Research into Practice: 
how applied research can underpin innovative practice

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DRAFT

Abstract  The construction industry is notoriously conservative and slow to change, and until recently, only the largest players have engaged in research. However, concerns over global warming and the need for sustainable development, have led to substantial investment (particularly in Europe) into the research and development of technologies and design approaches which will reduce our dependency on fossil fuels. The application of these techniques to building projects has spread around the world, in parallel with the research programmes, and is slowly becoming part of the mainstream, but there is a perceived knowledge and skills gap among construction professionals, which is seriously restricting further take-up. There is widespread understanding of the ‘need’, but a lack of widespread ‘know how’.

The transfer of knowledge from research into practice is therefore vital. But this is difficult in an industry which habitually dislikes change, which has traditionally undervalued research and dismissed academics as ivory towered dreamers. One way of convincing critics that the ‘new’ technology is not necessarily also risky, is by demonstrating that it is cost effective and technically viable through its application in major projects. Attention can then be focused on the process by which innovation in low carbon buildings is achieved.

One thing is very clear: it is no longer satisfactory to rely on previously acquired knowledge and experience alone. In the last 20 years, major advances have been made in both our understanding, and the application, of bioclimatic design principles in buildings. Similar advances have been made in new and renewable energy devices, and their integration in buildings. Strategic thinking about these issues needs to be part of the early design process, and rigorous testing of options (using a wide range of analytic tools) is required in order to give clients the confidence to proceed with a radical solution. Not all projects can afford specialist testing and analysis, but simplified techniques exist, and this is where the ‘know how’ really counts.

As a research led educational institution, the School of the Built Environment at Nottingham University, has been engaged in innovative R&D and consultancy in the fields of ‘bio-climatic’ design and sustainable energy technologies for over 15 years. Professor Saffa Riffat has developed the concept of ‘Life Labs’ (Ref), where innovative or experimental technologies are integrated within the school’s own buildings, providing reduced carbon emissions and the opportunity to undertake experiments in a ‘live’ building. Professor Brian Ford has been involved in both research and consultancy in the application of bio-climatic design principles in numerous projects around the world. This paper illustrates this process of transferring ‘Research into Practice’ and the sometimes conflicting relationship between different measures to reduce carbon emissions from buildings.

Introduction

It is important for us to look at the scale of the task that faces us, in terms of reducing carbon emissions and their impact on global warming. Atmospheric carbon today constitutes 370ppm compared with the pre-
industrial concentration of 280ppm. The projection of future carbon imbalance indicates that ‘Business as Usual’ is not an option. A strategy of avoiding fossil fuel use entirely would re-establish global carbon balance to pre-industrial levels, but even if this may be achievable technically, this is unlikely to be acceptable socially or economically. Current proposals suggest a target upper limit of 550 ppm by the end of the century, although significant climate change is already apparent in many parts of the world, so the implications of this limit for the following century are rather alarming. For an energy strategy in buildings to be based on efficiency measures and the integration of renewables, both professional practice and education within the construction industry must change. The transfer of knowledge gained from recent research, into practice, must form part of this process. But in order for EC targets to be achieved, gaps in knowledge and skills also need to be addressed among all who work in the industry.

Energy Efficiency
In the UK, the 2003 Government White Paper on Energy proposed reductions in carbon emissions of 10% by 2010, 20% by 2020 and 60% by 2050. This is broadly in line with EC policy, but this implies a ‘step change’ in both professional practice and attitudes to the way we design and refurbish buildings.

The carbon emissions from existing service sector buildings are primarily derived from the demand for space heating and lighting. Changes in the Building regulations in the UK have begun to address this, but it is apparent that improvements in the performance of the building envelope (ie reductions in the space heating load), can potentially result in an increased cooling and ventilation load.

In the Queens Building in Leicester UK for De Montfort University (Sneider A. 1996), designed 15 years ago, we reduced energy consumption for heating and lighting by 50% (from 240 kwh/m2 for a typical similar building to 120 kwh/m2). We realized that this raised the potential risk of overheating but we avoided the need for mechanical cooling by combining natural ventilation with a high thermal mass interior. The design also involved careful consideration of daylighting and solar control to the different spaces, enabling savings in electrical energy use as well. Over the last ten years the building has performed well and has consistently met energy use expectations.

