWS	ALUMINIUM FRAME WINDOWS	2.64		health comfort	reduction pollution
NATURAL WOOD DEVICES	ALUMINIUM/ PVC DEVICES	2.85		no harmful substances	no harmful substances
PP AND PE SEWERS	PVC SEWERS	0.03 -		good quality internal air	reduction greenhouse effect
NO METALS GUTTERS AND DRAINPIPES	ALUMINIUM, COPPER, PVC	0.25		fire security	reduction eutrophization
FLOORING SYSTEM LOW BURNING	FLOORING SYSTEMS HIGH BURNING	0.55 -		low level of pollutants	saving no renew energy
CORK INSULATION	PUR INSULATION	0.36			
ELECT. INST. NO PVC	ELECTRIC INSULATION PVC	1.70			
NATURAL WOOD WARMISH	SYNTHETIC WOOD WARMISH	0.08 -			
EXTERNAL NATURAL STONE	SYNTHETIC STONE	0.70 -			
WATER-BASED PAINTWORK	ALKYD PAINTWORK	0.54 -			
SUM. CHAPTER B		10.29	4.32		
C. ACTIVE SOLAR ENERGY					
THERMIC SOLAR ENERGY	NO THERMIC SOLAR ENERGY	2.55		70% saving energy sanitary water	reduction pollution
PHOTOVOLTAIC ENERGY	NO PHOTOVOLTAIC ENERGY	9.79		5.7 kW free	save no renew energy
SUM. CHAPTER C		12.34	5.18		
D. WATER AND PLANTS SYSTEM					
SAVE WATER DEVICES	NO SAVE WATER DEVICES	0.05		saving 50% water	low level of pollutants
RAIN WATER SYSTEM	NO RAIN WATER SYSTEM	0.17		no refrigeration system	saving no renew energy
PLANTS AS MICROCLIMATE EFFECT	NO PLANTS	0.93		refresh air	refresh air neighbourhood
GARDEN PARTITIONING	MASONRY PARTITIONING	0.77 -		sensitive comfort	sensitive comfort
SUM. CHAPTER D		0.38	0.14		
TOTAL SUMMARY					
		27.24	11.43		

2. Procedure and definition of physical range

2.1. Description of the physical range

The building, composed of three terraced houses, built in a medium size Spanish city (Valladolid), for the average social class type. This location experiences continental climate. All specifications are in accordance to national standards and regulations, including interior quality. Each terraced house has a surface area of 175m² and belong to a private developer in a residential area. The construction was done using average level technology. The data obtained from this housing development can be applied to most common residential building.

2.2. Identification of sustainability

The sustainability criteria have been compiled and categorised in four groups namely chapters A, B, C, D in order to evaluate the over cost. The chapters summarises the passive solar system and items of bioclimatic design; such as the use of low environmental construction materials; active systems of solar energy; and rain water system, natural and passive cooling, and plants used as hedges to create microclimate effect.

2.2.1. Bioclimatic design solutions. This chapter combines all the different strategies to adapt the building geometrically to the particular climatic conditions, such as South orientation of living spaces, orientation of windows, minimum size openings to the North and maximal to the South, optimised shape and size and factor, shading devices, etc. Passive solar energy systems are included in this chapter: the *trömb* walls and the greenhouse. Natural strategies for summer conditions are also provided, such as a grill for natural cross ventilation above windows and doors, both internal and external, in order to maintain the quality of internal air and to ensure good interior comfort in the hot summer months. (Table 1, Chapter A, Column 1)

2.2.2. Selection of construction materials of less environmental impact. A thorough selection of materials used in buildings was made using life cycle analysis and environmental impact characteristics. For example wood was used for roof structure, windows and frames, or floor and wall tiling of low burning, water based paintings, natural varnishes not oil or chemical derivates, etc. Other solutions are new, such as not using PVC in pipes, insulation ducts and electrical connexion boxes, or applying an electric wiring low in halogens. The PVC used for the plumbing and services has been substituted by polythene and polypropylene. Natural cork has been selected as thermal insulation, for walls, floors and roofs. The cork used has a conductivity coefficient of 0.034 Kcal/h°Cm. The thermal insulation glass is 2.8 Kcal/h°Cm². Other thermal coefficient for the essential construction elements are 0.38 Kcal/h°Cm² (external walls); 0.71 Kcal/h°Cm² (floor); 0.29 Kcal/h°Cm² (roof); 2.8 Kcal/h°Cm² on window frames, and 1.20 Kcal/h°Cm² for internal partitions among properties. The global thermal coefficient of transmission of the houses is 0.494 Kcal/h°Cm². (Table 1, Chapter B, Column 1)

2.2.3. Active solar energy systems. The buildings were installed with thermal solar energy to produce hot water and electric energy by means of photovoltaic solar energy, with a connection to the mains. Each house has a 3.8 m² surface thermal collector, and a 300 l capacity tank. The photovoltaic system is a complete system, integrated in the roof, with a triple-junction thin film silicon technology of total capacity 4,608 Wp. Both systems are not very common in the city. (Table 1, Chapter C, Column 1)

2.2.4. Water and plants systems. The recollection of rain water in a tank in the basement is also planned to be later used, as well as low consumption sanitary fittings and air valves in the taps. Plants and vegetation carry on a very important role in the design of the buildings. The landscape architecture with sunshades, pergolas, canopies and the gardening to separate and design the free garden space, is used as an architectural barrier to separate the building, provide shades and create a microclimate. (Table 1, Chapter D, Column 1)

2.3. Definition of conventional construction

The definition of what a “conventional” material is, depends to a great extent on the parameters. The daily professional practice, nevertheless, demands no special explanation on the issue of defining “conventional materials” since it is given for granted. In a systematic way, the construction of small-to-

medium sized buildings for residential use in this area has traditionally been developed with a reinforced concrete structure, vitrified ceramic walling, polyurethane or polystyrene foam insulation, aluminium or PVC windows and door frame, ceramic floor finishing of high burning gres, parquet floors with PVC finishing, chemical and plastic paintings and interior plywood treatment in PVC. Neither the recollection of rain water is applied, nor are the plants and vegetation used as architectural elements. The alternatives presented here are seldom used, due to a hypothetic increase in the budget. Nevertheless, constructions carried out in an unconventional way are more expensive. (Table 1, Column 2)0

3. Establishing the comparison criteria

3.1 Economic data. (The absolute cost of introducing sustainable criteria into construction).

The results of the comparison between real cost and conventional cost are summarized in Column 3 of Table 1. In the case of positive quantity in this Column, there is an over cost in relation to the budget of the reference building, built with conventional construction materials. In the case of negative results in Column 3, building with these particular sustainable devices is cheaper.

In this particular case and circumstances, the general conclusion is that building in a sustainable way would increase the price more than a 27 % compared to a conventional system. The total cost of a conventional operation is calculated at about 780-800 € per m². Nevertheless, the total cost of this low impact building reaches 991 € per m². This study shows that there are sustainable criteria which does not result in cost, such as an adequate size, shape and orientation North-South. All of these are bioclimatic solutions for design.

Secondly, those which can reduce construction cost are for example, the use of PP and PE sewers, low burning flooring finishes, natural wood varnish, natural stones, water based paintwork, and gardening partitioning instead of masonry partitioning.

In contrast, those devices which are directly related to the chapter of active solar energy have an unavoidable over cost, so does the green house and the *trömbe* wall. Other inputs are more a consequence of wrong policies and market changes than with material cost themselves; as it is the case of wood frames, or the use of other natural materials like cork, etc, which have almost disappeared from the conventional construction today and can only be found in special cases.

3.2. The relative cost related to the final price for consumer

The cost of a building depends on the site location ie. cost of land. Private investors will base the price taking into account the market balance (Malinowsky et al, 2004). In this particular case, it is the proportion of the cost of the land over the final price is 33%; the construction cost itself is 42%; and other costs (technical surveys, taxes, certifications to relevant standards) (Yudelso, 2002) plus the owner's profit, which reaches up to 25%. Column 4 of Table 1 defines the cost of sustainable criteria related to the final cost for the owners.

3.3. Economic and environmental profit for tenants

There is considerable benefits to be gained from low environmental impacts such as sensitivity aspects, health cares, high comfort, and general wellbeing. The environmental solutions offer great possibilities for creating both economic growth and greater life standards (Olsen, 2002). The sensitivity factors are defined by the optimal relation with Nature, through the connection with its elements, such as sun, plants, wood, cork etc.

The high level of comfort comes from the selection of low environmental impact construction materials, especially those which have a natural origin, such as wood, water paintings and cork. They have no harmful substances, low rate of VCO, and good quality internal air. The specific electric insulation provides better safety in case of fire.

The economic profit depends on free solar energy itself and therefore on local and state policies. In this case, the photovoltaic energy implies important benefits for property managements. Other important economic benefits are low rate heating system, and less refrigeration. Those criteria can eliminate the necessity of a refrigeration system and provide a considerable reduction of fossil-fuel products for heating (approximately 25%). The economic saving for the consumer and the refund cost of inversion must be included in this general chapter. The active thermal solar energy provides 70 % of energy saving for sanitation. The photovoltaic cells system produces a free equivalent production of 5.7 kW for each house, due to the legal regulations of connection to the mains. (Column 5, Table 1)

3.4. Environmental profits for community

The construction is directly related to all the environmental impacts. In this particular case, only the production of carbon dioxide has been studied, but, the same study can be applied to other different harmful effects implicated by the construction industry on the environment. For example, the emission of heavy metals, the use of non- renewable energies, the effects of eutrophization, water consumption etc.

Quantifying the use of primary energy can be a useful reference in relation to the emissions of the greenhouse effect arising from housing construction, and therefore upon the environmental impact. Similar studies were conducted previously in New Zealand by Mithraratne et al, 2004. This case study showed a reduction of 25 % of embodied energy compared to that of conventional construction. Consequently, there is a reduction of environmental impacts in the construction phase. In addition, the use of renewable energy in the maintenance phase involves a reduction of pollutants and CO₂, as example solar energy.

4. CONCLUSIONS

From the practical experience acquired in the case study above, it can be concluded that economic values is minimal, in comparison to environmental benefits to both tenants and community. In this particular case, 11.43 % of the cost of the final budget is highly compensated for the economic savings in the maintenance period. Other important benefits are related to better comfort and health care. But all of these aspects must be studied and calculated in terms of economic assessment and costs. The final budget of this sustainable building can thus, be calculated however, the environmental benefits must be economically verified. Promoting the collaboration between environmental benefits and business opportunities is a very important issue to definitely change the myth that "green buildings are more expensive" to build.

Acknowledgements

This work is a continuation of the project awarded by the Obra Social of Caja España de Inversiones, Caja de Ahorros y Monte de Piedad, for their Research Prize Convocation in renewable energies in 2003.

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ASSESSMENT OF BUILDING ENVELOPE REFURBISHMENT OPTIONS TO ACHIEVE SUSTAINABLE ENERGETIC PERFORMANCE IN A HIGH THERMAL MASS OFFICE BUILDING

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Abstract

In the United Kingdom (UK), buildings represent almost 50% of energy demand namely for electrical, heating, cooling and lighting. In terms of non-domestic building stock, the majority of 1960's buildings have poorly insulated facades and so consume a disproportionate level of energy per m² compared with more modern buildings. This paper assesses options for building envelope refurbishment of high thermal mass office buildings, which were commonly constructed in the 1960's, in the so called 'international style'. The aim is to achieve a reduction in energy consumption coupled with an improvement in environmental quality for building users. A typical 1960's office building on the main campus of Southampton University, UK has been investigated in terms of its existing energetic performance. Various solutions for refurbishing the building envelope are presented and evaluated by thermal simulation studies. The potential application of utilising the large thermal mass of such buildings combined with smart façade systems to facilitate night cooling in particular is discussed. The predicted energy savings in terms of both heating and cooling that can be achieved represent a 60% reduction from present levels.

Keywords: Sustainable Buildings, Office Buildings, Building Refurbishment, Building Envelope, Thermal Simulation.

1. Introduction

To achieve a more sustainable urban environment at large it is necessary to investigate the possibilities of refurbishment of the existing building stock. In the UK only a small proportion of the entire building stock is replaced each year (DTI, 2001). Space heating of UK service sector buildings is responsible for 55% of the total energy consumption in this sector (DTI 2002). According to Schuler and Lechner (1999) a typical 1960's building in Germany requires more than 150 kWh/m² per annum heating energy to compensate transmission losses through the façade. The UK Department of Trade and Industry (DTI) has been at the forefront of legislation to address this problem by improving the performance of both existing and new build facilities. The most important piece of legislation is Part L of the UK building regulations (DTLR, 2002) which places limits on U-values for construction elements such as windows and walls and specifies minimum heating system efficiencies. The importance of Part L is highlighted by, for example, the fact that in the UK 6% of the total energy consumption is due to transmission losses from glazings in domestic buildings alone (Muneer et al, 2000).

Traditional office buildings are in general the result of a problem based and not an integrative planning procedure which results in high energy consumption and poor environmental performance. In many office buildings energetic issues have been dealt with as technical problem and not as the starting point for the design of the building and its envelope. If, for example, effects like summer overheating occur, a problem based approach is to apply an add-on 'end of pipe' solution such as an air conditioning unit in order to 'solve' the problem. The drivers for the application of end of pipe technologies such as air-conditioning are often a result of a recent change of use that has occurred within the building. The advent of computers, photocopiers and other electronic devices have created thermal loads and issues with glare within 1960's buildings that would never have been envisaged by the original architect. The low cost of energy in the UK makes end of pipe air conditioning the easiest solution for facilities managers to adopt. Such an approach however, leads to an ever spiralling increase in energy demands in the built environment. An alternative design philosophy is to establish an integrative planning approach integrating all the boundary conditions concerning the building and its use into a more

sustainable refurbishment concept. The building envelope, acting as the mediator between the inside and outside environment clearly plays a vital role in this planning approach.

1.1 What is a Comfortable Building?

The most fundamental approach to building is to provide security and shelter against uncomfortable outside environmental conditions, and this is still today the basis for human well being in the built environment. The basic measure for operational quality of a building is the human feeling of comfort which is determined by the sum of the interior and exterior climatic conditions as well as social expectations (Römhild and Jentsch, 2004). A good feeling of comfort, the 'ideal environment', is achieved when these environmental conditions are as desired by the majority of occupants. The aspects of human feeling of comfort which can be influenced most directly by the construction and design of the building envelope are the aspects of thermal comfort, visual comfort and acoustic comfort. According to Oral, Yener and Bayazit (2004) these three physical components are the core aspects for evaluating the performance of a building envelope. In the following investigations these core aspects of human feeling of comfort are considered in conjunction with aspects of reducing energy consumption for heating in winter and prospective cooling in summer (Fig.1). Only by addressing comfort related aspects from the onset of a project is it possible to reduce the need for retrofit end of pipe solutions to be applied to compensate for poor comfort. Clearly, such an approach reduces additional energy requirements and so reduces the carbon footprint of a building.

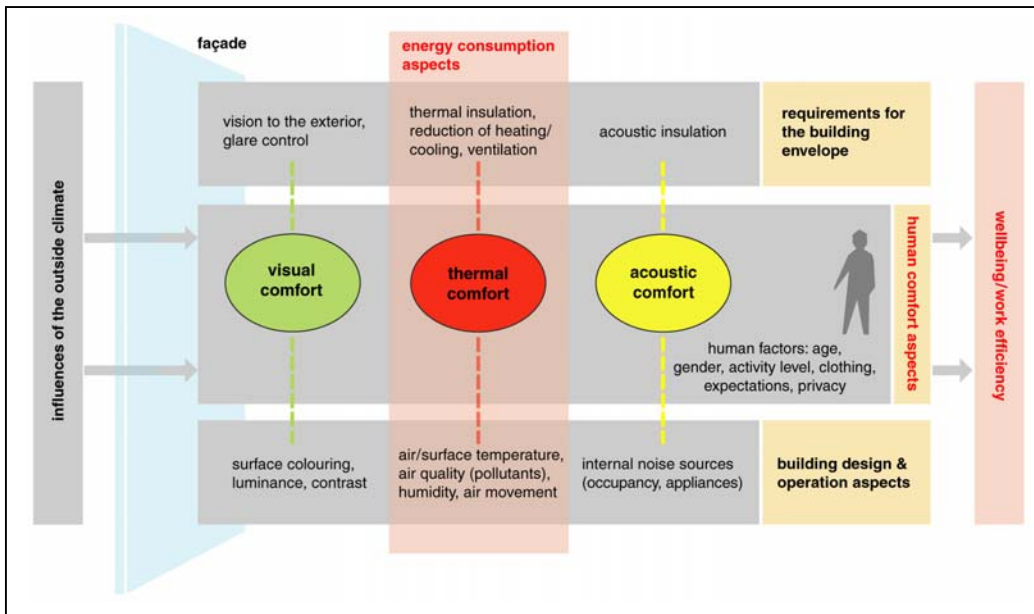


Fig.1 Interaction between the human feeling of comfort, building use, building envelope and energy consumption

2. Case Study: Environmental Performance of a Representative 1960's Office Building at Southampton University, UK.

The Highfield Campus of the University of Southampton consists to a large extent of buildings constructed in the 1960's and early 1970's. These buildings are generally skeleton constructions with curtain wall façades of which typically around 60% are covered by fenestration. The majority of building envelopes still possess their original cladding and windows which are mostly steel framed with large single glazed window panes. Architecturally these buildings reflect the era of "International Style" in which it was believed that environmental conditions influencing the building were negligible since they could be met with suitable technologies (heating, cooling). Building 21, the Faraday tower, which is investigated in this paper is a good example for this understanding of the built environment. The building was designed by Sir Basil Spence and completed in 1963 is one of the first of its type in the UK. Its façades are absolutely uniform in appearance and construction irrespective of orientation, giving all

its occupants the same possibility of vision to the exterior, yet causing serious problems of overheating and glare in most of the offices (Fig.2). During the summer months the South facing offices in particular suffer from excessive solar gain. The building's lack of air tightness is a particular problem during windy days over the winter months. Strong draughts and large temperature gradients are experienced by occupants resulting in high levels of discomfort. In essence, the building has outlived its working life in terms of façade performance and is in desperate need of refurbishment. Structural surveys have shown that the building is in an excellent physical condition (Estates and Facilities, 2003).



