New Skills for Low Energy Architecture

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Abstract

The UK Government has set out policy for all new buildings to be zero carbon by 2019 with new homes leading the way in 2016 and public sector buildings in 2018. However, much of the UK construction industry is still struggling to get to grips with the 2006 revision of the Building Regulations that required a mere 25% cut in carbon emissions.

This paper examines the current state of education and practice in the discipline of Building Engineering Physics, a key discipline in the development of energy conservation design for buildings. The author makes recommendations for educational and industry initiatives key to addressing the present knowledge and skills gap in low energy design.

Keywords: Low Energy Design Skills

1. Introduction

Construction across the world is facing an unprecedented challenge in recognising and addressing the fact that energy consumption in buildings is responsible for a substantial proportion of carbon dioxide emissions. The drivers are not just the mitigation of future climate change, but also addressing unnecessary energy demands in preparation for the time when we are far more reliant on variable output renewable energy generation.

Now enshrined in UK law is a commitment to an 80% reduction in carbon emissions across the UK economy by 2050 [1]. In order to contribute to this requirement Government policy states that all new homes must be zero carbon from 2016 and new non domestic buildings zero carbon by 2019[2]. This is to be achieved by progressive cuts in carbon emissions allowable under revisions to Part L of the Building Regulations.

In the UK, buildings presently account for some 45% of carbon emissions and it has been estimated that about 80% of the buildings that will be in use in 2050 already exist, creating a vast demand for low energy refurbishment. It has further been estimated that there are some 20mn homes and commercial premises in the UK requiring refurbishment by 2050, implying a rate of refurbishment of 10,000 buildings per week over the next 40 years.

Whilst the policy targets require an enormous and concerted effort, the construction sector largely lacks the skills and knowledge necessary to deliver these ambitions. Further, the pace of change has outstripped the ability of Universities to update the education of undergraduates and the construction industry has traditionally underinvested in training and development. This has resulted in a serious and widening skills gap, which can only become more pronounced as the demand for novel skills in low energy design and engineering increases.

The Engineering Construction Industry Training Board estimates a potential shortfall of professional engineers of up to 15,000 by 2015 [3] and in a recent skills survey [4] 43% of engineering practices in the construction sector indicated that they had experienced skills and competence gaps among their professional engineering staff.

The Stern Review [5] estimated that the cost of stabilising atmospheric greenhouse gas levels to be about 1% of global GDP. This implies a worldwide annual investment of over $600bn in new low carbon technologies and services according to World Bank figures for 2008 (pre-recession) [6]. On these estimates, the new low carbon economy would be worth some $25bn annually in the UK and around $140bn for mainland Europe.

In the UK construction historically accounts for about 10% of GDP, whilst energy use in buildings presently accounts for some 45% of carbon emissions. Thus if the low carbon investment is made pro-rata to emissions in each sector, this would suggest that the construction sector needs to grow by 0.45% of GDP or 4.5% of construction output, with the growth focussed on low carbon. This estimate is likely to be on the low side as the move to renewable and nuclear energy to supply other sectors of the economy will involve substantial construction and infrastructure effort. Since the construction industry employs over 1.5mn people there will be the need to recruit or train around 70,000 low carbon specialists across the industry. To meet current UK policy this will have to happen within about 10 years.

The Engineering UK Report 2009/10 [7] suggests that in total the construction industry will need to be employing over 500,000 professional engineers and technically qualified engineering staff by 2017. We can therefore estimate that at least 15% of these people need to be experts in low energy design or technologies. At present the numbers of practicing low energy specialists are unknown, but reports from industry suggest that they are few with widely ranging experience and approach [8]. Therefore in order to meet the demands for new expertise we must undertake a radical overhaul of education and training in construction engineering disciplines, something that the universities are simply not prepared for. However, in order to deliver genuinely low energy buildings, it is necessary not just to address the specialists; the remainder of the industry also has to be sufficiently familiar with the concepts to facilitate their application.

2. Introducing Building Engineering Physics

One of the most urgent areas to be addressed is the lack of scientific, analytical and design skills appropriate to the new low carbon paradigm. Building engineering physics is a key scientific discipline, the understanding of which allows designers to manipulate the thermal and environmental characteristics of buildings to achieve performance criteria without necessarily relying on energy consuming building services installations.

