Sustainability special issue · CDM questioned · CHP guide · Low carbon design · Harlow Carr · Carbon emissions and risk assessment · Going for green in Australia

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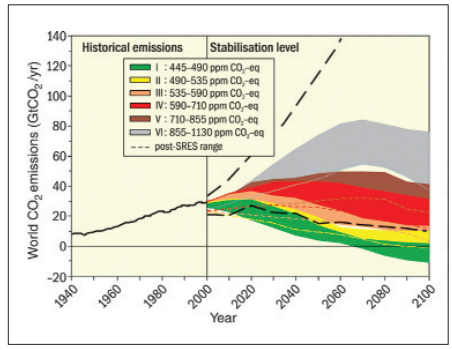
Sustainable construction special issue

News

Features



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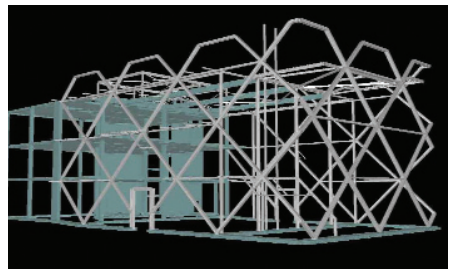

Regulars

Cover Image: Computer generated image of Curtin's Engineering Department (see p28)

The Structural Engineer
– promotes the learned society role of the Institution by publishing refereed papers aimed at advancing structural engineering which is the science and art of designing and making, with economy and elegance, buildings, bridges, frameworks, and other similar structures so that they can safely resist the forces to which they may be subjected.
– provides structural engineers worldwide with information on practice, design, development and research, education and training associated with the profession of structural engineering and offers a forum for discussion on these matters
– assists *The Institution of Structural Engineers* in maintaining its internationally recognised high standards
– provides the membership with worldwide information on recent professional and technical activities, headquarters and branch events, and provides a medium for relevant advertising.

The Institution of Structural Engineers is the only qualifying body in the world concerned solely with the theory and practice of structural engineering.

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Bribery laws: prepare for changes

New bribery laws received Royal Assent on 8 April which will place significant responsibility on company directors.

If bribes are paid by or on behalf of an organisation, the company will have to demonstrate that it has 'adequate procedures' in place to prevent corrupt business practices or face the penalties. Guidance is likely to be issued by the Ministry of Justice in June or July but will not be prescriptive. It is likely to cover anti-bribery policies, training of staff, corporate entertainment and gifts, and better due diligence on agents and business partners.

Having been pushed through Parliament before the election, the Act is likely to come into force on 1 October 2010. This gives businesses a short window of opportunity to review their systems and procedures to avoid falling foul of the new law.

The Bribery Act introduces a general offence of offering or receiving bribes, a specific offence of bribing a foreign public official, and a corporate offence of failing to prevent bribery. According to recent research by legal firm Eversheds, which canvassed the views of almost 700 executives, 60% of businesses are unaware of the corporate offence of failing to prevent bribery and one in four board directors don't know that they could face prosecution. One in five (20%) organisations don't have robust systems to prevent bribery from taking place and there is also confusion about what constitutes bribery.

Neill Blundell, Head of the Fraud Group at Eversheds, said: 'The Bribery Act is now a reality and businesses need to be aware of the penalties they could face if they don't comply. The UK has previously been criticised for its approach in dealing with major bribery cases, so this is a significant step change that will go far beyond the scope of the US Foreign Corrupt Practices Act.'

While three-quarters (73%) of those surveyed understand more explicit forms of bribery – giving or receiving an illicit payment – there was a lack of awareness of the more discreet forms that will be covered by the Act, such as offering a commercial advantage or offering and receiving lavish gifts.

Mr Blundell said: 'It is worrying that our research identified a real lack of awareness and understanding in relation to the Bribery Act – particularly when it comes to the new corporate offence of failing to prevent bribery – and that many businesses aren't set up to minimise their exposure to corrupt business practices. These are serious laws with tough penalties and businesses need to take steps to minimise their risk by showing that they have actively taken steps to prevent bribery. This includes delivering training on ethical business practice from board level down, and ensuring that there is a policy in place which is communicated throughout the organisation.'

Businesses which want to find out more about the Bribery Act can visit (www.eversheds.com/briberybill) to request a copy of the *Corruption Clampdown* report and to view Eversheds' video, *Bribery and Corruption: What your business needs to know*.