Fig.2 Faraday Tower viewed from The East



Fig.3 Existing glazing with steel framing

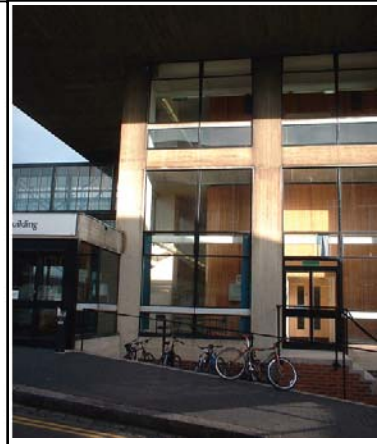


Fig.3 Building core with all supplies

The Faraday tower is a freestanding building with 11 floors of which the upper 8 are identical in size and façade construction. The fenestration covers 62% of the facade and consists of 3mm single pane glazing with steel frames (Fig.3). The average U-value of the fenestration is $5.6 \text{ W/m}^2\text{K}$. The remaining 38% of the façade is covered with concrete panels in front of a light-weight concrete block wall with an almost negligible air cavity of about 13 mm between them. The total U-value of the outer wall construction was calculated as $1.0 \text{ W/m}^2\text{K}$ (Weller and Youle, 1981). These values are in excess of the standard U-values for construction elements specified in the Part L of the building regulations in the UK, which are 2.2 for windows with metal frames and 0.35 for walls (DTLR, 2002). The building plan is a square of about 21.6m on 21.6m with offices which are grouped around a central core area housing all the building supplies, staircases and corridors (Fig.4). Since the offices have a room depth of about 5.2m the interior core has an approximate size of 10m by 10m. This core represents a thermal mass that has a high potential for being used as active mass for night cooling of the building, especially since the floors consist of a structural 0.6m solid concrete plate. Space heating is achieved using an under floor heating system.

2.1 Refurbishment Options for the Faraday Tower

The initial points for a refurbishment aiming at an energetically more sustainable building performance are clearly changes to the façade (fenestration and walls) and an active use of the building's mass. General requirements for the building are therefore a better U-value to reduce heat losses in winter and an approach to prevent overheating and glare in summer whilst retaining good ventilation throughout the year. In the summertime, the thermal mass of the core can be used for night cooling of the adjacent offices and in winter for preheating of fresh air needed for ventilation of the offices (Fig.5). This may contribute positively to the human feeling of comfort, since air movements and air quality are technically controllable according to occupancy demands. To improve both the cooling and heating efficiency pre-treatment of air by passing it through pipes in the ground prior to entry to the building is an option. However, this would be difficult for such a mature building with extensive existing services located around the building footprint. A low cost retrofit solution would be to duct air into the core from below the overhang of level 4 of the tower. The acoustic performance of the building in its present form is generally considered to be good because there are no significant noise sources in the proximity of the building.

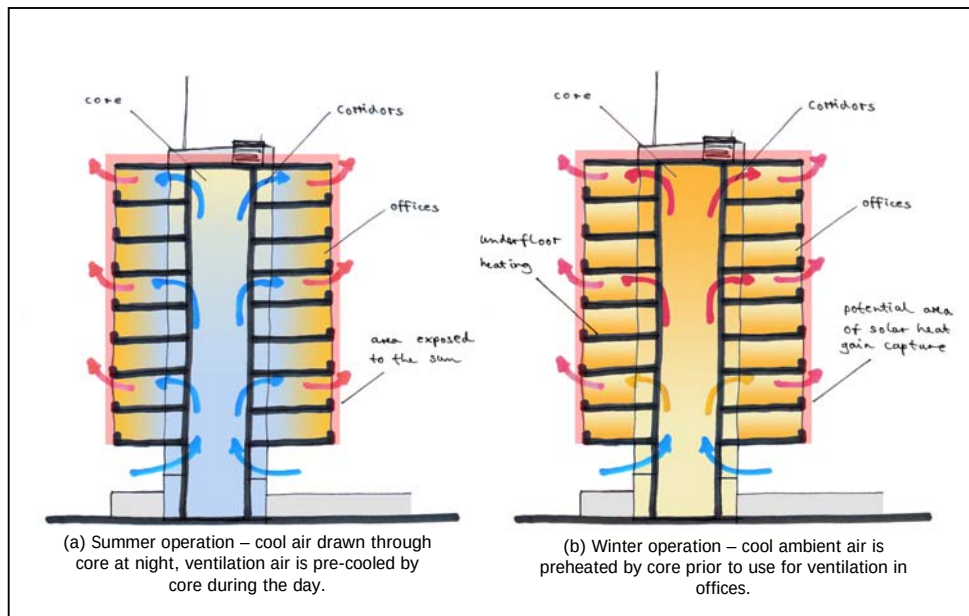


Fig.5 Use of the building core for forced ventilation and night cooling of the building.

There are three basic refurbishment options for the building envelope. The first one would be an improvement of glazing and wall construction and the second one the integration of an additional skin creating a double skin façade, either as a corridor or box window type (Fig.6a, 6b). A third solution would be the design of a climatic envelope which would cover the entire façade with a second mediating façade layer (Fig.6c).

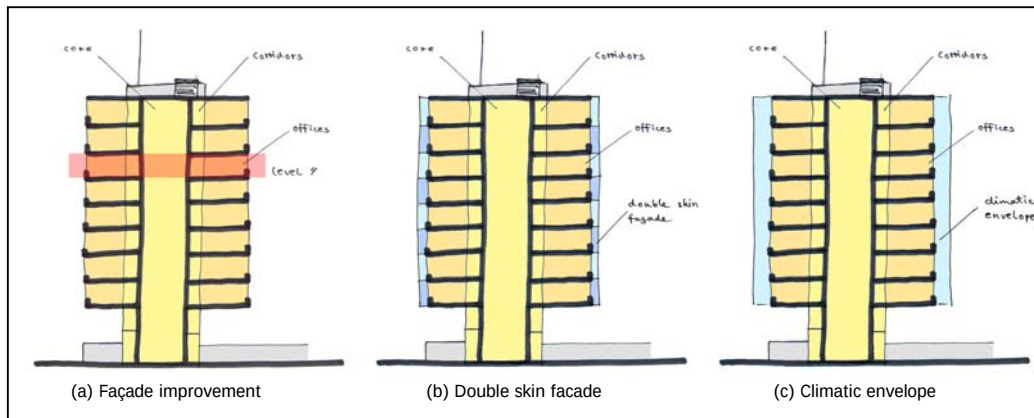


Fig.6 General refurbishment options.

3. Simulating Thermal Performance of the Faraday Tower

In order to establish the energetic performance of the existing building envelope a transient simulation software package was used (TRNSYS, 2002). Since floors 4 to 11 of the Faraday tower are identical the simulation model was reduced to one floor with thermally linked zones above and below representing the remainder of the structure. Floor 9 was chosen for detailed analysis in this study because it consists solely of offices and so is more representative of commercial buildings than other floors which often contain laboratories. Floor 9 has a maximum occupancy of 65 people split between 19 offices. A room by room survey of computer and other electrical equipment was undertaken combined with electrical lighting. On average, each member of staff has 1.2 computers, a working area of 5.2 m² which is illuminated at a level of 10 W/m² using fluorescent lighting. The offices range in size from 8 to 26 m², with a typical occupancy of 3.1 people (range 0 to 6). The central services core (2 lifts, 2 stairways) is surrounded by a linking corridor which leads to all the offices. The building is aligned 26 degrees off

true South towards the West (i.e South façade has an azimuth angle 26°). During the TRNSYS simulations the following conditions were used:

Working day	09:00 – 17:00	Monday .. Friday	60 % occupancy
Weekend	09:00 – 17:00	Saturday, Sunday	10 % occupancy

Electrical loads were determined per office based on maximum number of desktop and laptop computers. Each appliance was assumed to consume 230 W when in use. This high figure accommodates associated loads from other appliances such as printers, scanners and photocopiers. Each occupant was assumed to produce a heating load of 120 W based on the ISO7730 scale for light office working (ISO7730, 1994). The occupancy and electrical loads were scaled by the occupancy percentage and time of day parameters. Occupancy and appliance use factor account for internal heat gains which is especially important for the thermal situation in summer.

The Faraday tower is linked into the central heating system of the University (currently being upgraded to a combined heat and power system) which restricts heating to specific months of the year. The simulations assumed there was unlimited heating power available between the 1st November and 30th April to maintain all the offices at a set point of 21°C . There was no mechanical cooling or heating available during the summer months. 50% of the internal blinds within the offices were assumed to be closed at any point time.

4. Simulation Results for the Faraday Tower

Table 1 summarises the *at present* construction of the Faraday tower and compares it to a simple double glazing refurbishment combined with an option for night cooling of the core. The present building construction does not provide any active cooling and is predicted to have an annual heating demand of 132 kWh/m^2 per annum. A peak office temperature of 38°C is predicted for the highly glazed South West corner office of the building. The high peak value is an artefact of the simulation not taking into account occupant intervention, such as fans to increase the air exchange rate and so drive down the temperature in the office. 27°C is generally considered as the upper limit for thermal comfort within offices (ISO7730, 1994). Therefore, the table shows the predicted air conditioning load (energy required to expel from building) to maintain the offices below three different set point temperatures (27°C , 25°C and 23°C). The air conditioning loads for these 3 set points are relatively small ($9 - 35\text{ kWh/m}^2$ per annum) in comparison to the annual heating load. In addition, the coefficient of performance (COP) of a well defined air conditioning system is typically 2.5 or better meaning that the electrical load is in effect 0.4 kWh per kWh of heat ejected from the building.

Replacing the façade with a significantly improved glazing system (U-value reduction from 5.6 to 1.7) and improving the air tightness (ac/hr reduced from 2 to 0.75) exacerbates the summer months thermal problems of the building. This is despite a reduction in the solar heat gain coefficient of the glazing that is achieved through the use of a low-e coating. The predicted heating savings however, are quite dramatic, reducing demand by approximately 80% from $\sim 132\text{ kWh/m}^2$ per annum to around 25 kWh/m^2 per annum. The high level of occupancy and electrical loads within the building provide the majority of the heating and this could be enhanced further by improving the façade insulation which is poor by today's standards with a U-value of 1.0. However, such a simple glazing refurbishment would make the building virtually uninhabitable in the summer months and additional ventilation and cooling would be required. The predicted number of hours per year, for example, that the hottest office in the building would exceed the 27°C limit would rise from 1272 to 3240. Mechanical air conditioning of the refurbished offices would require 22 kWh/m^2 per annum compared to just 9 kWh/m^2 /annum for the building in its present state. Night-time cooling of the building core at an air exchange rate of 5ac/hr between 00:00 and 06:00 enables a significant reduction in the air conditioning loads, but cannot on its own provide the necessary level of climate control. The air conditioning loads for the building are projected to be reduced from 22 to 10 kWh/m^2 per annum for a set point of 27°C when night cooling is combined with air conditioning.

Table 1. TRNSYS simulations of various refurbishment / operating schemes for the Faraday building

Scheme	Operation	Heating load (kWh/m ² per annum)	Cooling load (kWh/m ² per annum)
At present construction - Single glazing 3mm with steel frame (U-value 5.6 W/m²/K) - U-value 5.6 W/m²/K SHGC 0.75 T_{vis} 0.75 - Façade cladding insulation U-value 1.0 W/m²/K	Heating in winter 21°C set point.	132	None
	No provision for summer cooling.	38 °C Peak office temperature. Hours per year office temp > 27 °C Best office mid N 316h Worst SW corner 1272h	Infiltration 2 air changes per hour
	Heating in winter 21°C set point. Mechanical air conditioning in summer	132 133 134	9 27°C set point 19 25°C set point 35 23°C set point
Double glazing refurbishment - Outer glazing IGDB 933 3.9 mm Comfort Ti-PS on low-e (AFG Industries) - Air 12.7 mm - Inner glazing 3.0 mm generic clear - U-value 1.7 SHGC 0.50 T_{vis} 0.75 - Original façade cladding	Heating in winter 21°C set point.	27	None
	No provision for summer cooling.	41 °C Peak office temperature. Hours per year office temp > 27 °C Best office mid N 1521 h Worst SW corner 3240 h	Infiltration 0.75 air changes per hour
	Heating in winter 21°C set point. Mechanical air conditioning in summer	22 23 26	22 27°C set point 34 25°C set point 51 23°C set point
	Heating in winter 21°C set point. Mechanical night cooling only.	27 39 °C Peak office Temperature. Hours per year office temp > 27 °C Best office N 482 Worst SW corner 2363	None Infiltration 0.75 air changes per hour
	Heating in winter 21°C set point. Mechanical night cooling combined with mechanical air conditioning in summer. Ventilation of offices via core in winter	27 28 32	10 27°C set point 20 25°C set point 35 23°C set point 00:00 – 06:00 5 airchanges per hour in core and offices 06:00 – 00:00 1 airchange per hour from core to office

SHGC = Solar Heat Gain Co-efficient

T_{vis} = Visual Light Transmission (%)

IGDB International Glazing Database Number (LBNL, 2004)

Unless otherwise stated air infiltration for offices set at 2 air changes per hour (ac/hr) for the *at present* construction and 0.75 ac/hr for the *double glazing refurbishment*. 50% of internal blinds area is assumed to be closed in each office. Note: simulation does not account for forced air exchange by occupants (fans / window openings)

Fig.7 shows the predicted office temperature profile for a South facing office of the Faraday Tower, Southampton, UK during a 7 day summer period of high solar gain. Day 225 = 13th August. Days 230 and 231 are the weekend where lower occupancy of the building reduces office temperatures. The low U-value of the single glazing means that peak office temperatures are similar to that of the refurbished double glazing when night cooling is applied.

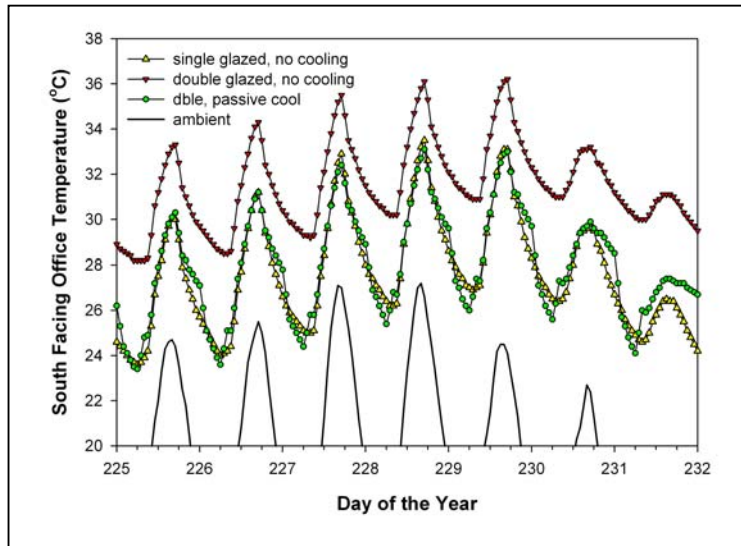


Fig.7 Predicted office temperature profile for a South facing office of the Faraday Tower, Southampton, UK during a 7 day summer period of high solar gain. Day 225 = Days 230 and 231 are the weekend, lower occupancy of the building reduces office temperatures.

5. Discussion

This study has shown that simply replacing the façade of a traditional 1960's building will result in significant energy savings in terms of space heating. However, these benefits must be offset against the resulting problems of summer months overheating that will almost certainly be the result of the refurbishment. The studied building has excellent potential to be used in a night cooling mode, but it appears that even this approach is not sufficient to provide the required level of thermal control. Additional protection of the façade such as solar shading or a secondary skin may be required, but this must be combined with better control of the interior loads of the building. Combining façade changes with interior load control (interior lighting based on occupancy / daylight factor, low energy appliances) will enable the building to approach performance requirements, but inevitably there will be certain days when the 27 °C upper limit will be exceeded.

Acknowledgements

This work has been undertaken as part of a project within the Sustainable Urban Environment (SUE) programme funded by the UK government Engineering and Physical Sciences Research Council (EPSRC). Project: Innovation in Design, Construction & Operation of Buildings for People (IDCOP), Project Partners: ARUP, Imperial College London, University of Greenwich, University of Reading, University of Southampton.

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BUILDING SUSTAINABILITY ASSESSMENT METHODS: INDICATORS, APPLICATIONS, LIMITATIONS AND DEVELOPMENT TRENDS

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Abstract

The aim of this paper is to analyse different ways of measuring sustainability in architectural projects. Measuring the level of sustainability of a construction project is not easy to achieve particularly when trying to quantify qualitative data and determining the most effective indicators for measuring such projects as defined by various stakeholders can be a complex process. A solid basis for decision making at all levels of building design and planning has been taken into account in terms of identifying key sustainability indicators relating to building development. Indicators of sustainability are necessary in assessing building projects at various levels: regional, national and international, in order to carry out the most balanced evaluation of environmental, economical and social factors.