Building engineering physics investigates the areas of natural science that relate to the performance of buildings and their indoor and outdoor environments. The field deals principally with the flows of energy, both natural and artificial, within and through buildings. The understanding and application of building engineering physics allows us to design and construct high performance buildings which are comfortable and functional, yet use natural resources efficiently and minimise environmental impacts of their construction and operation.

Building engineering physics emerged during the latter part of the 20th Century, at the interface between building services engineering, applied physics and building construction engineering. Building services engineering provides mechanical and electrical systems to maintain comfortable internal conditions that enable occupants to achieve their maximum performance potential. Through the understanding of the science governing energy flows in buildings, building engineering physics complements and supports building services engineering. However building engineering physics must also consider the engineering performance of parts of the building not traditionally considered to be systems, such as the frame and envelope.

Building engineering physics comprises a unique mix of heat and mass transfer physics, material science, meteorology, construction technology and human physiology necessary to solve problems in designing high performance buildings. Add to this the requirement for rigorous engineering analysis creative design and a systemic approach to designing the whole building as an interdependent system and it can be seen that building engineering physics is quite distinct from any of the established engineering disciplines.

Few people in the UK construction industry are even aware of the discipline of building engineering physics, let alone know how to apply the principles in the design of buildings. Building projects are traditionally led by architects, not engineers, but building energy performance hardly features in architectural education. This lack of essential knowledge to inform strategic design decisions has led to the perpetuation of an experimental approach to building performance, rather than an approach based on rigorous analysis, synthesis, testing and feedback.

The life-spans of buildings are long and it may take years for performance issues to come to light; by which time the original designers have long moved on and the opportunity to learn from experience is lost. Further, the competitive and adversarial nature of UK construction inhibits the dissemination of building performance information. Thus the construction industry is generally still delivering buildings that are little better in terms of real carbon performance than they were in the 1990s.

3. A New Low Carbon Paradigm

In order to create buildings fit for the 21st Century, energy prediction and rigorous performance analysis must replace the experimental building development of the preceding generations. In an industry where each product is essentially a prototype, and when it may take years or decades for building performance problems to come to light, we can no longer afford the luxury of experimenting with the physical form of buildings. Without integrating the rigorous performance analysis brought by building engineering physics with the architectural design and with the empirical construction knowledge embodied in the industry, we will continue to construct buildings whose energy performance falls far below that which we need to achieve.

In practice building engineering physics may be described by any number of names: building analysis, environmental engineering, sustainable design, low carbon consultancy. There is no accepted scope of services for low carbon design included in any of the standard forms of professional appointment. Building services engineers, who deal with energy issues, often lack detailed understanding of building fabric and construction. Architects and structural engineers, who understand the construction, are unfamiliar with energy issues and the interdependence of the services installations. Whilst a quantity surveyor can advise on the financial implications of design decisions, few teams have anyone with the necessary skills and overview to advise on the carbon emissions impact of decisions.

The building envelope is specified by the architect, but it is now necessary to consider thermal insulation, building air tightness, solar shading and window performance as part of the low carbon strategy. It has therefore become common for the architect to look to the building services engineer to define the performance of these elements, but clearly these do not form part of the building services installations. This leads to confusion over the responsibilities for specification of components and assemblies. The fees paid to the building services engineer do not cover the additional work necessary to properly analyse the construction components, nor will his PI Insurance cover liability in an area outside his expertise.

The energy performance of buildings can be influenced by many diverse factors from the location and construction to the use of information technology. In order to assimilate sustainability into our construction projects we must re-integrate all the disciplines to deliver holistic solutions. By identifying component solutions that complement each other, by avoiding over-engineering and designing elements to deliver multiple benefits, such as using the concrete building frame for thermal storage, we can achieve the goals of both economic and environmental sustainability.

