Sustainable development in construction

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Abstract
A review of concepts of sustainable development and its assessment are given in this paper and some critical comments made. Considering the magnitude of the impact of the construction industry on the environment, a considerable improvement in efficiency and effectiveness of the construction process is necessary to help to restore the ecological balance. Further development of life cycle assessment techniques and social and economic aspects of sustainability will play an increasingly important role. Keywords: Sustainability, sustainable construction, sustainability criteria, indicators.
1 Introduction

This paper attempts to review current thoughts on sustainable construction particularly with regard to the main elements of sustainable construction and sustainability criteria and indicators. It will also review environmental assessment methods currently in use and attempt to develop an agenda for future research in sustainable construction.

There is growing evidence that the earth’s ability to sustain life as it has been known for thousands of years has been seriously eroded, particularly since the Industrial Revolution, and if unchecked, will result in an irreversible degradation of the planet, its ecosystems, resources and ultimately quality of life of its inhabitants in the not so distant future. Modern forms of human existence, associated with rapid economic development, have contributed to an over-exploitation of renewable natural resources such as land and forests, and the exhaustion of non-renewable resources such as minerals and fossil fuels. The generation of CO$_2$ emissions well in excess of the natural carbon storage capacity, ozone layer depletion, the contamination of air, water and land through pollutants and the weakening of the whole ecosystem are also apparent. Depending on regional and often political issues, the importance of such phenomena may not always be recognised. Often insufficient or inconclusive data is available on environmental problems.

While most countries have in the past 10 years committed themselves to work actively towards improving the environment, the challenge in the future will be to mobilise every individual and every business to embrace change through a range of activities. These may be as simple as recycling household wastes and products, energy and water conservation, rejection of disposable in preference to recycled products, and the demand for reduced packaging of products. At the regional and national level, more wide ranging changes may be expected such as lower emissions, use of renewable sources of energy, better land management and the reduction of population growth.

The research methodology adopted for this study is based on literature review only. An extensive search was carried out and relevant journal articles, conference papers and books summarised. Because of the restriction on the length of this paper, no literature review section is included.

2 Sustainable construction

2.1 Definitions

According to DuBose et al [1], “sustainability offers a way of interacting with our world which reconciles the ubiquitous human desire for a high quality of life with the realities of our global context. It calls for unique solutions for improving our welfare that do not come at the cost of degrading the environment or impinging on the well-being of other people”.

Sustainable development or ecologically sustainable development was defined by WCED [2] as development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

The term ‘development’ includes activities across different industry sectors. As the impact of the construction industry on the environment rates as one of the highest among all the industries, a close scrutiny of the construction industry is necessary to minimise its impact on the environment, hence the emergence of the term ‘sustainable
construction’. A clear definition of ‘sustainable construction’ as a subset of sustainable development will serve as a starting point for any such scrutiny. In the context of this discussion, the word ‘construction’ implies a process which starts well before the actual on-site building activity commences and extends to post site-building activities such as commissioning and asset management. In fact, it covers an entire project development life cycle.

The term sustainable construction was originally proposed to describe the responsibility of the construction industry in attaining sustainability, see Hill and Bowen [3]. They have singled out four attributes of sustainability – social, economic, biophysical and technical – to advance understanding of the concept of sustainable construction. Kibert [4] sees sustainable construction as creating a healthy built environment using resource-efficient, ecologically based principles. According to Lawson [5] and Wyatt [6], sustainable construction includes ‘cradle to grave’ appraisal, which includes managing the serviceability of a building during its lifetime and eventual deconstruction and recycling of resources to reduce the waste stream usually associated with demolition. Bourdeau et al [7] defined sustainable construction as the creation and responsible maintenance of a healthy built environment based on resource efficient and ecological principles.

2.2 Impact of construction on environment

Construction industry is commonly one of the largest industries in both developing and developed countries in terms of investment, employment and contribution to GDP. Consequently, the impact of the construction industry on the environment is expected to be considerable particularly as far as the loss of soil and agricultural land, the loss of forests and wildlands, air pollution, and the loss of non-renewable energy sources and minerals are concerned [8].

According to Levin [9] buildings’ contribution to total environmental burden ranges between 12-42% of the eight major environmental stressor categories: use of raw materials (30%), energy (42%), water (25%) and land (12%), and pollution emission such as atmospheric emissions (40%), water effluents (20%), solid waste (25%) and other releases (13%). Buildings and building construction services account up to 66% of total UK energy consumption [10]. A similar level of energy consumption in the USA (54%) was quoted by Bonini and Hanna [11]. They further reported that the US residential sector is the highest consuming sector. Cooper and Curwell [12] estimated that in the UK the construction industry uses about 6 tonnes of building materials annually for every member of the population.