Professionals' hopes and fears for future

A study on the current state of the UK architecture and engineering has found uncertaintly about the future, realism about business in 2010 and a strong focus on where future opportunities may be found. The report revealed a surprising willingness to invest in technology, training and people in the midst of the slowdown.

A decisive 75% of respondents to a survey which made up part of the report said they are planning capital expenditure over the next 18 months to enable them to work more efficiently. To consolidate this, 75% said that they would include training in this investment.

Thriving in 2010 and Beyond – a Practical Guide for Architects and Engineers, was researched by Unwired, written by former *Architects' Journal* Editor, Ruth Slavid, and commissioned by Deltek. It was compiled using a mix of survey data, comments from architects and engineers who are experiencing life and work in the recession-hit sector and the knowledge of the key industry spokespeople who make up the report's advisory panel.

The report paints a picture of a sector still in shock after the punishing economic conditions of 2009 and still unsure about a new post-boom era. 90% thought existing practices would need to be more agile to survive – and business skills were rated as more important than design skills in defining the qualities of a top professional. 'The rules have fundamentally changed. I don't know what the new rules will be', said one senior industry figure talking about planning and the commercial market.

Some 32% of respondents thought that refurbishment projects, bringing old buildings up to current environmental standards could be a major source of future work for their practice. And the continuing globalisation of the industry was emphasised by the fact that 75% thought it was either 'essential' or 'quite important' to work internationally to survive.

There was some optimism about the housing sector with 35.5% thinking that it would need to grow in some way because of the pressure of housing shortages. However, the promise of the infrastructure boom appears to have been shortlived in view of public spending cuts, with only 10% thinking current volumes of work would increase.

The key points for the future were:
– Business and people management skills are becoming more important than design skills compared with 5 years ago.
– A decisive 90% thought existing practices would become more agile in order to survive.
– Nearly 75% believed there would be takeovers and mergers leading to larger companies.
– 80% still believe there will be opportunities for new practices to emerge.

Thriving in 2010 – and Beyond follows on from the success of last year's *Thriving in the Downturn*. Both reports were commissioned by Deltek (Nasdaq: PROJ) provider of software applications and solutions designed specifically for project-focused businesses. This year's report can be downloaded free from the website: (http://www.thrivingreports.com/).

Midland Counties: Visit and student competition

The President of the Institution, Norman Train recently visited the Midlands Counties Branch where a design and build competition had been organised jointly with the University. He viewed the design-build activities undertaken by students, and awarded the prizes.

The objective of the competition was to develop an environment of creative thinking in structural design, followed by the application of theoretical concepts that were then put into practice. It attracted 70 students who formed 12 teams.

The competition brief was based on a realistic scenario for both designing and constructing an elevated platform above a crossing such that it could only be supported from within four designated areas. The model platform had to be positioned between 280mm and 350mm above ground level without any support below 200mm. The model also had to be constructed as a space frame, capable of supporting at least 10N, but to fail before a load of 100N had been applied. The model had to be built in a manner that proved feasible to lift it as a single unit for testing purposes, but without any permanent connection to the floor.

The President with Head of Civil Engineering, Associate Professor Kamel Hawwash at the design and build competition

Incoming Chair, Susan Giahi Broadbent, with the President

All of the models built by the student teams were checked for compliance with the brief at the end of the allocated construction time. Those that complied qualified for the testing stage of the competition. Each model was loaded progressively until failure. Some models failed by overturning, some by buckling of compression members, while others were excluded from the competition because the design capacity exceeded the specified failure load of 100N. Four model structures proved capable of carrying the specified working load, but failed at 80N. The President assessed the models after short presentations from the four teams, and chose the winning team. The winners each received voucher prizes and certificates.

The competition provided a clear demonstration of teamwork, engineering judgment and critical thinking.

During the evening the President presented the Retiring Chairman's Medal and inaugurated incoming Chair, Susan Giahi Broadbent, the first female Chair of the Midlands Counties Branch in its 85 year history. Her inaugural address was entitled 'A Contrast of Experiences and Challenges'.

In brief...

EEFIT meetings on Haiti and Chile earthquakes

EEFIT's mission team to Haiti returned safely on 13th April, after spending a week in Port-au-Prince studying the effects of the 12 January 2010 earthquake. The team's blog can be found at: (http://www.booth-seismic.co.uk/haiti). They will present their findings at Institution HQ on 11 May at 18:00h.

A further meeting will be held on the Chile earthquake on 9 June at 18:30h at the Insitution. See EEFIT website: (www.eefit.org.uk).

Amendment to Manual for the design of plain masonry in building structures to Eurocode 6

Two errors have been found in the Manual.