Over the last ten years it has been increasingly important to understand the sustainability performance of buildings across a broader range of considerations. This has stimulated the development of a number of sustainability assessment tools that aim to encourage designers and planners to improve a building's performance. They aim to deliver objective measurements of a project's impact upon the sustainability, by taking in the three dimensions of environmental, social and economic measures.

This paper attempts to define key indicators for sustainability assessment, and compares three separate methods for the sustainability assessment tools: the Green Building Challenge (GBC) assessment; Building Research Establishment Environmental Assessment Method (BREEAM); and Sustainable Architecture Matrix (SAM). Such comparison is essential in order to evaluate the strengths and weaknesses of the various methods in order to allow for less subjective sustainability measurements.

Keywords : Sustainable assessment methods, Sustainability Indicators, Green Building Challenge (GBC), Sustainable Architecture Matrix (SAM), Building Research Establishment Environmental Assessment Method (BREEAM), Limitations.

1. Introduction

Measuring the level of sustainability of buildings is not easy to achieve. Indicators of sustainability are necessary for determining how well buildings perform against environmental, social, socio-cultural and economic criteria on regional, national and global scales. Sustainable assessment methods have emerged in recent years as a means to evaluate the performance of buildings across a broad range of sustainable considerations. The importance of such methods can be regarded firstly in terms of helping architects and planners in what is defined as the principles of "**selective environmental design**" (Hawkes et al., 2001) in which there is a strong relationship between climate and comfort and where a building is understood as a complex system of interrelated uses, spaces, materials, components and sources of energy. Secondly, the usage of such an assessment provides considerable theoretical and practical experience on their potential contribution in furthering sustainability responsible building practice. This issue was addressed by the WCED in 1987 and the Rio Summit in 1992, referred to as Agenda 21, and has encouraged the integration of 'indicators of sustainable development' in the monitoring of progress by international European governments. In addition to this, an important indirect benefit is that the broad range of issues incorporated in sustainable assessments requires greater communication and interaction between members of the design team and various sectors within the building industry. For example, sustainable assessment methods encourage greater dialogue

and teamwork. This paper as a result addresses the differences between the notion of sustainability and green indicators, and what are called effective indicators. It identifies some of the key limitations of existing building sustainable assessment methods and discusses the emerging importance of issues such as indicators, applications and development trends. These are presented as a basis for providing a positive direction for the emergence of less subjective sustainable methods and protocols.

The 'Green' Assessment Agenda? Assessment implies measuring how well or poorly a building is reacting, or is likely to perform, against a set range of criteria and indicators, named over a period of time: "green design", "ecological design" or "sustainable design". The distinction between the notions "Green indicators" and "Sustainable indicators" is critical in what structures sustainable assessment methods. In the early stages of the development of assessment methods 'green' as a concept has referred to design that maximizes the use of solar energy, day lighting and natural ventilation, as well as the harvest of rainwater, treatment of any waste on site and the use of environmentally sound materials. Applying the notion of green has a high market value and green buildings are more expensive than standard buildings. In other words, green buildings are proposed to have additional features to normal buildings and these additional features must carry with them additional costs. Meanwhile, the application of sustainable principles to building design usually lead to more simple solutions (for instance, smaller mass and energy flows), which by contrast with green application are less expensive in investments associated with running costs (Kohler, 1999) .

Sustainable Development. In terms of assessment scale, "green" assessment models place a higher emphasis on comparing performance on a regional and local scale, placing less focus on national and international comparability. Hence, sustainability has emerged to cover the broader concept for the environmental assessment methods. Such a concept is called Sustainable Development (SD) which attempts to address the conflict between protecting the environment and natural resources, and answering the development needs of the human race. However, it is believed that sustainable development would not be possible without certain social and economic changes; SD has environmental, social and economic dimensions including all factors of human activity such as industry, transportation, food production, and so on. *"A development which is respectful of the environment, technically appropriate, economically viable and socially acceptable to meet the needs of present generations without compromising the ability of future generations to meet their own needs"* (UNEP/ MAP/Blue Plan, 2000).

As to the application of sustainable development, unlike that of green architecture, it takes into consideration overlapping sustainability dimensions along with the wider scope of an assessment scale from the building itself to national and global scales. What can be added in terms of the integration of economic and social considerations is that environmental measures must not lead to a socially unacceptable development. Instead, sustainable development requires a continuous process of balancing all three systems to achieve an optimum result and cannot achieve less subjective results by providing sustainable answers for each system independently, as is illustrated by the following figure, where each step taken in the context of the measuring process is considered (Plessis, 1999) .

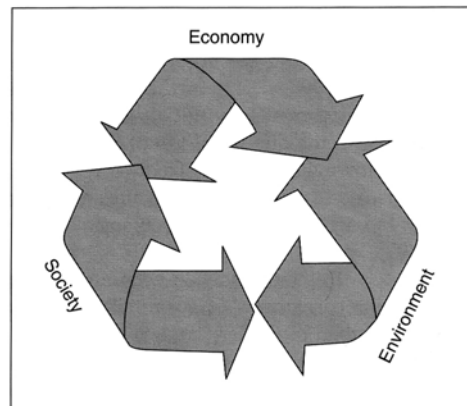


Fig.1 The decision making cycle for sustainable development. Author 2004 adapted from Plessis. C. D

2. The Selection of Sustainability Indicators (SI)

Indicators have become widely acknowledged as tools for measuring the performance of systems, policies, projects and so on. Depending on what is being measured, indicators have been used within different frameworks. The actual framework for indicators recognized by Pressure- State- Response is the mostly widely used. Furthermore, sustainable indicators are aimed at improving the economy, society environment patterns for the benefits of current and future generation's indicators. In other words, sustainable indicators have the overlapping dimensions of sustainable development. *Sustainability indicators are intended to give the level of sustainability in the past, for the current situation and in the future according to certain assumptions about change and evolution (UNEP/MAP/Blue Plan, 2000).* Therefore, sustainable indicators have been met with two main complementary definitions:

(i) A sustainability indicator is a land mark in the spatial scale (SDI Group, 2000). That is to say, using the indicator offers the opportunity to read the level of sustainability of a building design in space dimension, taking into account:

- The geographical location of the building, which is considered to be one of the main boundaries of sustainable assessment.
- The spatial level of intervention: Building, regional, national, international.

(ii) A sustainability indicator is a snapshot on the time scale, which offers the possibility of reading the level of sustainability for any building in the time dimension, taking into consideration two important factors:

- Continuous period, which help to define the trends over a continuous period of time.
- Fixed period, where the measurements are made at a certain time during a fixed period.

2.1 Characteristics of effective sustainability indicators.

An indicator is something that points to an issue or condition, the aim of the indicator being to reflect how a system works. If there is a problem, an indicator can help to determine what direction to take to solve this issue. Effective indicators have in common the following characteristics (Sustainable Measures, 2000)

- Effective indicators are **relevant**, which present something about the system that we need to know.
- Effective indicators are **easy to understand**, even by people who are not experts.
- Effective indicators are **reliable**; you can rely on the information that the indicator is providing.
- Lastly, effective indicators are based on **accessible data**; the information is available or can be gathered while there is time to act.

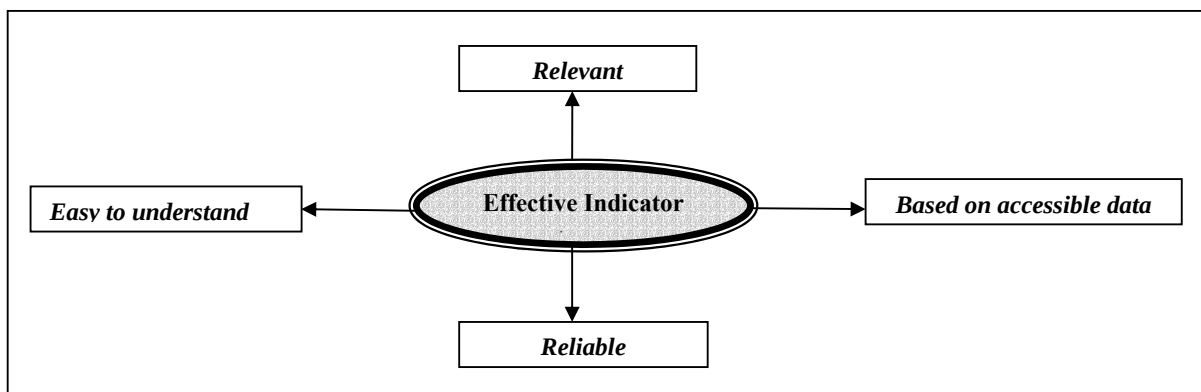


Fig.2 Characteristics of effective sustainability indicators, Author 2004

Items 1 and 2 are straightforward. However in point 3 the problem is ensuring reliability. Verifying and validating the techniques and data in this context is very difficult. In point 4, the problem is that only limited data is readily available and may not be in a form that is useful for the purpose of sustainability measures. Added to that we can not quantify what is an acceptable level of accessibility. Furthermore, achieving effective indicators depends on what dimension or element of sustainability they are trying to measure. Therefore, SIs as an actual framework is categorized into three groups: (Bell and Morse, 2003)

- (i) *State SIs*: in this case, SIs describes the state of variable. For instance, human population, income equality, female and male wage ratio.
- (ii) *Process (also referred to as pressure, control or driving force) SIs*: these are engaged in the case of measuring a process that in turn will influence a state SI. For example, a control (process) SI may be the rate at which a pollutant is passed into the environment.
- (iii) *Response SIs*: these are used to gauge a required process in terms of responding to governments. For example, to achieve adequate values of state and process indicators.

A good indicator however, alerts designer, planner and regulator to a problem before it gets worse, bringing into account qualitative and quantitative factors and helping to recognise what needs to be done to fix the problem.

3. Limitations in Sustainable Indicators Evaluations (Problems of Measurements)

When sustainable evaluation is used as a decision-aid within the public decision process, boundaries of assessment can be difficult to define, forming a critical issue in relation to the sustainable assessment method and revealing what are called ***limitations in sustainable evaluations (Problems of measurements)*** Understanding such limitations can help in providing positive direction towards prompting sustainable assessment methods in terms of delivering as close to objective measurement as possible. Thus some factors have been used to clarify these limitations as in the following paragraphs.

3.1 Boundaries of assessment

The scope and boundaries of the sustainable assessment method are critical; the figure below shows what can be used as a conceptual framework in terms of the wider perspective of sustainable issues in current buildings assessment methods, such a scope consisting of three “dimensions”: **Criteria, Time and Scale** (Cole, 1999). *“The level of sustainability is assessed by the team according to a deep understanding of the relevance and interpretation of the combined messages of the selected sustainability indicators. A view of the sustainability of the system can be built by the systems diagrams. The sustainability of the system can be monitored over time. Periodical re-examination is necessary in order to take into consideration changes occurring over time”* (UNEP/MAP/Blue Plan, 2000).

3.1.1 Criteria (Indicators). The criteria dimension refers to a set of considerations within sustainable assessment, distinguishing between ecological concerns (resource use, ecological loadings etc) human resources (indoor environmental quality, culture heritage integration etc), and economic factors (Maintenance, prosperity, etc). These issues can be divided into further actions as follows.

- The performance criteria, which can be considered as quantifiable factors or numerical, are defined and assessed and can be illustrated as solid lines, such as energy use, water use and so on. Such criteria (indicators) in this case, can be measured and hence can be called direct indicators due to their explicit influence on the way of assessment.

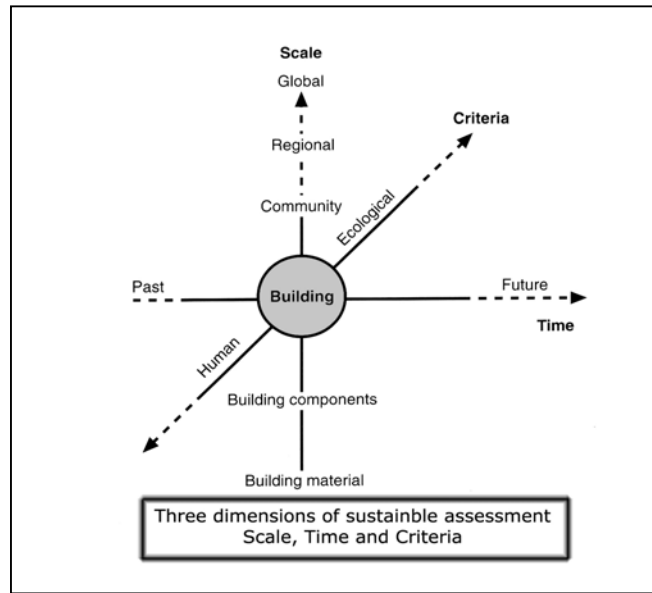


Fig.3. Three dimensions of sustainable assessment, Author 2004, adapted from Cole, R, 1999.

- Some performance criteria (indicators) that can be described qualitatively can be met with a wider interpretation. For instance, the loss of biodiversity etc. Therefore, their assessment is less certain and these are illustrated as broken lines. The application of these criteria in some points can be described as indirect impact because of the difficulties in assessing these or the lesser impact on the environment. Hence, what can be useful in this context is the converting of qualitative issues (feelings, impressions) into a quantitative value (Bell and Morse, 2003).

3.1.2 Time. Time scale is one of the most important factors in assessing sustainable development due to the changing nature of the performance criteria and the appearance of new ones over a period of time. The previous figure indicates two types of lines representing the time scale in the past, present and the future of a building. The distant past and long term future are less clearly known and less certain than the immediate past and future.

3.1.3 Scale. Building location and other contextual issues are important and can help in terms of the discussion regarding their legitimacy for inclusion in either a building assessment or design tool. Consequently, scale is obviously the critical dimension in relation to building environmental performance within the context of sustainability, architecture and urban planning. The individual building, however, is itself useful in the “green” building debate; conversely it is not valid as an appropriate scale to define and discuss optimal performance within a sustainability model. *“The spatial and temporal scale upon which Sustainable Development (SD) is built is considered to continue from the individual to the global” (Dahl, 1997).*

The objectivity and subjectivity of sustainability assessment, however, for building location is not sufficient in itself to obtain good results, despite having been considered for a long time as good enough tools in terms of environment assessment. There are cultural and social variations between regions and countries and measuring sustainability in one region according to several criteria is subject to differences from one area to another even when the same criteria are applied. A flexible assessment system is therefore required to allow the user to consider various spatial boundaries, while retaining an understanding of what is being changed and why it is best (Todd and Geissler, 1999).

4. Problems of Measurement (Combining Qualitative and Quantitative Factors)

Most assessment methods are based on explicit and measurable quality criteria, for instance, air quality and energy use. Meanwhile, some other studies focus on what are called quantitative techniques, striving for objective and comparable measurement, which can be regarded with reference to socio-psychological aspects of quality like privacy and human interaction. There is no doubt that the existing quantitative studies have great value for science and practice, but the problem is that they fail to

address the 'softer' and intangible aspects of quality. For example buildings should consider a good indoor environment and functionally support internal activities, but these characteristics only partly define excellence or delight in design because human response is equally important (Dewulf and Meel, 2004).

Another problem has become associated with the scope to find objective or universal quality standards. One of the most interesting issues is that no consensus has yet been validated on what constitutes excellence in building sustainability performance, and hence, one who deals with such an assessment can try to be as objective as possible in developing an assessment system. Achieving this might be possible in terms of basic qualities such air quality, but it seems to be very difficult when the issues are related to privacy and territoriality, not to mention beauty and delight. The question here is why such issues should be judged based on opinion instead of facts and therefore, many methods have accepted that many qualitative performance issues are, and will continue to remain, judgmental. However, it is important that we move towards making such judgments as objective as possible. Moreover, a number of researches have confirmed differences in quality and preferences between architects, other professionals and the public, highlighting major differences in judgments between various stakeholders.

"The definition of the level of sustainability for any given indicator is a difficult task which assumes an acute knowledge of both the indicator and of its milieu. Developing and evaluating indicators is further complicated because this process as applied in the current context is being undertaken in a subjective and participatory manner" (UNEP/MAP/Blue Plan, 2000).

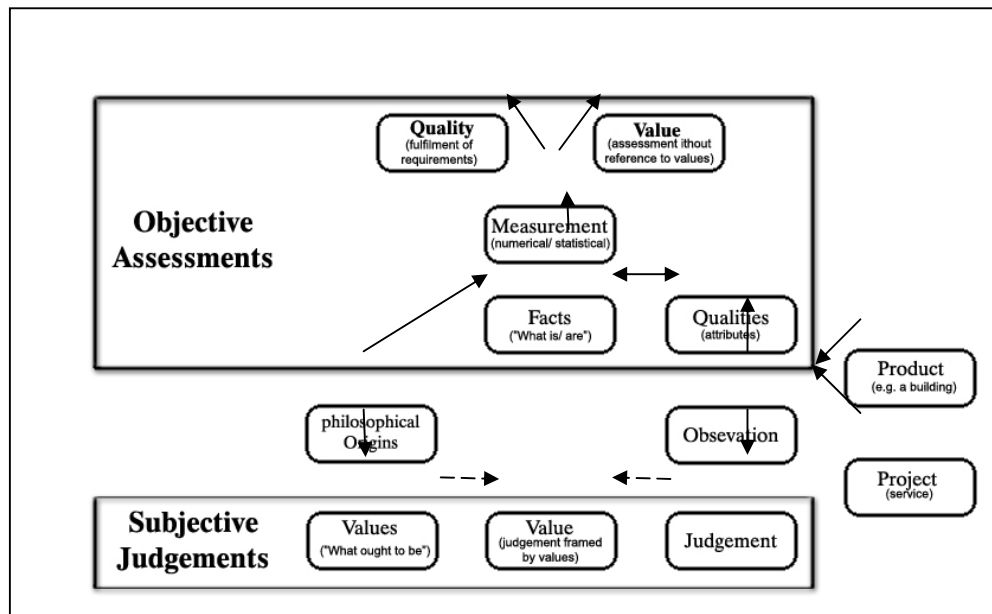


Fig.5. Value translation and assessment framework, Author 2004 adapted from Thomson et al.