The above figures clearly support the notion that the construction industry imposes considerable loading on the environment and impacts severely on practically every environmental issue affecting sustainability. The challenge for the construction industry is to re-engineer its entire process in order to significantly reduce its impact on the environment.

2.3 The key principles of sustainable construction

The above definitions of sustainable construction are all framed towards creating a healthy built environment through resource efficient and ecologically sound processes, preservation of ecosystems and maintenance of natural balance between development and carrying capacity of this planet. The key principles upon which the above definitions have been phrased can be summarised into the main principles of
sustainable construction. A range of models detailing principles of sustainable construction will now be briefly reviewed.

Hill and Bowen[3] aggregated the principles of sustainable construction into four pillars – social, economic, biophysical, and technical. These are supplemented with a set of over-arching, process-oriented principles. “These process-oriented principles suggest approaches to be followed in deciding the emphasis to be given to each of the four pillars of sustainability, and each associated principle, in a particular situation”.

Palmer et al [13] classified the principles underlying sustainable development as futurity, environment, public participation and equity. These were adopted as the principles of sustainable urban development by BEQUEST [12]. More definitions of principles of sustainability can be found in DuBose and Pearce [1], Graham [14], Wolley [15].

3 Sustainability criteria and indicators in construction

Performance criteria and indicators in sustainable construction are needed to assess the performance of a building/facility and measure its impact on the environment. They need to be comprehensive to address specific environmental issues/problems. These are commonly identified as population growth, availability and use of natural resources such as land, water and forests, depletion of non-renewable resources such as mineral reserves and fossil fuels, urbanisation, pollution, geopolitical problems, habitat destruction/deterioration (biodiversity loss), global warming, stratospheric ozone depletion, soil erosion, acid deposition, wastes, indoor environment.

A considerable effort will be required to translate the requirements for sustainable construction into specific, technical performance criteria for buildings, components, systems and materials. Cole and Larsson [16] defined performance criteria as the basic building blocks which formulate the specific characteristics of the building/facility that will be assessed. Performance indicators are then specific units of measurement that will be used to describe the performance criteria in both quantitative non-quantitative forms. They are parameters of values that provide information about a phenomenon. They gauge progress towards sustainability in a simplified and readily understandable way. However, they need to encompass the relevant environmental impact and other sustainability aspects, be verifiable and measurable, be mutually independent of each other, and be comparable to a reference level [17].

A hierarchy of performance criteria and indicators for specific environmental issues/problems in a matrix format is possible to develop, see DuBose and Pearce [1], Levin [9], Beetstra [17], Chatagnon and Nibel [18], Guy and Kibert [19].

4 A brief review of environmental assessment methods

The first generation of environmental development controls in Australia was known as an environmental impact statement of a new development. It was to show the impact of the proposed development over its lifecycle on the surrounding environment and how the development satisfied the local urban planning requirements. These controls were regional in nature and focused on issues such as traffic flow, noise, size and height of the development, pollution, landscape, rogue reflection, disposal of surface water, etc. Without any performance benchmarks, environmental impact
statements were judged subjectively within the context of prevailing social, economic and political climate.

In the last decade or so, a wide range of environmental classification or building rating systems based on life cycle assessment (LCA) emerged in response to commitments to sustainable development by a number of developed countries. Among the best known systems are BREEAM (UK), BRE Office Tool Kit (UK), Home Energy Rating (UK), BREDEM (UK), Waster/Environmental Data Sheet (Europe), European Eco-labelling (Europe), SIB (Switzerland), BauBioDataBank (Germany), Ecocerto (Italy), EcoLab (Netherlands), BMES Index (Australia), Athena (Canada), BEPAC (Canada), LEED (US). A brief review of the above systems can be found in Cole and Larsson [16] and Wolley [15]. Beetstra [17] and Gay et al [20] criticised LCA, claiming that many environmental aspects have been left out and that LCA method is not capable of weighing different sustainable criteria and assess trade-offs among various environmental objectives. The method is said to be too complex when all building materials and components are considered and thus unusable unless various criteria and indicators are aggregated.

A growing need for a more rigorous and systematic assessment of projects has provided an impetus for the development of many new assessment methods. A brief review of some such new methods under development will now be given.

Beetstra [17] reports on the development of BEDS - Building-related Environmental Decision Support, a new integral assessment method in Netherlands. The method composed of a limited set of objectives, and quantitative and verifiable indicators, can be used in all phases of a project development cycle. In total eight indicators are used, three of which are site oriented (use up of space; accessibility; green balance), three are building-oriented (water balance; energy balance, HBF influences), and two are aimed at building elements (material use, reuse). Indicators will measure outcomes in numerical values between 0-100% with 100% being the maximum yet technically realised level.