The Manchester Justice Centre competition proposal by Pringle Richards Sharratt uses a conceptually similar strategy to that of the Queens building. Heating and lighting still represent the largest demands for energy. On a restricted inner city site, a five point environmental strategy was adopted: 1) Light shelves to throw light deep into the section, providing even illumination and avoiding glare. 2) The central atrium space and perimeter corridors to act as thermal and acoustic buffers to the internal courtrooms 3) naturally ventilated courts via a deep floor plenum. 4) Traffic noise is reflected back into the street. 5) Supplementary cooling is provided (when required) by borehole water.

This magistrates court resolves the necessary split between the public and the judiciary by placing the courts between the large central atrium (public) and perimeter outward looking circulation for the judiciary. Performance analysis indicated that total energy consumption would be reduced by over 50% compared with typical existing magistrates courts.
The contribution which daylight and natural ventilation can make to reducing energy use is increasingly being recognized even in large deep plan projects which had previously been entirely mechanically conditioned. Recent examples with which the author has been involved include the Sydney Olympic Stadium, Australia (completed 2000), the Duxford AirSpace aircraft museum, UK (design stage), and the Pittsburgh convention center, USA (completed 2003).

**Passive and Hybrid Cooling**

In southern Europe, the combination of high ambient temperatures and internal gains will normally mean that supplementary cooling is required. *Give info on demand for cooling - Altener proposal.* If we compare the prevalence of air conditioning in existing and new commercial buildings in southern Europe, we find that air conditioning is, not surprisingly, very much on the increase. It also indicates the significance and potential value of finding energy efficient alternatives.

The I Guzzini office building at Recanati designed by Mario Cucinella (ref), promotes natural ventilation at night to pre-cool the exposed floor slabs, and supplementary cooling is provided during the day by fan coil units. A certain level of control is also in the hands of the occupants to open and close windows etc as they feel fit. Of course, light is also a major driver of the design, and all office areas benefit from proximity either to the perimeter glazing, or the central light well. Orientation is carefully considered, and although the south elevation is highly glazed (and shaded) the east and west elevations are almost blank, protecting the building from low altitude solar radiation. The separate elements of the building - shading, façade, light-well, staircases, rooflights, - articulate the environmentally responsive philosophy of the project.

In seeking to minimize reliance on mechanical cooling, various ambient heat sinks have been exploited in the past. Both direct and indirect evaporative cooling has been exploited in the past, and there is renewed interest in this in conjunction with downdraught towers. The application of Passive Downdraught Cooling (PDEC - see *Ford, B 1996*) to the Torrent Research Centre in Ahmedabad, India (*Ford,2001*), was one of the first applications of this technique. In a context where electrical energy is both expensive and unreliable, energy savings of 65% represent a significant achievement. This technique is now beginning to be applied in southern Europe. In a speculative office project in Seville, Spain (*Ford,B. 2002*), PDEC was found to meet 85% of the cooling load, and achieve a 6% capital cost saving over its air-conditioned equivalent. Significantly, this approach simultaneously deals with problems of urban noise and pollution.

In Malta, direct evaporative cooling is only applicable for 25% of the summer cooling period, and so a hybrid cooling system has been adopted for the new Stock Exchange (*Ford,B & Diaz,C.2003*). There are three parts to this cooling strategy: 1) When ambient temperatures are high and relative humidity is low, then PDEC operates; 2) When the internal relative humidity reaches 65% PDEC is switched off and high level cooling coils are activated; 3) At night in the summer, when ambient temperatures drop below internal air temperatures, vents are opened and air is driven through the building to pre-cool the building for the following day. Temperature traces recorded during commissioning indicate that internal temperatures within the main atrium space are stable around 23-25°C when ambient reaches 31°C, although there is also stratification.
This project demonstrates that in large volume spaces of this kind air flow through the building can be driven by buoyancy (and wind) forces without the need for fans and ductwork.