5. Example of existing assessment methods

Over the last ten years it has been increasingly important to understand the sustainability performance of building across a range of considerations, stimulating the development of a number of sustainability assessment tools aimed at encouraging designers and planners to improve a building's performance and to deliver an objective measurement of a building's impact upon sustainability within the three dimensions of environmental, social and economic patterns. In order to identify a suitable methodology measurement, this section will present (in chronological order) analyse and compare different methods. This is essential in order to understand the demanded criteria for future proposed models to make the measurement less subjective and to understand the potential advantages and disadvantages of each method in terms of indicators, applications and scoring.

5.1 Sustainable Architecture Matrix (SAM), the original model.

Malcolm Wells in his book *Gentle Architecture* (1981) developed a matrix as a first attempt in terms of a Sustainable Architecture Matrix (SAM), first published in *Progressive Architecture*, March 1971. SAM is a distinctive matrix subdivided into categories representing a group of sustainability indicators. Each category is further sub-divided into sub-categories, the indicator weighting criteria. The priority level of each sub-category is determined within a range of 1 and 10, with (10) as the highest and (1) as the lowest priority. In this case, designers along with their client's assistance elaborate and decide which priority applies, taking into consideration the developer and the designer's impact criteria. The positive side of this approach is noted from the fact that the matrix itself responds to changing time, place and culture. Salem (1991) adapted this to his own matrix in Egypt with special reference to a tourist development in the Red Sea area. The evaluation mechanism in Salem's measuring matrix works according to both the priority level chosen by the designer and the degree to which the design achieves sustainability standards (25%...100%). Each category can be met either by a positive extreme or by a negative one (+ or -). In this model there is no consideration for a neutral point or Zero. A system of multiplication has been established which helps in obtaining the score level of sustainability of the project through its indicators:

$$\text{Level of priority} \times [+ (\text{percentage of achieving})] = \text{sustainability score}$$

Eq. 1

The sum of all the scores represents the level of sustainability of the project, taking into account the whole range of indicators to the developer and/or designer. The limitations of this matrix rest in the consideration of a sole group of indicators (mainly the environmental ones) and reflect an important limitation for SAM in terms of assessing the wider social and economic aspects. In addition, most of the indicators depend on quantitative rather than qualitative factors. The multiplier was identified as the priority level, set on a scale of 1 to 10, making the process of assessment complex and a controversial issue for the assessor to decide. For instance what is the difference between 7, 8 or 6? As a consequence the priority level is dependent on whoever carries out the evaluation, so ending in a subjective result.

Table 1. SAM test of category of water (Salem, 1991)

	-100 always	-75 usually	-50 sometimes	-25 seldom	Priority Level	+25 seldom	+50 sometimes	+75 usually	+100 always		
Negative Extreme (-)					Water					Positive Extreme (+)	Score
Destroys pure water					7.00					Creates pure water	-350.00
Wastes precipitation					4.00					Stores pure water	+300.00
Ignores use of grey-water					9.00					Uses grey-water	-900.00
Wastes run-offs					5.00					Creates percolation	+125.00
Obtains water from hinterland										Obtains water locally	+400.00

Score= -425

5.2 BREEAM, Building Research Establishment Environmental Assessment Method: UK experience.

Before the existence of BREEAM as a tool for environmental assessment, some consideration was given to a large share of environmental impacts arising from buildings and constructions in the UK. Such issues have been included as follows:

- People in northern Europe spend on average 90% of their time indoors, likely more than that in an urban environment.

- Buildings have a major impact on the global environment through energy use and the use of chemicals such as CFCs. In the UK and other Western European countries buildings account for about 50% of primary energy use and hence CO₂ output, far outweighing the contribution of either transport or industry sectors. Meanwhile, world wide, buildings account for 40% of energy use, 40% of materials use, 25% of timber and about 16% of fresh water.

Therefore, BREEAM, the Building Research Establishment Environmental Assessment Method has been launched as a mechanism for environment assessment, aimed at reducing environmental impacts across a wide range of issues affecting **"Global, Local and Indoor environments"**. The facts indicate that clients, designers and building users are convinced by the BREAAM scheme, with 25% of new office developments applying it in the UK. Such a method has covered different building types - new offices, new homes, new superstores, and supermarkets, new industrial buildings and existing offices. In terms of assessment scope however, each issue receives individual credit - a credit represents the design satisfies for the issues concerned. In other words, the assessment has taken into consideration positive aspects, but conversely, the principles of sustainability assessment aim at concerning the importance of diverse impacts for issues, which can be met with negative credit. However, to help the communication of this scheme with the user, a summary of performance has been included, expressing a wide rating of, Fair, Good, Very Good and Excellent where, for instance, a rating of excellent indicates a high standard of performance across the range of impacts.

Since 1990 BREEAM has become the most important organization in the UK dealing mainly with a wider perspective on assessing and improving building environmental performance issues, such as daylight, materials and construction, a wider meaning of energy, and so on. BREEAM has similarities with BEPAC, *Building Environmental Performance Assessment Criteria*, 1993-2000, in Canada and LEED, *Leadership in Energy and Environmental Design*, 1998-2004, in the USA. The similarities in assessment and weighting can be recognised in the use of labelling systems to consider mainly environmental aspects and positive applications. For this reason BREEAM is chosen as the forerunner among these organisations. Furthermore, BREEAM in 2002 developed a new checklist for development, taking into account this integrating process of a wider meaning for sustainable development, covering the aspects of social and economic dimensions for the first time in this method. Despite this attempt to join social and economic factors in this model, still the main purpose is restricted in building and local scales as well as a labelling system of assessment where it is not sufficient to say, good or very good in terms of performance level, because environmental labelling as a concept is not given even an obvious agreement on what it means to build or create a green building or how to define what is called a "good" building. Consequently, what is special about this organisation in recent years is a particular method for sustainability assessment, representing a unique checklist called ***a sustainability checklist for developments 2002***, depending on the combination of three associations and authorities in the UK, BREEAM, DTLR transport and local government regions, and the DTI (Department of Trade and Industry). Such a process works in terms of integrating all the principles of sustainability development, taking into account the importance of issue and sub issue and their impact on Environment, Social and Economic factors. A set of eight issue headings have defined these principles and are described a follows:

*** Land use, Urban form and design *Transport *Energy * Buildings * Natural resources * Ecology * Community *Business**

Concerning the way of assessment, this method has its own potential in terms of scoring, divided into four main parts of the checklist where in each of these issues; specific questions have been designed to cover the main aspects of sustainability in a schematic process:

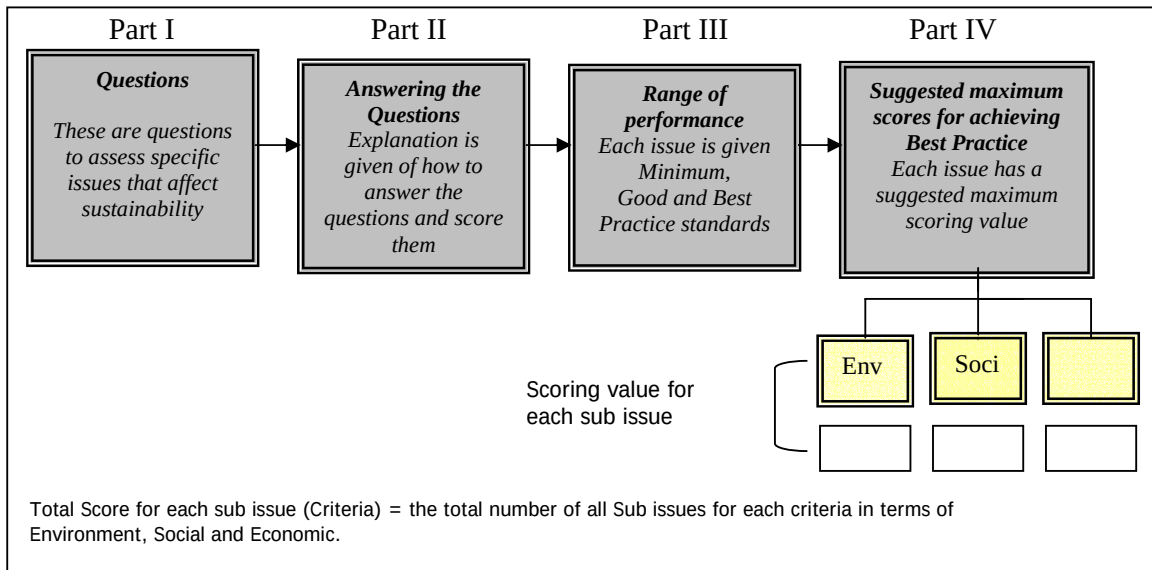


Fig.8 A sustainability checklist for developments 2002: Schematic process (Author, 2004)

In spite of the essential improvements of this method, the use of this mechanism can be met with both positive and negative aspects, where the table below indicates the potential advantages and disadvantages of the checklist process:

Table 3. Potential advantages and disadvantages of the checklist process (Author 2004)

The potential advantages of the checklist process	The potential disadvantages of the checklist process
1- Provides a framework for assessing the sustainability issues relating to buildings and infrastructure. 2- Provides guidance to developers, designers and planners on standards and indicators adaptable to local circumstances. 3- Valid mechanism employing overlapping sustainability indicators in the UK. 4- Assessment result diagrams help the reader understand the output result (Positive considerations), although still not valid in terms of presenting the complex relationship between indicators and sub indicators of sustainable development.	1- Focuses on limited indicators which relate directly to the building potential and its impacts on the sustainability dimensions (to obtain a less subjective assessment). 2- Considers a wide range of issues which can be issued in different countries, but range of performance and scoring in the UK cannot be applicable and sensible in countries like Egypt, where the criteria along with regulations and their impacts are different. (National scale) 3- Method does not use negative scores of sustainability indicators which are important in some organizations as mentioned above. 4- In terms of flexibility and readability, the method structure is not systematic or easy to understand, even worse sometimes an explanation for the process of translating the data to numeric is not clear, whereas it is significant for the reader to understand the process.

5.3 Green Building Challenge GBC and GBTool, the original model.

Green building challenge 98 (GBC 98) was a process developed by international teams from 14 countries which considered 34 cases in 1996. The objective of green building challenge 98 was to develop and demonstrate an improved method for measuring building performance within a range of environmental and energy issues, afterwards informing the international community of scientists, designers, builders and clients of the results. The GBTool as a scheme is aimed at defining explicit reference performance levels for all performance criteria. The purpose of this is to help the national teams establish what is called "reference building" to create benchmark performance levels. Furthermore, the GBTool assesses approximately 120 individual sub criteria and criteria; this can be regarded as an important limitation for GBC where it is necessary to reduce these assessment scores to a manageable number in the output models. Added to that the two critical issues within this debate are

the basis for deriving weightings and the manner in which the weighting process affects the interpretation of the aggregated results. As well as this, one of the main issues in this model is that no consensus had yet emerged on what constitutes excellence in building environment performance and what defines good environment building so that most users have found the GBTool difficult to use because of the complexity of the framework. Therefore, the scheme has been developed for use in GBC 2000, GBC 2002 and recently 2005.

Such improvements in the applications of GBC have been considered by international teams throughout the world, trying to find the answer to how one begins to define a 'good' or 'excellent' environmental building, which seems to be less objective than before, along with initial features for integrating environment, social and economic impacts. As a result, this process has been developed to deliver the closest objective measurement possible, using a special GBTool subdivided into categories representing a group of sustainability indicators, using seven main categories. The international team reach a consensus on the importance of each category, where each category has been met with a percentage out of 100% depending on its impact in sustainable dimensions. Each category is further sub divided to represent the indicator weighting criteria. A special range of scoring starting from -2 to +5 is established as a translation of an indicator value into a sustainable measure, as below.

	Highest Level Issues
A	Site Selection, Project Planning and Development
B	Energy and Resource Consumption
C	Environmental Loadings
D	Indoor Environmental Quality
E	Functionality and Controllability of Building Systems
F	Long-Term Performance
G	Social and Economic aspects

Fig.6 Highest level issues (GBTool 2005). Author 2004.

+5 (demanding performance) represent the advance considerations of current practice (Excellent performance)
+1 to +5 represents good practice reflecting stable conditions in terms of sustainability, (+3 Good Performance)
0 represents current standard or typical practice for the particular building type and region or due to the difficulty in obtaining data, these criteria will be given a score of 0. (Usually but not always defined by regulation)
(-1to -2) represents that the performance is not likely to meet the accepted industry norms, or the indicator performance can be met with negative impact.

Fig.7 Translation of an Indicator value into Sustainability Measure, (Author, 2004)

This method is considered to be much less subjective, the GBTool projects a linear ranking scale to identify the value of each criterion's coefficient: in terms of sustainability this is called a *Sustainability Multiplier*, and as it is mentioned in SAM matrix, the designer elaborates and the client decides which priority applies taking into account the developer and the designer impact criteria. Such multipliers are based on the importance of each criterion and weighted according to importance. For instance:

- 1- **Multiplier 0.9** corresponds to a macro level of importance (90% significance)
- 2- **Multiplier 0.45** corresponds to a medium level of importance (45% significance)
- 3- **Multiplier 0.1** corresponds to a micro level of importance (10 % significance)
- 4- **Multiplier "0"** means that has a nil impact (Insignificant impact now), or if the indicator is excluded from the assessment or if it is not applicable in the area. (0% significance)

Afterwards, each score is then multiplied by the weighting to give a criterion score:

$$\begin{matrix} \text{(Level of Performance)} \times \text{(Multiplier)} = \text{Sustainability Score} \\ V_n \quad \times \quad W1 \quad = \quad Sc_n \end{matrix}$$

$$V_n = -2 \text{ to } +5, W1 \leq 1$$

Eq. 2

The addition of all the scores in one category represents the level of sustainability of this category taking into account the whole range of indicators and sub indicators. Afterwards, adding the entire category scores (Seven categories) represents the level of sustainability of the project. In response to using this model/mechanism, the potential advantages and disadvantages of the GBTool test can be summarised:

Table 2. Potential advantages and disadvantages of the GBTool test

The potential advantages of the GBTool test:	The potential disadvantages of the GBTool test (Limitations):
➤ Application of a “sustainable rating” in terms of scoring and weighting. ➤ Coverage of a wide range of issues and sub issues on a building, national, and international scale. ➤ Integration of overlapping sustainability indicators (Environment economic and social). ➤ In term of objectivity, use of a Multiplier with a clear definition to some extent to create good practice, best practice and negative practice. ➤ Concern for Comprehensive measurement (positive and negative applications) ➤ In the case of feasibility and flexibility for the assessor, provision of defaults for issues whilst allowing teams to change these and to indicate what basis they used for their decision. ➤ Creation of a less subjective mechanism where the evaluator is able to highlight the importance of each individual category, indicator and sub indicator in terms of score and weighting ➤ Use of Excel programme provides cross cultural networks and adoption of international information for use at local level. ➤ Diagrams in the assessment results help the reader to understand either positive or negative outputs.	➤ The range of criteria and sub criteria can not be applicable for all types of building. Applying criteria can not be seen to be at the same level of importance from one region to another. ➤ In accordance with the achieving of less subjective measurements, this should focus on carefully selected indicators (Criteria) which are related directly to the building potential and its impacts on the sustainability dimensions, taking into account (Building, regional, national and global) scales. ➤ Measuring sustainability must express the overlapping sustainability indicators in the concepts of Environmental, Economic and Social aspects, where in GBTool model the variety of three dimensions are not considered despite the initial use of the interaction between these factors. ➤ Using the diagram still is not legible enough for the reader in terms of showing the complex relationship between criteria and sub criteria for each principle of sustainability.

6. Comparative Analysis of SAM, BREEAM, BEPAC, LEED, Checklist 2002 and GBTool

An overall conclusion can be drawn in the table below, the potential applications described in the proviso section, where the applications and scope for sustainable assessment in the building sector are used to contrast these six assessment methods: BREEAM 2002, Sustainability Checklist 2002, SAM, BEPAC, LEED, and GBC2005. These are based upon author's experience using the six assessment methods. As can be seen from the table, most methods do not meet all the identified applications needs for building sustainable assessment. Although GBC 2005 comes closest in terms of reliability, comprehensive measurement, considerations of overlapping sustainable indicators and so on.