Levin [9] outlines the development of SEABEP - Systematic Evaluation and Assessment of Building Environmental Performance model. “SEABEP addresses the need for comprehensive performance evaluation and assessment based on life cycle assessment, comparative risk assessment, and industrial ecology”. It assesses the contribution of buildings to the total environmental burden, weighs various environmental problems on a global scale and on a local or project scale and establishes targets based on defined sustainability criteria.

Chatagnon and Nibel [18] describe a methodology for the development of a model in the form of a matrix for environmental assessment in the design phase of a project. It targets continuous assessment of the environmental quality of a project at different design stages. The evaluation model calculates the environmental effects due to the sources, and expresses them according to assessment criteria. The proposed procedure is iterative and allows each project to be assessed from the environmental quality point of view.

A different approach to assessing sustainability of projects is described by Gay et al at [20]. This approach attempts to develop a sustainability index appropriate for assessment of buildings. The index is determined by “expressing environmental impacts of a building in terms of external costs which represent either measurable or calculable costs of direct impacts such as health injuries, death of the forest, etc., or the costs of preventing these”. The fact that the final result can be expressed as a
monetary sum is being seen as an advantage. When added to the conventional construction cost, an easy comparison between different alternatives will be possible.

DuBose and Pearce [1] advocate the use of The Natural Step (TNS) method for environmental assessment of buildings that was developed by Robert [21]. The proposed methodology consists of interpreting specific TNS system conditions and finding building-specific indicators for each of the system conditions. The authors concede that while comprehensive, this approach is rather complex.

Cole and Larsson [16] present an overview of GBC 98 – ‘The Green Building Challenge’ project, which is being developed in Canada. The aim is to develop an environmental assessment system and establish internationally comparable benchmarks for building performance. The system will measure Basic Performance such as functionality, maintainability and economic performance, Green Performance such as energy use, land use, materials use, airborne emissions, etc., and Process Performance to evaluate whether certain protocols have been specified. The proposed system will be able to address global and regional issues, and will also make it possible to measure both potential and actual performance.

5 Future research agenda

It may be useful to consider this in two overlapping parts based on the type of building technology to which it relates.

Conventional building technology, based on bulky, common, cheap materials has led to initiatives in waste reduction, recycling, regulatory control and conventional life cycle assessment based on a building life of 50 to 100 years. Sustainability is largely seen as a question of balance between what can be extracted with minimal environmental impact and demand. It is assumed that these can be readily agreed and quantified and the relevant sums done. Design for deconstruction (DFD) to facilitate recycling [22] is based on reducing the quantity of virgin raw materials needed to be extracted and used or in reducing the need for landfill disposal.

New building technology, based on the use of fewer materials in a more sophisticated or ‘clever’ manner (Less is More) points in a somewhat different direction. Assessment of sustainability may focus on what is covered in assessment schemes rather than attempting to standardise and agree a fixed methodology. Life cycle assessment may be based on a much wider range of building lifetimes, from very short (accompanied by total recycling/reuse/renewability) to very long (where environmental impacts are ‘written off’ over the long life of the building). The focus of attention may shift to relatively small quantities of key resources or materials which play an important role in modern sustainable building. These might include the alloying agents in steel rather than iron ore and limestone, rare metals such as titanium and indium which may come from very environmentally sensitive areas (eg. beach sands) or because they are rare, generate an inordinate amount of waste in their production. These rare elements may play a critical role in the development of ecologically sustainable building and DFD will be based on the recovery of small quantities of critically important materials. They may become politically strategic further complicating issues of equity.

The issues of equity in the social and socio-economic aspects of sustainability, both within and between countries, will become more critical as populations continue to increase and demand higher material standards of living.
6 Conclusions

The ability of this planet to maintain an environmental equilibrium has been disturbed, perhaps irreversibly. Population expansion and the corresponding increase in consumption on one hand and the reduction in the carbon storage capacity through deforestation on the other pose the most critical threat. The construction industry is the major contributor to the environmental loading on the earth and needs to respond to by substantially improving efficiency and effectiveness of in its entire production process. However, with an inevitable increase in population and demand for buildings and infrastructure services, even a dramatic improvement in environmental management of the construction industry is unlikely to offset an overall rise in the environmental loading caused by the increased level of building activity. If the scientists are correct in warning that the carrying capacity of the earth has already been disturbed, then the major challenge will be to minimise the rate of consumption increase and match it with a corresponding improvement in environmental efficiency and effectiveness associated with human activities.

How this is achieved will differ according to circumstances. The development of life cycle assessment techniques and their role in the assessment of sustainable construction will continue to be crucial. As building technologies develop further the key elements of sustainability may change and researchers need to be aware of such developments.

Social and economic aspects of sustainability need to be further developed.

7 References