The applicability of PDEC to non-domestic buildings in southern Europe has been assessed as part of two EC funded research projects: a JOULE project (ref) completed in 1999, and an ALTENER project (ALTENER Cluster 9 Ref:4.1030/C/00-009/2000 - see Ford B & Cairns K. 2002) which was completed last year. The Altener project has established a database on existing and new non domestic buildings in Italy, Spain, Portugal and Greece, from which estimates have been made of the proportion of the building stock to which PDEC is applicable. The greatest potential exists in Spain and Italy, where a hybrid system of the type applied to the Malta Stock Exchange, could achieve electrical energy savings of 30-50kWh/m², which represents 10 - 20% of the total energy consumption of a typical office building. At a national scale, the technical potential (assuming a scale of interventions from minor to full scale refurbishment) is substantial : this approach is applicable to 70-80% of the existing commercial building stock, and in many situations will be more cost effective than comfort cooling. Of course market barriers will limit the take-up of the technology, but for PDEC the ALTENER study suggests that the national annual electrical energy savings could represent 1.5% - 2.5% by 2025.

This technique does not lend itself so easily to small cellular spaces, and at the Malta Stock Exchange cellular offices are conventionally conditioned with fan coil units. However, the ‘Gravivent’ system, developed in Germany, has been applied to cellular spaces, and we have also recently been developing simpler direct and indirect evaporative cooling systems using porous panels placed within wall ducts or mounted in roof vents. Results from laboratory testing indicate that we can achieve 30 - 40 watts cooling /m² of panel. These systems also lend themselves to refurbishment projects, and are applicable both to housing and offices, suggesting substantial potential.

The use of cooling coils in conjunction with buoyancy driven air movement was part of proposals for the cooling of concourses and atria in the competition winning entry for the Singapore Management University campus by Edward Cullinan Architects. The supply of fresh air needs to be carefully controlled, but this approach is clearly viable for warm humid climates.

Refurbishment - opportunities for performance improvements.

Data on the frequency of refurbishment in different countries within Europe indicate that most commercial buildings are refurbished every 10-20 years. The scale of intervention and modification of the existing building will vary, but clearly there is a major opportunity to improve performance as well as making cosmetic improvements.

Temple Way House in Bristol was built in the late 1960s and is in need of refurbishment. Located on a noisy and polluted dual carriageway, this office building was originally air conditioned, but the system was at the end of its life, and we were asked to find an alternative to replacement. The building is predominantly narrow in section (approx 12metres wide), and although the east side is noisy and polluted, the west side is adjacent to the harbour which is quiet and clean. We therefore proposed to supply air from the harbour side and exhaust
on the east side via glazed stacks which terminated above roof level. The glazed stacks were sealed externally, providing a thermal and acoustic buffer to the noisy road, while maintaining daylight penetration. CFD analysis indicated that, with refinement, the idea would work. In a sense, the glazed stacks are like a partial double façade.

Of course, overcladding with glazing to form a second façade, protects the inner façade and provides a thermal and acoustic buffer between inside and outside. However, this approach can also give rise to increased overheating risk, and consequent increased cooling load. Recent buildings by Renzo Piano Building Workshop (eg at the Parc D’Or, Lyons) have resolved the overheating risk by making the whole façade openable using automated glazed louvers. This solution is extremely expensive and also reduces the acoustic effectiveness of the ‘buffer zone’. Mechanical extraction of air from the cavity can reduce cavity width, but may increase energy and maintenance costs.

An innovative porous cladding element has been developed which induces direct evaporative cooling of the air within the cavity. (See EC Framework 5 research project EVAPCOOL  Ref: ENK6-CT-2000-00346). This innovation enables the external façade to be sealed (apart from small vents at top and bottom) and reduced in width, potentially reducing the cost associated with opening facades, improving noise reduction, and reducing the cooling load in adjacent offices. Cladding support systems similar to those used for current ceramic cladding systems can be used for the porous panels, with a similar loading on the façade. This idea is currently the subject of on-going research.

**Integration of Renewables**

The integration of new and renewable energy devices in buildings is widely heralded as the means to move from energy efficient building design to ‘Zero Energy’ building design. The contribution of renewables to total energy use in the UK is due to increase from 3% in 1989 to 20% in 2020.