Table 4. Assessment procedures for each method, Author 2004

Scope and Applications	SAM	BEPAC	LEED	BREEAM 2002	A Sustainability Checklist 2002	GBC 2005
Labelling/ Rating System	Rating	Labelling	Labelling	Labelling	Rating	Rating
National/International Scale	National/ International	National (Canada)	National (USA)	National (UK)	National (UK)	International, more than 14 countries
Consideration of overlapping sustainability indicators (Environment, Social, Economic aspects)	Environmental issues (can be more comprehensive)	Environmental issues	Environmental issues	Encompass the underlying Sustainability principles	Encompass the underlying Sustainability principles	Encompass the underlying Sustainability principles
Using a Priority Level (Multiplier)	Yes (1 10)	NO	NO	NO	NO	Yes (-2 +5)
Comprehensive Measurement (Positive and Negative applications)	Yes	Positive Only	Positive Only	Positive Only	Positive Only	Yes
Translated Data into Numeric (Interpreter)	Yes	Yes	Yes	Yes	Yes	Yes
Distribute the scores and weights of Indicators, sub Indicators according to their impacts and importance on SD.	NO	NO	NO	NO	NO	Yes
Using a special equation for Scoring process	YES	NO	NO	NO	NO	YES
Using a Readable and flexible process (Systematic process).	YES	NO	NO	NO	Start using systematic process, not flexible and easy to understand	YES
Using a Diagram in the final result (helping the reader to understand the output result)	NO	NO	NO	Start representing new figures (not comprehensive)	Start representing new figures (not comprehensive)	Start representing new figures (not comprehensive)

“SAM” Sustainable Architecture Matrix
“BEPAC” Building Environmental Performance Assessment Criteria

“LEED” Leadership in Energy and Environmental Design
“BREEAM” Building Research Establishment Environmental Assessment Method

A Sustainability Checklist for Developments 2002
“GBC” Green Building Challenge 2005

Conclusions

Significant advances in sustainable assessment methods have been seen in the last ten years. However, significant work remains to be done on the development of tools to make the measurement less subjective, more reliable, and the process of calculation more flexible and easier to follow. Having carried out a comparative evaluation of various models for the measurement of sustainability it is now possible to define or make recommendations on what a future good model should contain. In order to achieve the higher level of objectivity in the measurement and calculation process the following factors should be carefully considered. The following points summarise carefully the most appropriate and vital principles towards measuring the levels of sustainability of buildings in general:

- 1- Appropriate (Selective) indicators (SIs): In order to measure sustainability, a SIs based model is the most appropriate format, and hence three overlapping components of sustainability (Environmental (EI, Social SI and Economic ECI), are considered as a basis for sustainable assessment, and form the components of this system. The frontiers of sustainability however, are much larger and cover quite a wide range of issues. Thus, in order to obtain objective measurements a number of sustainability indicators (SIs) are required, directly related to the exiting issues in the region or building, taking into account time and spatial scales.
- 2- Considering Qualitative and Quantitative data: Apart from finding objective or universal quality standards, one of the most interesting issues in the scope of measuring sustainability is the implementation of qualitative and quantitative data. Until recently most data applied by most stakeholders has been quantitative, such as air quality. However, when it comes to issues of judgment data interpretation this seems to be very difficult and continues to remain subjective. What can be useful in this case is the conversion of qualitative issues into quantitative values (numeric).
- 3- Using a systematic process (readable and flexible model): The test of any case study should be regarded in a holistic way, where at the same time the tool itself should be flexible and adaptable, as it can be applied to different places, different scales and at different times. Unlike existing models where the structure of how the methods works is not systematic and not easy to understand, or even worse an explanation for the process of translating the data to numeric is sometimes unclear. The proposed model is essential to be readable and flexible in terms of understanding the arrangement of data and the scoring process in the pyramidal or in a systematic structure.
- 4- Use a comprehensive measurement method (Positive and Negative applications): Measurement of sustainability is regarded as one of the most difficult options for the researcher and the designer, where most stakeholders have implemented positive considerations in their attempt to improve building components or what is regarded as a good building. The problem lies with the notion that no consensus has yet been validated on what constitutes excellence in building sustainability performance, and hence, negative implications which can be applied as unsustainable applications in existing buildings may be ignored. Furthermore, the considerations of positive and negative applications can help the researchers, designers and planners in understanding what make up the various impacts on sustainability applications from both negative and positive dimensions. Negative aspects however, can help in terms of promoting our buildings towards more sustainable dimensions; taking into consideration the lesson we can learn from these applications.
- 5- Using interpreter, Multiplier and Equations: One of the most important factors in terms of making the sustainability measurement less subjective but readable, adaptable and easy to understand is the use of Interpreters, Multipliers and equations, where existing data for each indicator can be met with a specific numeric (interpreter) in the way of translating the data into a number. Moreover, the importance of this indicator and its difference from another can be translated into a special use of a Multiplier according to the impact of this indicator on the sustainability dimensions. To achieve the sustainability score, an equation is employed to reflect the application of indicator performance in terms of positive and negative applications. The use of

interpreters and multipliers will help the reader translate the reference data into numerical values achieving less subjective assessment and avoiding open interpretations.

- 6- Using a Graphic illustration for the Sustainability measurement, Rader diagrams show different variables simultaneously, allowing the reader to understand the existing data in graphic representation. Such illustrations should also help the reader in understanding both intermediate and final scores of sustainability and allow the comparison of scores across different case studies.

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LIFE CYCLE ASSESSMENT OF A BUILDING SERVICES FOR HOSPITAL OPERATING ROOM

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Abstract

The paper deals with the environmental Life Cycle Assessment (LCA) of HVAC plants operating in an emergency ward of a major hospital building in North of Italy. The analysis was performed in order to evaluate the environmental impact of individual components such as heat generators, heat pumps, air handling units and distribution systems and their effects on the overall environmental balance of the HVAC system.

When a component is utilized in a circuit for functional wards, LCA takes only into account of the fractional environmental damage to that particular ward. The assessment was made using the Dutch code SimaPro 5.0[®] in accordance to EcoIndicator 99 thus enabling quantification of the environmental damage due to different impacts. In this analysis the software uses a database built from past cases.

Keywords: Life Cycle Assessment, Sustainable Buildings, Environmental impact of Building Services, Green Policies.

1. Introduction

The introduction of the concept of Embodied Energy takes into account both the running energy management of a system (phase of management) and the energy used in all the processes, from the extraction of the materials up to the assembly of the components (phase of production), allowing a proper comparison of the two phases (Cammarata et al., 2001; Finnveden et al., 1997).

These studies highlighted that the energy consumed in the production phase could be of the same order of magnitude of the plant's annual consumption, (Di Filippo et al., 1986; Baroncini et al., 1988; Giachetta et al., 1988), hence indicating the significant importance of evaluating the energy assigned to the production of components.

The environmental impact for the production of a conventional heating system component has the same order of magnitude of damage for seasonal running energy consumptions, while it can be considered of the same order of magnitude of the running energy management of the entire life cycle in the case of a solar collectors plant (De Santoli L., 2005).

The present work deals with the case of a particularly high tech building, e.g. an operating room of an hospital placed in the North of the Italy, in order to verify the latter sentences in the extreme cases.

HVAC plants for an operating room depend on a series of typical requirements, such as:

- high air quality control, involving high airflow rate and high performance filtering;
- the necessity to maintain the correct relationships of pressure with the surrounding environments for asepsis's hygienic reasons and for the safety against the fires;
- high maintenance quality

which include particularly accurate HVAC systems (APAT, 2003; Allenby, 1997).

The approach used in the paper is related to the application of the LCA (Life Cycle Assessment) methodology for HVAC plants (Graedel E. T., 1997; Davies T., 1999; De Santoli L., 2005).

2. The methodology of LCA, Life Cycle Assessment

The LCA methodology is a quantitative method of analysis and evaluation for the environmental impact of products and services, normalized by International Standard Organisation ISO with the European Standard UNI EN ISO 14040 and approved by the CEN, (ISO 14000, 1997-2000). The analysis concerns the whole life cycle of the products from the extraction and treatment of the raw materials to the disposal of the products after use. Every phase is analyzed, from cradle to grave, for establishing the links among previous or following phases, skipping over the production and the disposal of the machineries used for processing.

In this study, the LCA software used was SimaPro 5.0[®] Code together with Eco-Indicator99 which evaluates environmental damage from the aspects of Human Health, Ecosystem Quality and Resources, (Prè, 1999; Goedekoop M.J., 1993).

The analysis used a Data Base on HVAC which was developed in the study (De Santoli L., 2005) and extended to processes of components and elements not included in existing archives. The so-called Egalitarian Cultural perspective, was adopted and modified in order to take into account the three effects of environmental damages mentioned above.

LCA was carried out following the procedure highlighted by SETAC (SETAC, 1993) and UNI EN ISO 14040, in four steps:

1. Definition of the goal and the field of application of the study
(*Goal and Scope Definition*; UNI EN ISO 14041,1998);
2. Inventory's analysis in which is compiled an inventory of substantial inputs (materials, energy, natural resources) and outputs (issues to air, to water, to soil),
(*Life Cycle Inventory* - LCI; UNI EN ISO 14041,1998);
3. Evaluation of the potential, direct and indirect, environmental impacts, related to these inputs and output, (*Life Cycle Impact Assessment* - LCIA; UNI EN ISO 14042,2000);
4. Analysis of the results and evaluation of the improvements made to the two previous steps's,
(*Life Cycle Interpretation*)

A brief explanation of each step is dealt with in the next sections.

3. Goal and scopes of work : Plant Description

The hospital has a total surface of about 75.000 m², a volume of about 220.000 m³ with 620 bed and 12 operating rooms.

The hospital has both thermal and cooling plant, to produce hot and cold water and vapor.

The thermal plant contained two heat generators with the capacity of 10500 kW and 8400 kW with two vapor generators of 5200 kW; each producing 7760 kg/h of vapor.

The cooling plant of the hospital is connected to three compression-type chillers, two of these are condensed by water and one by air. The water condensing units have a capacity of 1300 and 3300 kW with two evaporative towers situated near the hospital. The air condensing unit of 1394 kW was installed outside of the building.

Fig.1 shows the master plan of the hospital, in which the functional areas are outlined : hospitalizations, slab zone, mechanical plants (situated at level +1) and the operating block (situated at levels -1 and 0).

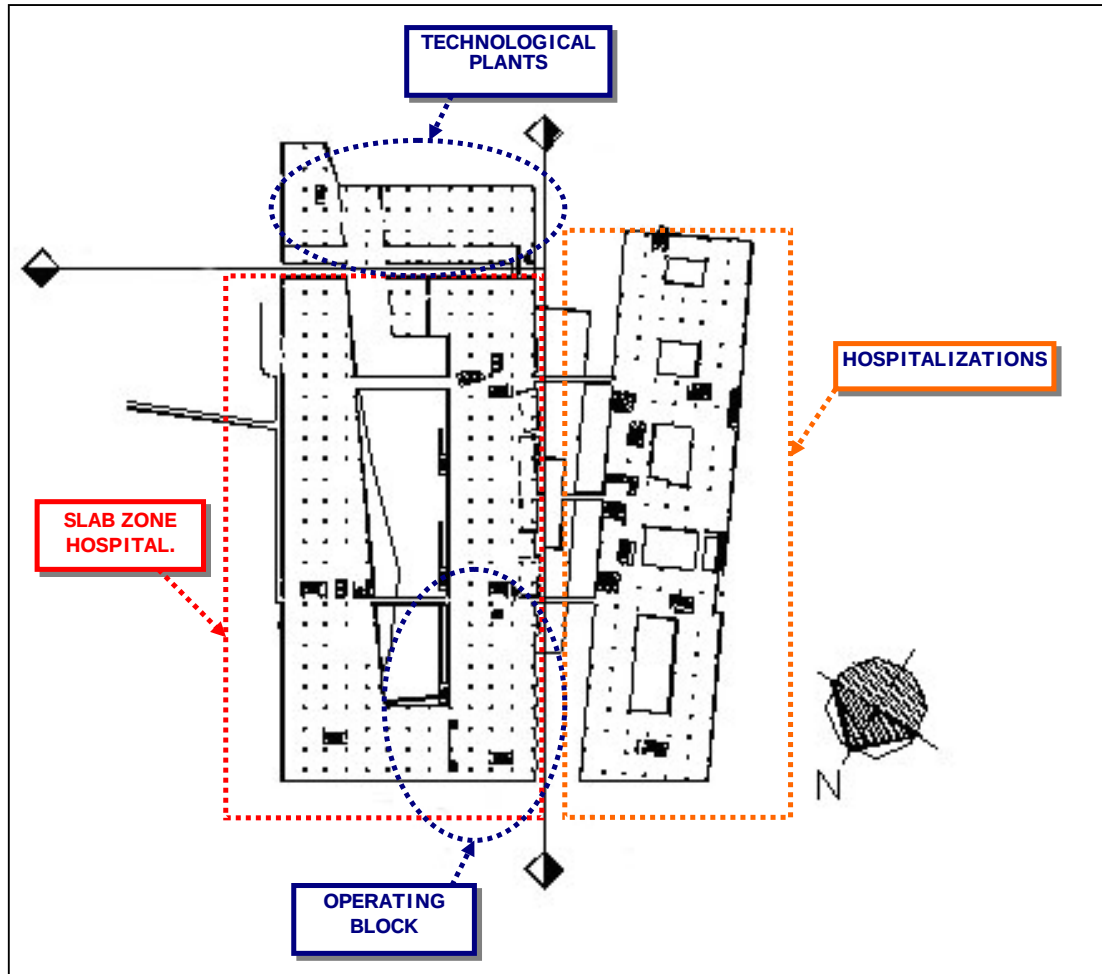


Fig.1 Hospital Master Plan

Primary water distribution and secondary lines distributing the thermal and refrigerating energy to the different end users are shown in Fig.2.

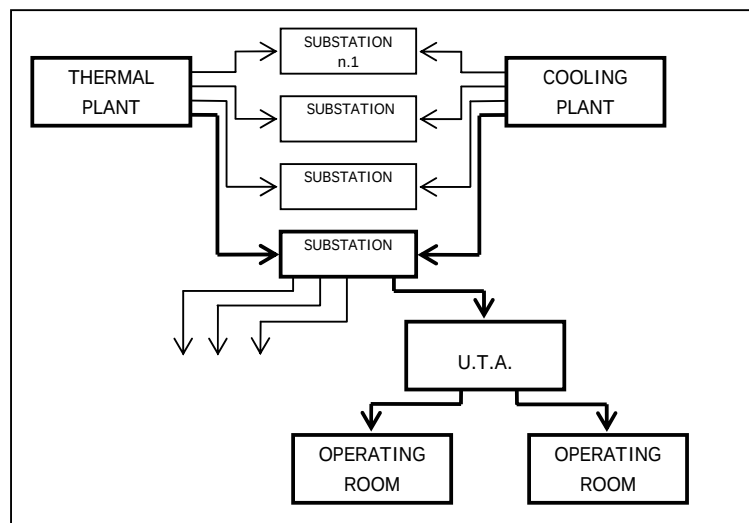


Fig.2 Operating Room Plants Scheme

The air conditioning of the operating rooms is realized by means of all-air type, with local post-heating coils. The air supply is distributed with unidirectional or laminar flow nozzles for the operation area. The air is being transferred is by means of airshafts with terminals located in the corners of the room.

The reference functional unity, used in the analysis, includes the whole air handling unit parts of plants and accessories for the operation and services to annexed rooms located respectively in the ground floor and the basement of the hospital. The corresponding volume considered is about 600 m³.

The ventilation system gives 20 h⁻¹ ACH, and can be limited to 10 ACH in stand-by position. Inside the rooms a temperature of 20÷24 °C is controlled at 50% humidity ratio.

4. Life Cycle Inventory

Every component is described by a process which were reported by Curran M.A., 1993 :

- the *materials*, the used quantities and increase of waste percentage.

Table 1. LCA of Operating room plant

	COMPONENT	SIZE	MEASURE UNIT	DURABILITY/SUBSTITUTION
	Air Treatment Unit	100 %	7850 m ³ /h	15 years
	Duct	100 %	604 m	30-40 years
	Diffusors	100 %	14	27 years
	Post-heating coil	100 %	4 da 1,5 kW 2 da 13,5 kW	20 years
THERMAL PLANT for warm water production 0,52%, for cold water production 0,34%.	Heat generator	0,52 %	10467 kW 8374 kW	25 years
	Vapor generator	0,34 %	5234 kW	25 years
	Water treatment	0,52 %	-	15 years
	Burner	0,52%	3200-17600kW 1800-12000 kW	20 years
		0,34 %	2 x 10500 kW	
	Pipe lines	0,52 %	50000 kg	20 years
	Expansion device	0,52%	4 x 750 L 5 x 150 L	20 years
	Pumps	0,52%	3 x 15 kW 1 x 18,5 kW 1 x 30 kW	15 years
		0,34%	2 x 11 kW	
	Heat exchanger	0,52%	5200 kW 5200kW	24 years
COOLING PLANT for cold water production 2,04 %.	Water cooling	2,04 %	1371,24 kW 3300 kW 1394 kW	15 years
	Evaporative towers	2,04 %	1932 kW 3828 kW	20 years
	Water treatment	2,04 %	-	15 years
	Pipe lines	2,04 %	50000 kg	17 years
	Expansion Vase.	2,04 %	1000 L	20 years
	Pumps	2,04 %	4 x 15 kW 1 x 22 kW 1 x 30 kW	15 years
THERMAL SUB-STATION Warm water circuit 2,19 %; warm sanitari water circuit 0,50 %; cold water circuit 5,26 %; vepor productior 0,80 %.	Water treatment	0,8 %	-	15 years
	Pipe lines	3 %	27000 kg	17 years
	Expansion Vase	2,19 %	2 x 1000 L	20 years
	Pumps	2,19 %	2 x 11 kW 1 x 15 kW	15 years
		5,26 %	30 kW	
		0,5 %	2 x 1 kW	
		0,8 %	4 kW	
	Heat exchanger	2,19 %	3 x 1500 kW	24 years
		0,5 %	2 x 500 kW	
	Reservoir	0,5 %	2 x 1000 L	25 years
	Indirect vapor productior	0,8 %	3 x 1660 kW	25 years

- the *packages*;
- the *functions* for every material, (Finnveden G., 1997; Di Filippo P., 1986; Baroncini C., 1988; Giacchetta G., 1988);
- the *transports*, specifying the types and means;
- the *land use* of the factory where they are produced;
- the *disposal* of material and specifying the kind of treatments (Fig.1) (APAT, 2001).