Systems engineering recognises that complex products, such as buildings, require many interdependent systems to function in harmony. The form, frame, aesthetics and choice of materials will all influence the final energy performance of the building as much as the building services installations. At times conflicting functional, structural and performance requirements will make it difficult to find an optimal solution and it is necessary to exercise engineering judgment to achieve a satisfactory compromise. Building physicists, when they are employed on building projects, already operate across the established frameworks of architecture, structure, construction and building services taking such a systemic approach to the design.

However the skills required for a low carbon approach often already reside, to a greater or lesser extent, in existing design team members. The building services engineer is trained in energy conservation, comfort and thermal performance and generally absorbs knowledge about window design, shading and space planning through professional practice. Formally integrating a systems engineering approach with the fundamentals of building engineering physics in the education of all building professionals would significantly strengthen their ability to design low carbon buildings. Awareness of the truly multidiscipline nature of low carbon design allows individuals to influence the design of a wide palette of components and solutions for the ultimate benefit of the project performance.

4. The Need for Education

Building engineering physics is relevant in the education of anyone who will design or specify the environmental performance of buildings. Whilst the fundamental principles of building physics are taught in our universities to some extent, there is insufficient exploration of their application to the creation of low carbon buildings to prepare graduates for industry. Whilst it has traditionally been the preserve of the universities to teach theory and leave the application to industry, the rate of change required in the construction industry calls for a radical transformation in building engineering physics education.

Chartered Institute of Building Services Engineers (CIBSE) guidelines for accreditation of undergraduate degrees [9] require that fundamentals of engineering and building engineering physics comprise 25% of the taught content, the remainder being specific building services engineering or general professional topics. CIBSE presently accredits 16 undergraduate degrees, but only 3 of these are at Master of Engineering (MEng) level, suitable for registration as Chartered Engineer (CEng) without further study.

In contrast the Joint Board of Moderators (JBM) currently accredits over 100 civil and structural engineering degree courses at MEng level alone [10], but sets no requirement at all for building engineering physics. A review of the JBM accredited courses indicates that only around 10 universities with civil or structural engineering courses offer any identifiable building engineering physics teaching, but this can be as little as one introductory unit in building thermal performance.

The Royal Institute of British Architects (RIBA) publishes criteria for the validation of degree courses which includes the integration of technology. However technology in this sense refers to the technology of constructing buildings, primarily structural and building services engineering. Some university courses are beginning to teach low carbon design, but architecture is a design discipline and therefore has even less opportunity to teach the analytical and engineering skills of building engineering physics.

Teaching both building engineering physics and low carbon architectural design is hampered by the lack of experienced professionals, current research and reference material. University courses take time to design, approve and implement and rely on there being sufficient authoritative reference material on a subject. Reliance on practitioners from industry, who themselves often struggle with keeping up to date with new developments, means that teaching of construction technology and design is often well out of date with regard to low carbon performance.

Many case studies used in teaching are significantly out of date, as recent built projects have not been evaluated to the same extent as projects from earlier times. Sometimes case studies are drawn from “Practice Books” written by commercial practices to promote themselves. These are often less than candid about the real performance of their designs and contain no independent analysis. With insufficient low carbon design knowledge amongst the teaching staff there is often little critical examination of the issues and inaccurate information about sustainability becomes received wisdom through repetition.

The current trajectory for carbon reductions embodied in Government policy and the plans for the Building Regulations will require a dramatic up-skilling of professionals in the construction sector. Yet the essential skills are simply not taught at present in the majority of universities. The quantity and quality of teaching must both be addressed and it will be necessary for more practitioners familiar with cutting edge low carbon design to be involved in education. Otherwise, with a four year MEng being the norm and planned revisions of the Building Regulations at three to four year intervals, the education of graduates is likely to be out of date even before leaving university.

The universities must develop new fields of multi-discipline research in energy and carbon efficiency, directed towards providing the industry with feedback on the success or otherwise of current initiatives. This will bring the cutting edge of low carbon design into universities where it will benefit the teaching of all construction disciplines. It will also create numerous opportunities for industrial and international partnerships, supported by a wide range of new funding and revenue streams, not traditionally available to academic researchers. Linking undergraduate teaching with research embracing the environmental zeitgeist will make university courses in construction disciplines highly attractive to environmentally aware young people.