Research and Development into building integration of renewables has been a major feature of work at the School of the Built Environment in Nottingham University. The ‘Life Lab’ concept has been applied to many of the schools own buildings. The ‘Eco-House’, incorporates a small wind turbine, solar chimney, PV roof tiles, light pipe, solar water heating, a ground source heat pump, and rain water collection. The Marmont Centre for Renewable Energy also incorporates a wind turbine, PVs, light pipes and solar water heating. The new ‘Sustainable Research Building (SRB) incorporates a 5kW PV roof, …. (expand).. but it is the University’s Jubilee Campus that gives the largest scale demonstration of an holistic approach to sustainable design in its architecture. The plan links narrow teaching blocks by atria which help to drive a novel low energy ventilation system, and incorporate PVs and other renewable energy systems. Wherever possible the buildings also incorporate sustainable materials…..(expand)...

The Jubilee Campus, by Hopkins Architects and Arups, is widely regarded as the world’s first ‘Green ’ campus.
CONCLUSION

This paper has identified the pressing need to transfer research knowledge into practice, and has illustrated a number of projects in which architects, engineers and building physicists from the school of the built environment at Nottingham University have contributed to this process.

Bill McDonough, one of the pioneers of sustainable design in the US, has said that: “Most architects who are sensitive to sustainability issues try to do more with less by designing buildings that make more efficient use of energy and resources. But is being less bad the same as being good? Does mere efficiency meet our need to connect with the natural world or does it just slow down ecological destruction”? (Gissen. 2003)

It is clear that a truly sustainable built environment is not a ‘goal’ or an ‘end point’, but rather a process. And the closer this ‘process’ mimics the natural world the more sustainable it will be. Nature is comprised of self-regulating ecosystems which maintain a delicate interactive and dynamic equilibrium, responding to the cycles of the seasons and of day and night. Our buildings and built communities need to cultivate a similar dynamic equilibrium, contributing to rather than subtracting from our ability to be ‘self regulating’. A society with these values will not mourn the passing of the fossil fuel era.

References

从研究到实践:如何让应用研究支撑革新性的实践

建筑业变革进程缓慢，出了名的保守。至今，也只有少有的几家大公司开始参与研究。然而，对全球变暖和可持续发展的关注已经导致对研究的大量投资（尤其在欧洲）以及在技术和设计方法上的发展从而将减少我们对石油燃料的依赖程度。随着研究的扩展，这些应用于建筑工程项目的技术已经遍及全世界，并且正在成为部分主流技术。但是，可以感觉到，在建筑专业上存在知识和技术鸿沟，它会严重限制新技术的应用。大家都认识到需要新技术，可是大都缺乏对如何实施的认识。

知识从研究转向应用因此非常关键。但是对于一个不喜欢改变的工业，一个在传统上就低估研究，将研究者鄙视为象牙塔下作白日梦人的工业，这样的转变变得非常困难。一种说服评论家了解采用“新”技术也不一定有危险的方法是要说明将技术应用在一些大型的项目中是可靠且花费高效的。

我们可以关注这么个过程，通过该过程可以达到对低CO2排放建筑的技术革新。

有一点是很明确的，那就是我们不再满足于单单倚赖以前获得的知识和经验。在过去的20年里，我们的认知和将生物气候设计理论在建筑中应用都取得了较大的发展。在新能源和可再生能源利用及其在建筑上的集成中也取得了类似的进步。战略性的考虑这些问题应该成为设计初期阶段的一部分。为了给客户采用彻底解决方案的信心，需要使用各种分析工具对技术的选择进行严格的测试。并不是所有的工程项目都可以请得起专家进行测试和分析的，但是简化的技术也是存在的，这就是“如何实施”真正的意义所在。

作为一个教育性的研究机构，诺丁汉大学建筑环境学院在生物气候设计和能源利用技术领域上进行革新性的研发和咨询活动已经有15年了。Saffa Riffat教授已经发展了“生命实验室”的概念，在这些实验室里，革新性的或是实验性的技术被集成到学校自己的建筑中去，使得建筑的CO2排放降低，并且有机会在这些“活”建筑中从事一些实验活动。Brian Ford教授致力于研究和咨询，已经将生物气候设计理论应用在世界各地的许多项目上。本文阐述了将研究转化为实践的过程和有时候为了降低建筑CO2排放采取的不同措施之间存在的矛盾关系。