Table 1 indicate the values used in the inventory.

The durability of each component (ASHRAE, 1993) and the consequent during the total life cycle of the plant were considered in the study.

According to the energy consumptions, two different conditions of working were studied (i) 24 hours/day running at 20 ACH (ii) 12 hours/day at 20 ACH and 12 hours/day (from 20,00 to 8,00) at 10 ACH.

In the two cases above the following values in Table 2 will be assumed.

Table 2. Annual consumptions of Operating Room.

	CASE I 24 hours/day		CASE II 12+12 hours/day	
	Electric Energy (kWh) ¹	Natural Gas Energy (kWh) ²	Electric Energy (kWh) ¹	Natural Gas Energy (kWh) ²
SUMMER	31308	48404	25679	37408
WINTER	3557	347945	3557	252477
TOTAL	34865	396349	29236	289885
1. COP of chiller = 3.				
2. Natural gas 38 MJ/nm ³				

5. Impact Assessment for reference functional unit

The environmental LCA for 20 years life shows a marked difference in energy consumptions; in fact the latter is responsible of 97% of the environmental damage in the first case and 95% in the second case, see Fig.3.

The impact connected to the production and substitution of the two HVAC components is similar to that caused by the consumptions of electricity and natural gas in a period of 2 years.

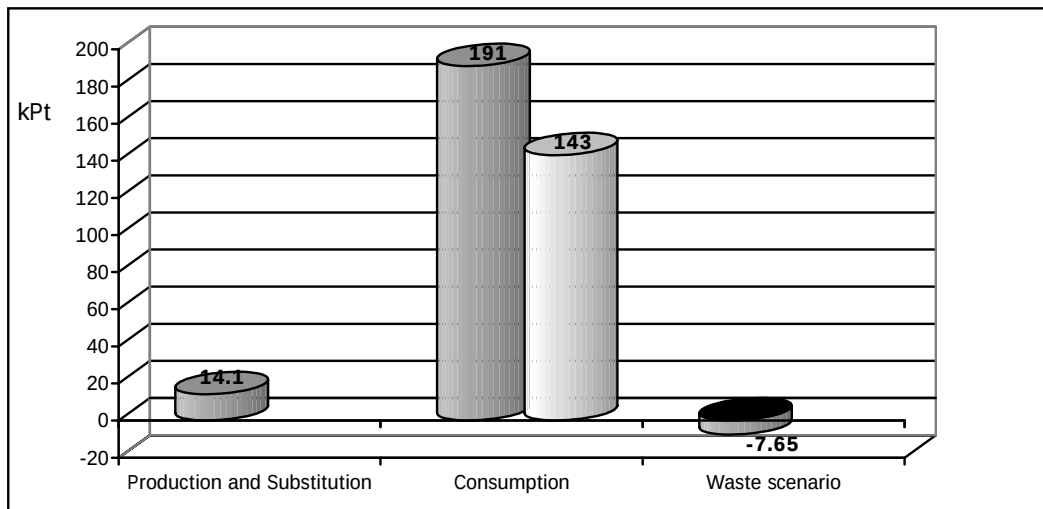


Fig.3 Evaluation about 20 years of Operating Room life cycle.

The elements that mostly contribute to the total environmental damage are the ducts in galvanized plate (Z200 and Z600) used for the distribution of the air; the damage is to attribute mainly to the long distance from the air handling unit to the operating rooms. The process of hot galvanization for the protection of the plates from the corrosion, emits in air a significative quantity of zinc (1,4 kg), provoking a consistent alteration of the ecosystem toxicity values; the subsequent protective layer cause a reduction of the steel quality for recycling, reducing the associated environmental advantage.

Among the components production, the air handling unit causes an higher environmental damage (1/5 of total assigned to the production phase); the entity of the damage is connected to the materials used independently by the sophistication of the components (i.e. the high performance filters are responsible of less than the 1% of the whole unit impact).

Chillers are very harmful; the refrigerant R134a used causes the 1,5% of the chiller total impact, but it important to highlight its damage in the Climate Change category (equal to the CFC's one) nevertheless its low impact in reference to ozone layer depletion.

In the analysis, the durability of the components assumes a remarkable relative weight, and the substitutions provoke an increase percentage of the environmental impact related to the elements.

The Table 3 shows the quantification of the environmental damage caused by the production and substitutions of HVAC components per operating theatre functional unit (600 m³), the energy consumption during the considered plant life (20 years), and by the prevision of a recovery strategy at the end of the life (APAT, 2001).

Table 3. LCA for the Operating Room in 20 years (functional unit 600 m³)

	COMPONENT	PRODUCTION AND SUBSTITUTION DAMAGE Pts	DISPOSAL DAMAGE Pts	I CASE PRODUCTION, SUBSTITUTION AND DISPOSAL DAMAGE %	II CASE PRODUCTION, SUBSTITUTION AND DISPOSAL DAMAGE %
	Air Handling Unit	3780	-1850	0.977	1.288
	Ducts	4740	-2390	1.19	1.569
	Diffusors	85.3	-23.6	0.031	0.041
	Post-heating coil	88.5	-13.5	0.038	0.05
THERMAL PLANT	Heat generator	544	-345	0.1	0.133
	Vapor generator	198	-125	0.037	0.049
	Water treatment	14.4	-7.66	0.003	0.005
	Burners	37.9	-17.9	0.01	0.013
	Pipe lines	265	-152	0.057	0.076
	Expansion Vase	3.5	-2.13	0.001	0.001
	Pumps	10.1	-1.98	0.004	0.006
	Heat exchanger	1.98	-1.14	0.0002	0.0003
	Water cooling	1690	-1080	0.309	0.407
COOLING PLANT	Evaporative towers	615	-426	0.095	0.127
	Water treatment	0.386	-0.0478	0.00015	0.00017
	Pipe lines	1030	-595	0.22	0.291
	Expansion Vase.	3.66	-2.23	0.001	0.001
	Pumps	53.7	-10.5	0.022	0.029
	Water treatment	0.091	-0.0153	0.0007	0.0009
THERMAL SUB-STATION	Pipe lines	818	-473	0.175	0.23
	Expansion Vase	7.85	-4.78	0.0018	0.002
	Pumps	40.7	-7.99	0.017	0.022
	Heat exchanger	22.8	-14.1	0.005	0.006
	Reservoir	1.88	-0.749	0.0005	0.0005
	Indirect vapor productur	1.53	-0.892	0.001	0.0004
					0.0004
CONSUMPTION I CASE	Electricity	35000		17.7	
	Natural Gas	156000		79	
CONSUMPTION II CASE	Electricity	29400			19.6
	Natural Gas	114000			76
HUMAN HEALTH				21000 Pts	16300 Pts
ECOSYSTEM QUALITY				3080 Pts	2440 Pts
RESOURCES				173000 Pts	130000 Pts
				197000 Pts	148000 Pts

Such a quantification is expressed both in Eco-indicator conventional points (Pts) and in percentage and it is referred to the three main damage categories.

6. Conclusions

The high level of performance requested to satisfy the demands of a complex building like an hospital is responsible of a relevant environmental impact quantified in approximately 250 Pts/m³, the score representing the global environmental damage in three reference categories: human health, ecosystem quality, resources.

The environmental impact related to the production and substitution of the HVAC components is equal to around two times the damage of the annual energy consumptions of the system (14 kPts against 7); in the simple case of a heating traditional system for residential premises, the impact of production on environment is of the same order of magnitude of the annual energy consumption (De Santoli, 2005).

The difference is related to the components of the HVAC for operating room, often characterized by a low running consumptions faced to an high environmental impact caused by the production and disposal phases.

The paper confirms the demand to enlarge the environmental analysis of the HVAC systems to all the life cycle phases, stressing the critical factors such as production, recycling and disposal with the purpose to improve the general environmental performances of the systems.

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A METHODOLOGY FOR LIFE CYCLE ASSESSMENT OF BUILDING SERVICES

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Abstract

The study described in this paper focussed on the requirements of Life cycle Assessment (LCA) of HVAC system. The environmental behaviour of an HVAC system evaluated by LCA considers all the process necessary for components production, use and disposal. A database for Italian conditions was created for examining the environmental impacts of material, transport, land use and energy consumption of HVAC's processing and management. The database is capable LCA of building services. The application of the methodology is proposed for there different heating systems i.e traditional, solar and heat pump systems for the energy requirements of residential buildings in Rome. The LCA was undertaken by means of Dutch Code SimaPro 5.0[®] in accordance to EcoIndicator 99. The LCA of the studies showed that the renewable energy sources (solar collectors) or high performance (heat pumps) cause low environmental damage for energy consumption but high impacts on global environmental balance of the plant production resulting from the components.

Keywords : Life Cycle Assessment, Sustainable Buildings, Environmental impact of Building Services, Green Policies.

1. Introduction

It is important to find a correct balance between the safety of the environment and the advantages brought about by technology. This is necessary in a society where the demands of environmental concerns are continually increasing and a consequent more and more innovative and sophisticated technologies are required to overcome these needs.

As the attention on environmental problems increases, consequently the interest for the development of methods and techniques that allows understanding, to assess and to reduce the environmental impacts of the products is demanded.

The research on the HVAC systems, analysed the energetic consumptions and the corresponding issues during the use and the management of buildings for reducing the environmental impact.

The concept of Embodied Energy takes into account both the running energy management of a system (phase of management) and the energy used in all the processes, from the extraction of the materials up to the assembly of the components (phase of production), allowing a proper comparison of the two phases (Cammarata et al., 2001; Finnveden et al., 1997).

These studies highlighted that the energy consumed in the production phase could be of the same order of magnitude of the plant's annual consumption, (Di Filippo et al., 1986; Baroncini et al., 1988; Giacchetta et al., 1988), so they confirm the marked importance of evaluating the energy assigned to the production of the components.

At the same time the complexity of the environmental problems, not easily referred to a clearly defined factor of pollution, highlights the limits of the evaluation method, referred to as the Embodied Energy, because it does not take into account the sources of energy, the transport, the land use, the demolition and the recycling which affect the environmental pollution.

The aims of a Life Cycle Assessment for the main building services components is related to such a demand.

2. Life Cycle Assessment and Eco-Indicator 99

The LCA methodology (Life Cycle Assessment) is a quantitative method of analysis and evaluation of the environmental impact of products and services, including the whole life cycle of the products, from the extraction and treatment of raw material to the waste treatment of the product after the use, "from cradle to grave", because any single action associated to a phase is strictly connected with the previous or the following phase, (ISO 14000, 1997-2000).

At Present several methods covering a complete LCA are available. They are generally two different approaches; (i) the bottom-up approach analyzes the inventory of the product or service [Life Cycle Inventory (LCI) of inputs such as materials, energy consumed for material processes, natural resources and of outputs as emission to air, water and soil]. In such approach, the phase for damage evaluation is an optional element, to be included separately for better understanding of the ecological consequences of results from the inventory analysis. (ii) the top-down approach starts by an aprioristic definition of the environmental problems, defined in an univocal way for the parameters influencing it, (Prek, 2004).

In this study the Eco-Indicator99 Method was used. It is applied by the SimaPro 5.0[®] Code software tool. Both were developed by the Pré (Product Ecology Consultants) on behalf of Dutch Ministry of Environment (Goedekoop, 1993; Prè, 1999). The method uses a top-down approach defining "environment" as the whole physical, chemical and biological parameters influenced by man. These parameters are reassessed in three categories of environmental damage: the Human Health, the Ecosystem Quality and the Impoverishment of the Resources, and subsequently in eleven impact categories, (Fig.1).

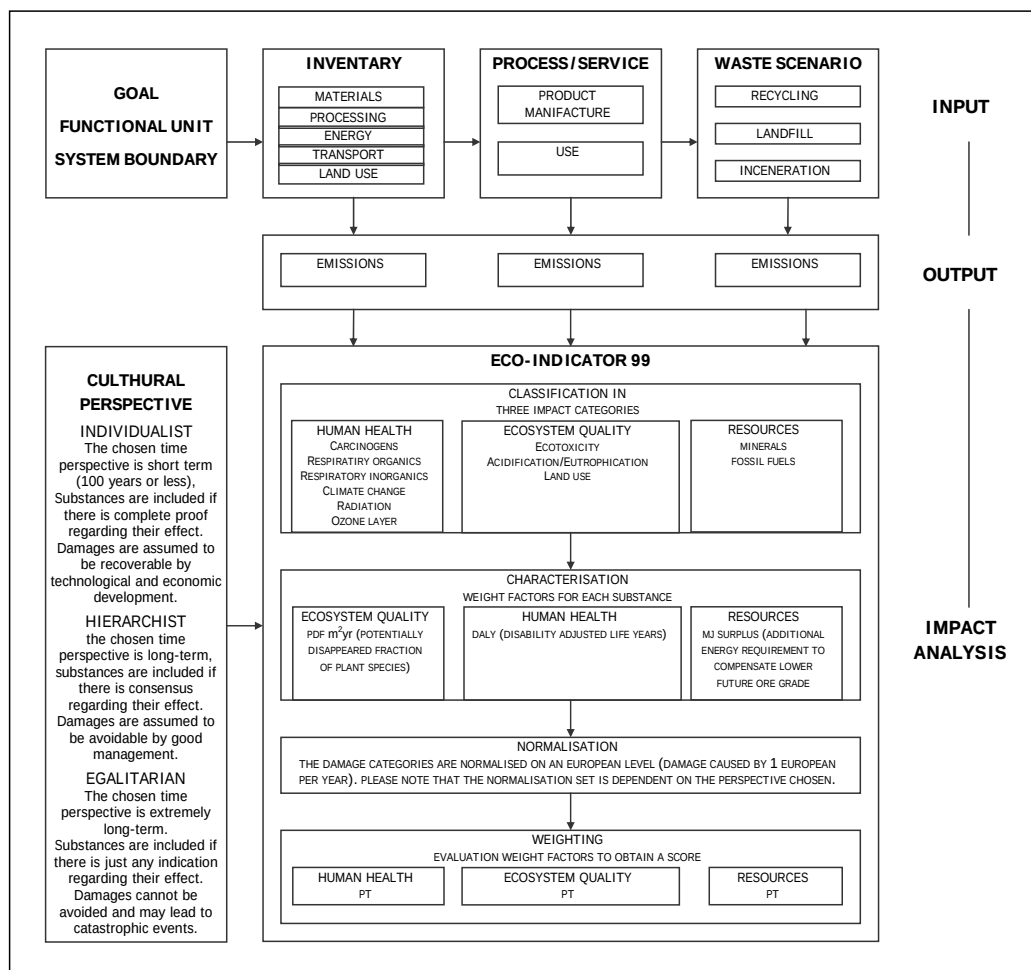


Fig.1 LCA methodology and Eco-Indicators 99

The final process of weighting allows one to obtain a unique score as the sum of single point of the three normalised damage categories.

In the Eco-Indicator99 Method the model of the subject described by Thompson (1990), which refers to different cultural perspectives is adopted. The method assigns different weighting factors to the three damage categories. In this study the adopted cultural perspective considers factors of the egalitarian perspective (characterization of impact analyses), and the same weights for the three damage categories (weighting of impact analyses), (Curran, 1996).

3. Construction of a Data Base

The result of LCA method is reliable and accurate and provides details of the DataBase of the several processes (materials and their disposal, working, transports, land use, consumptions) needed to completely describe the final product. A specific DataBase, using data coming from direct surveys, and those modified, as well as the literature references, has been provided. It updates typical values for the Italian market. The data used for the processes do not consider the LCA of the machineries used for processing, the transports, etc. (second order boundary), (Goedekoop, 1993; Prè, 1999; Heijungs, 1992).

Table 1 shows the analysis of the damage caused in the phase of production of some materials; the values of the main emissions to air; the consumption of water and the Embodied Energy. The data in Table 1 were obtained by means of the application of the SimaPro5.0® software.

Table 1. LCA for some material production, per unit of mass.

Material	Total Pt	Human Health Pt	Ecosystem Quality Pt	Resources Pt	PE Primary Energy (MJ/kg)	Water kg	CO ₂ To Air kg	SO ₂ To Air g	NO _x To Air g
Steel	0,63	0,14 (22%)	0,05 (8%)	0,44 (70%)	75,64	9,7	8,12g	29	3
Aluminium	0,81	0,23 (28%)	0,02 (2%)	0,56 (70%)	174,7	X	8,22	X	X
Copper	3,5	0,87 (25%)	0,12 (3%)	2,51 (72%)	89,98	0,126	7,51	673	24
Brass**	2,3	0,55 (24%)	0,08 (4%)	1,7 (72%)	82,95	29,3	6,13	409	20
Cast Iron	0,14	0,02 (19%)	0,002 (2%)	0,11 (79%)	33,2	2	2,9	1	3
PE*	0,33	0,03 (11%)	0,006 (2%)	0,29 (87%)	79,43	9,5	0,94	X	10
PVC*	0,22	0,04 (20%)	0,006 (3%)	0,17 (77%)	53,55	X	2	X	9
PUR**	0,78	0,18 (23%)	0,019 (3%)	0,58 (74%)	103,36	201	5,23	3	26
Glass	0,09	0,01 (12%)	0,002 (2%)	0,08 (86%)	12,96	19,5	0,996	X	X
Cardboard**	0,14	0,02 (16%)	0,006 (4%)	0,11 (80%)	12,5	60,5	1,09	X	X
EPS*	0,45	0,05 (12%)	0,006 (1%)	0,39 (87%)	82,04	175	2,4	0,031	12

**the process involves the damage caused by transports and land use

* the process involves only the damage caused by land use

The environmental assessment for the single phase of material production is penalised particularly, for the metallic products. In fact they are characterized by a more elevated score in all the damage categories than that of the plastics, because both high energy consumption for the extraction and the raw material processes; as well as high emissions of inorganic substances which are harmful for human health (i.e. sulphurous anhydride released in the air during the processes of copper).