5. Conclusions

Solving the fossil fuel energy crisis is vital to our future welfare. If we are to mitigate climate change and secure our future energy supplies with the minimum social and economic impacts, we must fundamentally change the way in which we design, procure and operate buildings. The UK Government has set challenging targets for reducing carbon emissions from new and existing buildings, which presently account for a substantial proportion.

However the construction industry presently lacks the skills and mechanisms to design buildings to achieve such targets. The need for professionals in the construction industry to be well versed in the discipline of building engineering physics has never been higher. Unless the construction industry urgently addresses the fundamental skills necessary to design genuinely carbon efficient buildings, then the transition to a low carbon economy simply will not happen.

The process usually adopted at present is to design a building following conventional methods, simulate the energy performance using software and then try to address the shortcomings by adding expensive renewable energy technologies. This leads to un-necessarily expensive buildings and often a failure to meet the original performance target as the final expense of doing so would be too great. This repetition of expensive failures has led to the widespread view that energy efficient buildings are always more expensive to construct and this inhibits progress in an industry largely funded by speculative developments.

Government policy now must urgently prioritise education and skills development to deliver the manifold increase in low carbon design professionals vital to the achievement of our national policy objectives. The education of new and existing construction professionals requires a paradigm shift in order to stop the existing skills gap growing even further and to prepare for the new low carbon economy. One of the most pressing problems is simply to identify how many experienced low carbon designers will be required by 2020 to deliver new zero carbon buildings at the rate the economy requires.

Many skills required for constructing low carbon buildings do exist, but they are often scattered throughout a design team and there are no mechanisms or incentives to deploy them effectively. The education of construction professionals needs to address the fundamental issues of building engineering physics and systems engineering in order to capture the diverse skills available and apply them to generate efficient holistic solutions. This will require a change to the traditional partisan roles in construction contracts and for clear allocation of carbon accountability. There is also a need for substantially more professionals to be equipped with these fundamental skills.

The industry and construction clients need clear guidance on which parties in the design team should be responsible for which aspects of the design. In order to achieve genuinely low carbon design this may require the re-allocation of design responsibilities on the basis of building performance rather than on the basis of components. Thus, rather than the architect being responsible for the specification of the windows, the architect would become responsible for the construction detailing and weather-proof-ness of the window assembly, whilst the building physicist on the team, whether architect, building services engineer or sustainability consultant, would be responsible for specifying the thermal and light transmission characteristics. The institutions and trade associations must draw up a universally accepted scope of services and responsibilities for low carbon design.

It is vital that we raise the profile of sustainable engineered solutions, subjected to rigorous independent analysis, over the marketing green-wash that passes for environmental responsibility in the popular media. Producing accurate and impartial analysis and case studies of buildings, which will become the reference and teaching material for future designers and students, is far too important to be left to commercial interests. This work should be undertaken by new industry and academic partnerships, which will have the added benefit of bringing low carbon research into the university departments which will teach the next generation of designers. Government can play a pivotal role in this effort by commissioning and publishing post occupancy evaluation of all recent public building projects.

6. References

[1] Department of Communities & Local Government (2007) *Building a Greener Future Policy Statement* Crown Copyright
[2] Department of Communities & Local Government (2009) *Proposals for amending Part L and Part F of the Building Regulations Consultation Document* Crown Copyright
[3] Engineering Construction Industry Training Board (2008) *Industry Report Building Capacity and Capability through the Regions* ECITB London
[4] Construction Industry Council (2004) *Built Environment Professional Services Skills Survey 2003/2004* CIC London
[5] Stern N (2008) *STERN REVIEW: The Economics of Climate Change* Cambridge University Press
[6] World Bank (2010) World Development Indicators Database *http://siteresources.worldbank.org/DATASTATISTICS/Resources/GDP.pdf*
[7] Engineering UK (2009) *Engineering UK 2009/10 Report* Engineering UK London
[8] King D (2010) *Engineering a Low Carbon Built Environment* Royal Academy of Engineering London
[9] Institute of Building Services Engineers (2009) *Educational Base for Chartered Engineer Registration, M22* CIBSE London
[10] Joint Board of Moderators (2009) *Accredited Degrees CEng, JBM151* JBM London