Table 2 and Table 3 show LCA for transportation and land use. It is necessary to consider the damages for the transportations of the products, assigning them an environmental load caused by the emissions, the fuel consumption and the use of the infrastructures. The land use has negative effects on the ecosystem (reduction of the number of animal and vegetable types).

Table 2. LCA for transports (functional unit: 1 ton km).

Transport	Total Pt/tkm	Human Health Pt	Ecosystem Quality Pt	Resources Pt	SO ₂ To Air Mg	NO _x To Air g	CO ₂ To Air g
Train	0,00739	0,00195 (26,38%)	0,000438 (5,929%)	0,005 (67,69%)	46,2	0,269	81,5
Truck	0,0088	0,0035 (39,74%)	0,000646 (7,343%)	0,00465 (52,91%)	231	1,34	83,1

Table 3. LCA for land use (functional unit: 1 m² yr).

Land use	Total Pt	Human Health Pt	Ecosystem Quality Pt	Resources Pt
Dump land use	0,0747	x	0,0747 Pt	x
Farm land use	0,0545	x	0,0545 Pt	x
Infrastructural net land use	0,0545	x	0,0545 Pt	x

In order to yield a complete evaluation on the materials it is also necessary to analyze the damage caused by the recovery or by the dump disposal. The process of recovery allows a circular life cycle for the raw materials, considering the physiological loss of weight and quality, however not for the product (Table 4). For environmental balance, the values related to recovery are negative, but because of the processes of transport, labour and land use necessary to reinsert the material in the cycle and its loss of quality and weight to be considered, the benefits would be less than the avoided damage for production.

Table 4. LCA for disposal (functional unit 1kg).

Damage category	Total Pt / kg	Human Health Pt	Ecosystem Quality Pt	Resources Pt	Recovery/ production %
Recycling Steel	-0,501	-0,114 (-22,85%)	-0,0458 (-9,135%)	-0,341 (-68,01%)	79 %
Recycling Aluminium	-0,713	-0,206 (-28,91%)	-0,0168 (-2,352%)	-0,49 (-68,74%)	88 %
Recycling Copper	-3,24	-0,824 (-25,47%)	-0,0912 (-2,819%)	-2,32 (-71,71%)	93 %
Recycling Brass	-2,21	-0,525 (-23,79%)	-0,0807 (-3,655%)	-1,6 (-72,56%)	94 %
Recycling Cast Iron	-0,0631	-0,00963 (-15,27%)	0,00104 (1,644%)	-0,0545 (-86,37%)	44 %
Recycling PE,	-0,292	-0,0291 (-9,947%)	-0,00453 (-1,55%)	-0,259 (-88,50%)	88 %
Recycling PVC,	-0,191	-0,0379 (-19,82%)	-0,00514 (-2,689%)	-0,148 (-77,49%)	85 %
Recycling PUR,	-0,726	-0,167 (-23,04%)	-0,0177 (-2,435%)	-0,541 (-74,52%)	92 %
Recycling Glass	-0,0468	-0,00117 (-2,507%)	-0,00007 (-0,148%)	-0,0456 (-97,34%)	49 %
Recycling Copperboard	-0,118	-0,017 (-14,37%)	-0,00526 (-4,454%)	-0,0959 (-81,17%)	84 %
Recycling EPS,	-0,384	-0,0461 (-12,02%)	-0,00714 (-1,861%)	-0,33 (-86,12%)	85 %
Materials Dump	0,00436	0,00288 (66,05%)	0,00048 (11,07%)	0,0001 (22,89%)	n.a.

Table 5 shows the damages caused by the consumptions of thermal and electric energy consumed. The consumption of 1 MJ of electric energy is related to different primary fuels or renewable sources (Italian Ministry of Environment, 2002).

Table 5. LCA for consumption (functional unit: 1 MJ)

	Pt / MJ	Human Health Pt	Ecosystem Quality Pt	Resources Pt	So ₂ To Air mg	No _x To Air mg	Co ₂ To Air g
Natural gas	0,00639	0,00048	0,000046	0,00586	28,6	49,6	65,7
Electricity	0,014	0,00315	0,00054	0,0103	853	535	163

4. LCA for Components

The DataBase gives the values of components production of the main Italian manufacturing factories. These data has been used to characterise the processes related to the plant's components and accessories, e.g. distribution and terminals.

Data from APAT, ONR (APAT, ONR, 2001) confirms that the metallic elements are almost completely recycled, while the greatest part of the plastic or insulating materials are disposed. As for the disposal of the package, the values indicated in the European Directive 94\62\CE have been considered. Fig. 2 shows the process as tree for the case of a boiler.

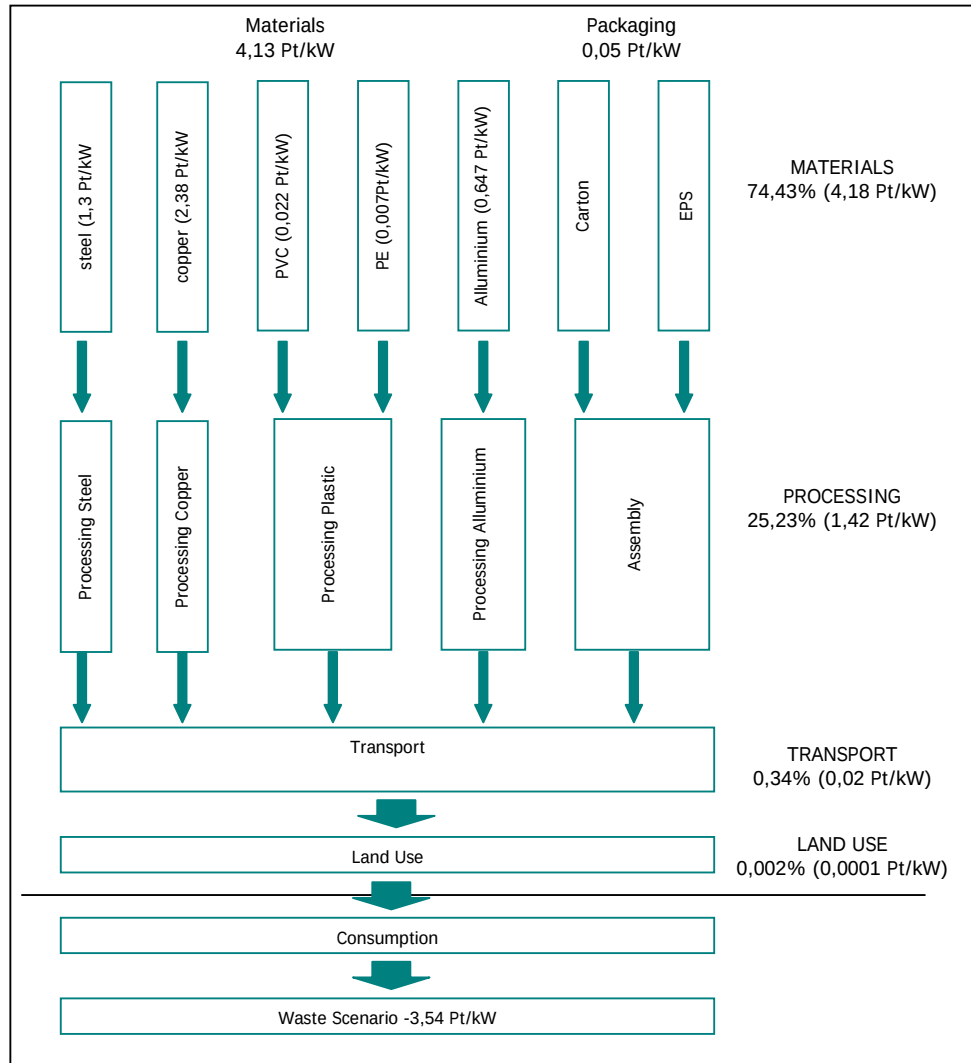


Fig.2 Process tree of boiler

LCA for HVAC components, accessories and terminals are shown in Table 6, Table 7 and Table 8 where production damage and waste scenario are reported. Using these values and assembling the entire considered system, a complete LCA can be carried out.

In the assessment of the single HVAC components, it is necessary to consider that the life cycle of some elements is shorter than the plants, and consequently taking into account of the environmental cost (ASHRAE, 1993; Costanzo et al., 2002).

Table 6. LCA of HVAC components

COMPONENT	kg/kW	MATERIAL	X (%)	Materials Damage Pt/kW	Processing Damage Pt/kW	Transport Damage in Pt/kW	Land Use Damage In Pt/kW	Total Production Damage Pt/kW	Waste Scenario Pt/kW	Pt/kW
BOILER	3	Steel	60	1,300	0,301	0,019	0,000136	5,619	-3,540	2,301
		Copper	20	2,380	0,291					
		PVC	3	0,022	0,029					
		PE	3	0,331	0,007					
		Alluminium	14	0,390	0,647					
		Package	/	0,052	/					
BURNER	0,4	Assembly	/	/	0,142	0,0026	0,000136	0,421	-0,199	
		Steel	94,5	0,254	0,073					
		Copper	4	0,070	0,008					
		Rubber	1,5	0,004	0,0003					
		Package	/	0,007	/					
PUMPS	30	Assembly	/	/	/	0,195	0,0409	12,60	-2,460	10,14
		Cast Iron	94	4,390	0,162					
		Steel	3	0,700	4,53					
		Carbon Fibre	3	2,000	/					
		Package	/	0,553	/					
HEAT PUMPS	12	Assembly	/	/	/	0,0835	0,000136	27,00	-17,40	9,600
		Steel	49	4,120	0,955					
		Copper	30	13,90	1,700					
		Alluminium	15	1,610	2,740					
		PVC	3	0,090	0,115					
		PUR	3	0,315	0,098					
		Package	/	0,207	/					
		Cooling fluid	/	0,588	/					
SOLAR COLLECTOR (Area: 1 m²)	20	Assembly	/	/	0,419	0,132	0,00004	51,10	-33,10	18,00
		Alluminium	30	5,360	8,890					
		Copper	40	30,80	3,770					
		Pur	3	0,520	0,031					
		Glass	27	0,362	0,441					
		Package	/	0,345	/					
UTA (1 m³/h)	0,12	Assembly	/	/	0,0002	0,0007	0,000001	0,2	-0,12	0,08 Pt/(m³/h)
		Steel	65	0,055	0,013					
		Alluminium	20	0,021	0,035					
		Copper	14	0,065	0,008					
		Cellulose	1	0,00005	/					
		Package	/	0,002	/					
RESERVOIR (lt)	0,4kg/lt	Assembly	/	/	0,129	0,0026	0,0000009	0,469	-0,187	0,282 Pt/lt
		Steel	85	0,238	0,054					
		Alloy	5	0,001	/					
		PUR	10	0,035	0,002					
		Package	/	0,007	/					

Table 7. LCA of HVAC accessory components

COMPONENT	Materials Damage Pt/kg	Processing Damage Pt/kg	Transport Damage in Pt/kg	Land Use Damage in Pt/kg	Total production Damage Pt/kg	Waste Scenario Pt/kg	Pt/kg
Steel Pipe	0,653	0,196	0,006	0,0000091	0,855	-0,496	0,359
Copper Pipe	3,517	0,612	0,006	0,0000091	4,220	-3,200	1,020
PE Pipe	0,348	0,075	0,006	0,0000091	0,429	-0,016	0,413
PUR Pipe	0,804	0,0473	0,006	0,0000091	0,858	-0,047	0,811
Galvanized Plate Air Duct	0,653	0,238	0,006	0,0000091	0,897	-0,496	0,401
Brass Valves	2,340	0,060	0,006	0,0000091	2,410	-2,190	0,220

Table 8. LCA of HVAC terminal elements

COMPONENT	kg/kW	Materials Damage Pt/kW	Package Damage Pt/kW	Processing Damage Pt/kW	Transport Damage Pt/kW	Land Use Damage Pt/kW	Total production Damage Pt/kW	Waste Scenario Pt/kW	Pt/kW
Steel Radiator	18	11,4	0,400	1,85	0,107	0,00013	13,70	-8,93	4,77
Alluminium Radiator	10	7,66	0,173	4,18	0,059	0,00013	12,10	-7,06	5,04
Cast Iron Radiator	60	9,55	0,504	10,1	0,357	0,00013	20,00	-3,75	16,25
Fan coil	4	4,14	0,07	1,55	0,024	0,0022	5,78	-3,46	2,32
Radiant Floor	8	2,65	0,138	0,602	0,0493	0,000073	3,17	-0,132	3,31

5. A case study for an heating system

The evaluation of LCA for three different heating systems typologies (traditional, solar collectors with auxiliary heating system, heat pump with auxiliary heating system) for a residential building placed in Rome has been carried out for a case study using the presented methodology.

A steel condensation boiler is installed in each typology considered. The components quantities per volume unit are listed in Table 9.

Table 9. Heating systems characteristics

Components	Heat Pump Plant	Solar Collector Plant	Traditional Plant
Boiler	0,014 kW/m ³	0,014 kW/m ³	0,014 kW/m ³
Burner	0,014 kW	0,014 kW/m ³	0,014 kW/m ³
Pump	4,2E-5 kW	8,4E-5 kW/m ³	4,2E-5 kW/m ³
Pipe (Steel Pipe and PUR insulation)	0,367 kg/m ³	0,367 kg/m ³	0,367 kg/m ³
Pipe (Copper Pipe and PE insulation)		0,048 kg/m ³	
Radiator			0,0176 kW/m ³
Radiant Floor	0,84 kg/m ³	0,84 kg/m ³	
Heat Pump	0,014 kW/m ³		
Solar Collector		0,04 m ² /m ³	
Réservoir		2 lt/m ³	

EN 732 has been used for seasonal consumption calculation, in terms of primary energy, 67,5 MJ/m³.

Heat pumps is responsible of about 40% of thermal energy demand (COP=3), being the remaining part supplied by the auxiliary heating system. The associated electricity in terms of primary energy is 8,7 MJ/ m³.

By applying the above described methodology, the LCA of each considered systems are analysed for environmental impacts (Fig.3). The solar plant causes the smallest environmental damage, about half of the traditional plant value. The environmental impacts of the systems differ in each case. The greatest electricity and materials consumption (i.e. the copper used for pipelines and components) are those by the non-traditional solutions hence the traditional configuration does not result in more harmful solution by the Ecosystem Quality category. In the Human Health category, the traditional plant is responsible of a damage lower than that of the heat pump (0,92 vs 1,29 Pts), due to the greater electricity consumptions of the latter which are responsible of a greater NO_x and SO_x emissions.

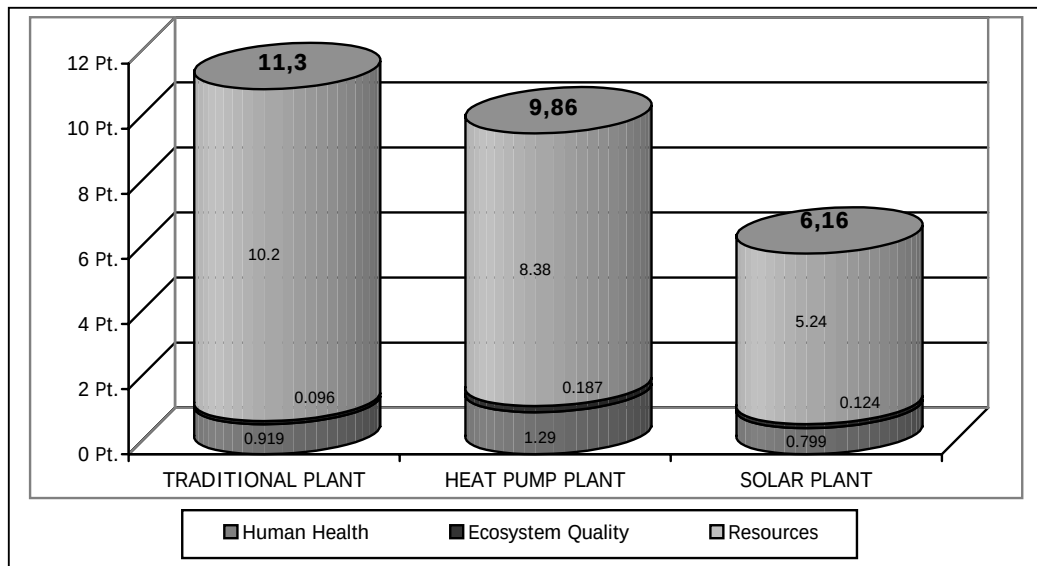


Fig.3 LCA for the three heating systems in a 25 years life cycle.

Fig.4 shows the trend of the environmental damages during the 25 years LFS (Technical Lifespan) of the three heating system considered.

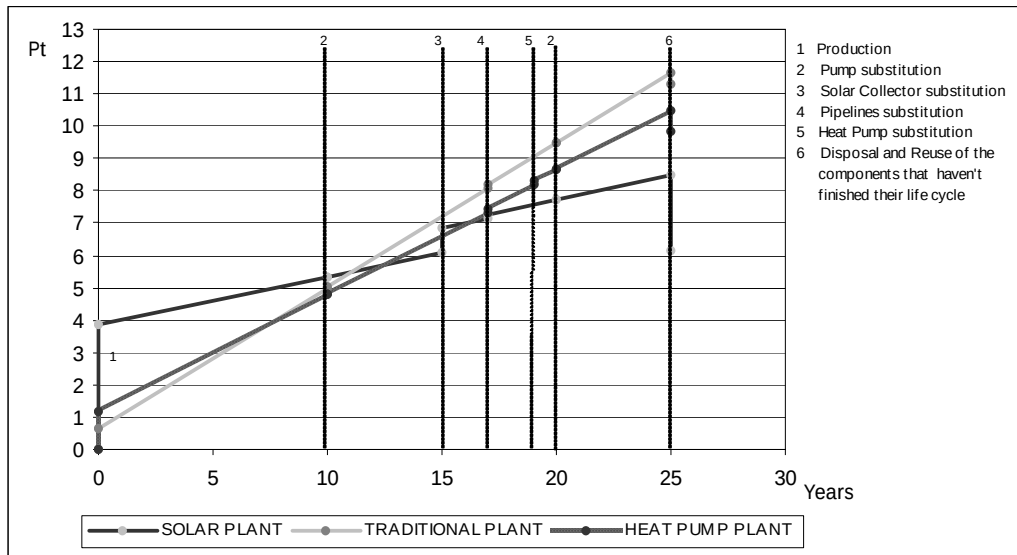


Fig.4 Environmental damage of the three heating systems as a function of the time

The graph shows that after a period of 10 years the environmental damage caused by the components production and by the energy management of the three considered systems is approximately the same, even if they are characterised by different shapes.

The phase of production (phase 1 in the Fig. 4) of the solar plant produces a damage of 3,84 Pts, nearly equal to that caused by its energy management in 25 years (8,48 final score without material recovery -3,84 production -0,71 collector substitution at 15 yrs -0,1 other substitutions = 4,64 Pts). The low environmental impact related to the production of the traditional plant (0,64 Pts) is of the same order of magnitude of the value given for its seasonal consumption (0,426 Pts obtained as (11,68-0,64)/25).

At the end of the 25 years, the solar collectors plant reaches a final damage score of 6,16 Pts after considering the recovery environmental advantage, while the traditional plant reaches a score twice higher (11,3 Pts). The heat pump system has a damaging effect for the production a little higher than the traditional one (1,17 Pts vs 0,64 Pts), and its final value is equal to 9,86 Pts. It is therefore necessary to outline the choice of the most advantageous system to establish the durability of the total life cycle of the system as well as, the durability of every component and their necessary substitutions.

6. Conclusions

The Life Cycle Assessment methodology applied to the HVAC systems is a useful tool both for the designer who has to choose the appropriate design characterised by the smallest environmental impact, and for the industry which needs to improve the productive processes.

The attention has been focused on the evaluation of the environmental contributions of every phase: the choice of the materials and their disposal, labour, the transportation as well as the land use, which are aspects generally not considered in an analysis limited to the efficiency of the HVAC systems however have a great impacts on the environmental balances. In particular, the analysis of renewable energy sources systems (solar collectors) or high performance systems (heat pumps) shows a low environmental damage related to the energy running consumptions, but a high incidence on the global environmental balance of the plant production due to the several components used.

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ON-SITE TEST ON THE PERMEABILITY OF INFILTRATION GUTTER

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Abstract

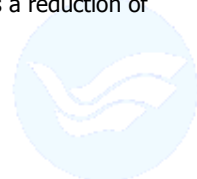
This study analysed the permeability of infiltration gutter for on-site tests and developed the design guideline for infiltration gutter by on-site tests. The permeable-brick type infiltration gutter was constructed on-site. Infiltration capacities for two vertical sides (NFS-2S), bottom (NFS-B), and three faces (NFS-3S) of the gutter were conducted under the conditions of non-flowing and steady state. The results from NFS-2S and NFS-3S tests indicate that the correlation between $A_{u,ss}$ which is defined as the final infiltration rate (Q_f) divided by saturated hydraulic conductivity of the soil (K_{sat}), and water depth (H) is linearly dependent on each other. But the correlation between the $A_{u,ss}$ and H for the NFS-B test is non-linear. Also experimental results show that when the bottom is clogged up, the gutter still has 90% of infiltration capacity of NFS-3S. Based on these results, the $A_{u,ss}$ for different water depths and widths for the gutter can be obtained.

Keywords: Infiltration gutter, BMP's, Green building, Rainwater utilization, Ecological engineering, Urban flood.

1. Introduction

Green building, a term commonly used in North American, demonstrates the building of environmental friendly, energy saving, water saving etc. In Japan, people use the name of environmentally symbiotic building instead but in European countries ecological or sustainable building is called. Taiwan has a history of promoting Green Building policy for more than ten years. In 2001, the Executive Yuan, the highest administration office in Taiwan, had passed the "Green Building Promotion Proposal" regulation that requires all the public buildings to adopt the concept of green building design at initial stage. To evaluate the degree of greenery of the building, ABRI (Architecture & Building Research Institute, MOI) proposes the rating system that includes nine indicators: biodiversity, greenery, soil water content, energy saving, CO₂ emission reduction, waste reduction, indoor environment, water resource and sewage and garbage improvement (ABRI, 2003). The purpose of soil water content indicator is to evaluate the ratio of water conservation between pre- and post-development by means of rainwater storage and rainwater infiltration.

Along with urbanization, the creation of any large impervious surface commonly leads to multiple impacts on stream systems. These impacts include higher peak stream flows which cause channel incision, bank erosion, and increased sediment transport (Konrad, et al., 2002). Another impact is a reduction of



infiltration that lessens groundwater recharge and pollutant loads to stream (Winter and Duthie, 1998). Infiltration gutters or trenches offer one solution to the problem of increased stormwater runoff and decreased groundwater recharge. Infiltration gutters are commonly made up of matrix of red-brick and permeable-brick with voids filled with sand, gravel or soil. These voids allow stormwater to infiltrate into the underlying soil, which in turn can play a significant role in mitigating the impacts of stormwater runoff caused by urban development (Watanabe, 1995).

The purpose of this study is to analyze the characteristics and develop the designed guideline for infiltration gutters by on-site tests and provide as the practical tools for designing infiltration gutters.

2. Background and Construction of Infiltration Gutter

2.1 Design

The major element of this study involved the construction of an experimental site with infiltration gutter. Out of the large variety of infiltration systems currently available and with opinions from constructors, permeable-brick type infiltration gutter was selected for analysis. The gutter was constructed on-site at the experimental site. A system of pumps, pipes, gutter, and gauges were installed to collect and measure the water inflow and variation of water surface elevation.

2.2 Experimental Site

The selected experimental site was located at the entrance of the Hsintien office, Water Resource Agency, Ministry of Economic Affairs. The entire facility is surrounded by a fence and is gated and locked during non-business hours, minimizing (or hopefully eliminating) any risk of vandalism.

2.3 Soil Properties Investigation

Three soil samples were taken at one-meter depth below surface at experimental site. Based on Casagrande method, properties of these soil samples were categorized as low plastic floury soil. The grain-size distributions of the soil materials of experimental site were quite consistent but not well graded.

2.4 Saturated Soil Hydraulic Conductivity (K_{sat})

Water infusing system to maintain the designed water level in the test hole, manufactured by the research team, was used to estimate the final infiltration volume for various water depths in a hole that is 3 cm in diameter and 60 cm in depth. Glover solution was then used to estimate the saturated soil hydraulic conductivity.

2.5 Infiltration Gutter Construction

Under the current construction regulations, the width of the gutter should be greater than 30cm and 40cm for the height. In order to meet these requirements, the on-site infiltration gutter was designed to be 45cm high and 35cm wide. However, the total length can only be 550cm due to space constraint. The top-view and cross-section profiles are shown in Fig.1 and 2. Permeable-brick has two sizes: L500^{mm}×W500^{mm}×H50^{mm} and L200^{mm}×W100^{mm}×H50^{mm}. The former size is used for the bottom of the infiltration gutter and the latter is used for the two sides. The pressure resistance is around 162kgf/cm² and the permeable coefficient is around 2.1×10^{-1} cm/sec.



Fig.1 Top-view of Infiltration Gutter

Fig.2 Cross-section Profile of Infiltration Gutter

2.6 Water Supply System

Water needed for experiment is supplied from two sources. One is from the rainwater collected from the nearby rooftop of parking garage; the other uses the existing water supply system pipelines. Water is recycled with underground storage tank having the storage capacity of 2.4 tons.

3. Experimental Design and Procedures

3.1 Experimental Design

A Double-Ring methodology is used to estimate the final infiltration volume for different criteria. The length of inner apartment of test section was 50 cm and 20 cm was left for each side to prevent from spreading infiltration. Data were measured from inner apartment of test section. Figure 3 shows a schematic of the layout. Self-design replenishing equipment to refill water at the test section for different water depths was used. To prevent water from leakage, oil clay and silicon were used. The amount and mechanism of water infiltration from bottom and both vertical sides were investigated separately.



Fig.3 The Layout of Double-Ring test for Infiltration Gutter

3.2 Experimental Procedures

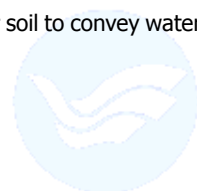
Major experiment steps included followings:

- Step 1 : Choose the bottom or vertical sides as the test object and seal the other by the oil clay and impermeable plastic sheet. If three sides of the gutter section were examined, this step may be neglected.
- Step 2 : Turn on the flow control valve and then start infusing water to inner and outer apartments.
- Step 3 : Maintain the same water levels for both inner and outer apartments of test section.
- Step 4 : Record the stable water depth using water level meter at the inner apartment.
- Step 5 : Measure the average final infiltration capacity at the inner apartment for the period of 600sec.
- Step 6 : Move to higher infusing water rates and repeat steps 3 to 5 for various water depths. At least five sets of data were needed.
- Step 7 : Estimate the specific infiltration area per unit length that was defined as the final infiltration volume (Q_f) divided by saturated hydraulic conductivity of the soil (K_{sat}).

4. Experimental Results and Analysis

4.1 Theory of Infiltration Gutter

K_{sat} (saturated hydraulic conductivity) is the parameter that represents the ability for soil to convey water.



Reynolds (1985) used the infiltration model to describe the cylinder shape infiltration well and established the theory of estimating on-site K_{sat} , that was presented as the following equations:

$$K_{sat} = \frac{CQ_f - 2\pi H\phi_m}{2\pi H^2 \left[1 + \frac{C}{2} \left(\frac{a}{H} \right)^2 \right]} \quad \text{Eq. 1}$$

$$C = \frac{H^2 \left\{ \frac{(H-b)}{H} \sinh^{-1} \left[\frac{(H-b)}{a} \right] - \sqrt{\left(\frac{a}{H} \right)^2 + \left[\frac{(H-b)}{H} \right]^2} + \frac{a}{H} \right\}}{(H-b)^2} \quad \text{Eq. 2}$$

Where C: shape factor; Q_f : the final infiltration volume; H: fixed-water head; a: radius for the infiltration well; ϕ_m : potential flux for unsaturated zone and b: the distance from water surface.

If equation (1) ignores the items of gravity and potential flux and assumes that b equals to zero, it becomes known as Glover solution. The Glover solution process is easier than that of Reynolds to obtain K_{sat} value. Therefore, Glover solution is used in the research to estimate K_{sat} . Equation (1) can then be further written as:

$$A_s = \frac{2\pi H^2}{\sinh^{-1} \left(\frac{H}{a} \right) - \left[\left(\frac{a}{H} \right)^2 + 1 \right]^{\frac{1}{2}} + \frac{a}{H}} \quad \text{Eq. 3}$$

Where A_s : the specific infiltration area per unit length that is defined as the final infiltration volume (Q_f) divided by saturated hydraulic conductivity of the soil (K_{sat}).

Equation (3) shows that A_s is only connected to the geometric shape of the cylinder infiltration well and the water depth and has no direct relationship with characteristic of soil.

4.2 Results

In the experiment, three scenarios were considered: (i) infiltration from bottom and two vertical surfaces (NFS-3S); (ii) infiltration from bottom only (NFS-B), and (iii) infiltration from two vertical sides (NFS-2S).

Experimental results will be discussed as this order.

(i) NFS-3S Scenarios

To understand the relationship between the specific infiltration area per unit length and water level, nine different water levels ranging from 3.3 to 24.6 cm were observed. Their relationship can be expressed as the following equation:

$$A_{u,s} = 176.41 H \quad R^2 = 0.999 \quad \text{Eq. 4}$$

Where $A_{u,s}$ is the specific infiltration area per unit length; H is the designed water level if the infiltration gutter and R^2 is the coefficient of determination.

(ii) NFS-B Scenarios

Twelve different water levels ranging from 3.3 to 27.2 cm were observed. Their relationship is expressed as the following equation:

$$A_{u,s} = 49.95 H^{0.75} \quad R^2 = 0.999 \quad \text{Eq. 5}$$

(iii) NFS-2S Scenarios



Five different water levels ranging from 10.3 to 27.1 cm were observed. Their relationship is expressed as the following equation:

$$A_{u,s} = 164.41 H \quad R^2 = 0.999 \quad \text{Eq. 6}$$

4.3 Discussion

From the continuity aspect, amount of water infiltrated from the surfaces of infiltration gutter is the sum of water from bottom and two vertical sides and can be expressed as:

$$Q_{\text{total}} = Q_{\text{bottom}} + 2Q_{\text{side}} \quad \text{Eq. 7}$$

Where Q_{bottom} : water infiltrated from bottom of infiltration gutter at steady state and Q_{side} : water infiltrated from the two vertical sides of infiltration gutter at steady state.

But from the results of this study, the amount of water infiltrated from NFS-3 is less than the sum of water infiltrated from NFS-B and NFS-2S for any selected water depth. To further investigate their relationship, the $A_{u,s}$ values of NFS-B and NFS-2S are divided by the $A_{u,s}$ value of the NFS-3S separately and these values are plotted against various water depths as Fig.4 shows. In Fig.4, ratios of water infiltrated from the bottom of the gutter to total water infiltration are high when water depths are low. As water depth increases, ratios will decrease and reach a constant value to about 38%.

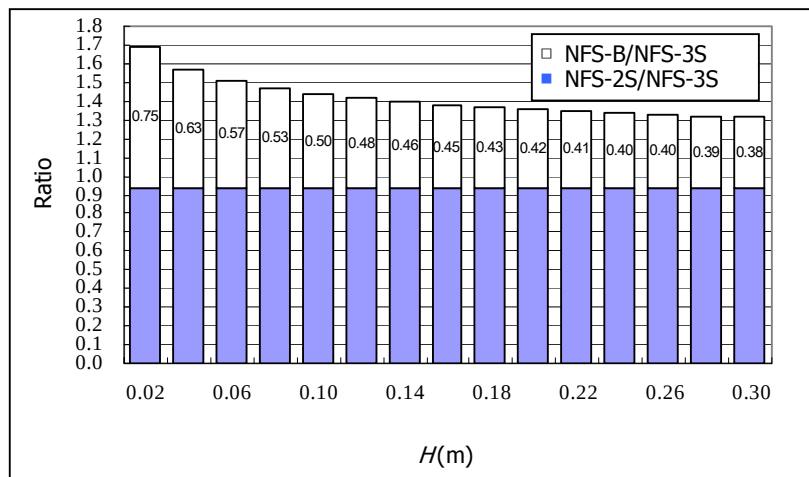


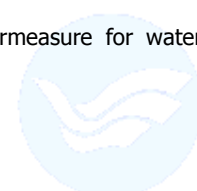
Fig.4 Ratios of Water Infiltrated from Bottom and Vertical Sides of the Gutter to Total Water Infiltration

The amount of water infiltrated from two vertical sides occupies 93.2% of total amount of water infiltration and becomes a constant value for different water levels. In the case of NFS-2S, water infiltrating through vertical sides will accumulate at the backfill layer because hydraulic conductivity of the backfill layer is greater than that of the original soil. The accumulated water will eventually flow to the backfill layer at the bottom. This will increase the infiltration surface and is similar to the mechanism of the case of NFS-3S. That is why the ratio of the $A_{u,s}$ value between the cases of NFS-2S and NFS-3S is high. Therefore, two vertical sides play an important role in the infiltration process of the gutter. The experimental results also reveal that when bottom of the infiltration gutter is clogged up, the gutter still has around 90% of infiltration efficiency compared to the original designed capacity.

The experimental results obtained by this study are restricted to the parameters selected. In addition to water depth, the width of infiltration gutter is also an influential factor that will influence the results. If the infiltration mechanism is the same for various widths of the infiltration gutter, the specific infiltration area per unit length of various widths of the infiltration gutter can be obtained through above equations.

5. Conclusions

Setting up infiltration facilities in the highly urbanization areas is the countermeasure for water



conservation and urban flood mitigation. Financial considerations, infiltration gutter plays a crucial role in determining the feasibility of any stormwater management project.

This study investigated the performance of permeable-brick type infiltration gutter from the perspectives of design and its characteristics. It was found that the specific infiltration area per unit length for the cases of NFS-2S and NFS-3S is linearly with water depth but not for the case of NFS-B. The ratio of water infiltrated through the bottom of the gutter to the total amount decreases as water depth increases and reaches a constant value. On the contrary, water infiltrated through both vertical sides plays an important role as water depth increases. It means that if bottom of the gutter is clogged up, the gutter still has around 90% of original designed infiltration capacity. All regression equations established by this study provide as the basis for infiltration gutter design.

Despite these generally quite favorable results, uniformly good performance cannot be guaranteed in all cases. The experimental site has particular soil conditions masking any potential consequences of change infiltration over time. Despite these limitations, we believed that these results provide clear indication of the value of infiltration gutters and their long-term suitability for broad expanses of the built environment.

Acknowledgements

Architecture & Building Research Institute, Ministry of the Interior, Taiwan, provided funding for site construction and subsequent investigation.

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