Firstly on page 72, which is non-conservative. The final sentence in s5.3.6.3 is incorrect because it makes no allowance for the slenderness of the wall or column being designed. If used where the middle height eccentricity is calculated to be less than 0.05t, it will lead to an overestimate of the vertical load capacity of the wall or column, if the middle height reduction factor governs. The correct value of the middle height reduction factor should be obtained from Figure 5.13 or the appropriate equation (see Annex G in EN 1996-1-1).

The second error is a typographical error on page 76. In the first equation in s5.3.8 the 't' should not be subscript as it is multiplied by the other terms.

The online version of the Manual, held on IHS, has been updated to incorporate these amendments. All copies of the manual sold from 26 April 2010 will be despatched with an amendment slip with the sentence deleted and the subscript altered.

The corrected pages 72 and 76 are in the April 2010 amendment downloadable from the publication amendments page of the website at: (http://www.istructe.org/knowledge/publications/Pages/publication_amendments.aspx).

Designing for security

New guidance has been published for built environment professionals on designing for counter terrorism, ensuring they are better equipped to think about designing-in security features from the outset. The guide, co-authored by TPS, part of Carillion plc, is part of the RIBA's ongoing work with the Home Office and the National Counter Terrorism Security Office (NaCTSO) on protecting public spaces.

The guidance sets out the most common considerations when designing for counter-terrorism in the built environment. It features real-life case studies of UK buildings, which show the different ways built environment professionals are responding to the challenge of creating spaces that are open and welcoming to the public yet reassuringly safe.

It considers different ways of reducing vulnerability to the terrorist threat and containing damage including:

– Mitigating terrorism through physical, technical and procedural protective measures, such as barriers, bollards, landscaping and surveillance.

– Damage limitation through materials used, such as blast and ballistic resistant glass, and the use of glazed façades to limit intrusion.

– Aspects concerning general security, such as vehicular access, landscaping, fire evacuation procedure and adaptation of the original building design.

TPS completed the technical authoring of the guide by providing the detailed input for the design of structures and glazing to resist blast, detail on the conduct of threat and risk assessments, and the application of technical security measures. The firm has extensive experience in major domestic and foreign security design projects including the completion of the security design of Heathrow Terminal 5, London's Portcullis House, and 'The Avenues' in Kuwait City; the Gulf Region's largest mall.

Mark Whyte, Director of TPS Security and Explosion Effects said: 'By bringing together information on threat and risk assessments and the need for designing integrated security solutions, the guide has marked out a major step in bringing security to the forefront of the design and construction process.

'We hope that TPS's contribution will encourage architects to consider issues of security and counter terrorism as early as possible in the design stage, as this goes a long way towards ensuring that security is effective and efficient.'

The guide is aimed at all property professionals,

TPS undertaking field trials of blast resistant building systems (*Photo: Mike Crossley*)

the hope is that it it will help develop a shared understanding of the concepts and options available. 'If we can achieve this understanding we will have taken a significant step towards creating buildings and landscapes that meet the challenges presented by terrorism, without sacrificing design innovation or turning our cities into fortresses or bunkers'.

A copy of the guidance can be found on the RIBA website at: (http://www.architecture.com /Files/RIBAHoldings/Communications/Press/General/ RIBAguidanceoncounterterrorism.pdf).

Obituary: James Hodgson Armstrong OBE 1926-2010

Peter Campbell (F), Past President ,writes:

James Armstrong OBE FREng, Hon.DEng, BSc, FIStructE, FICE, Past President, was a distinguished engineer and philosopher who I respected and admired for many years as a friend and colleague. He passed away a few days before Easter.

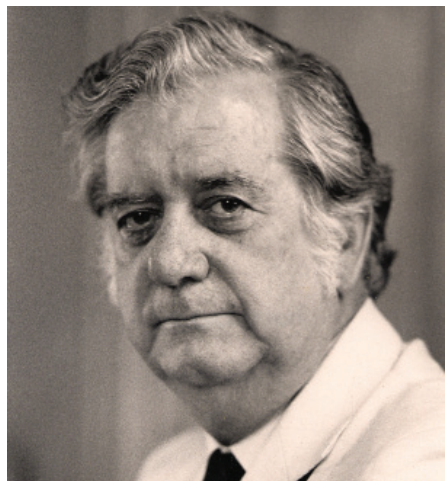
He played an active role in monitoring and developing policies in professional education, and played a significant part in co-ordinating and developing the Royal Academy of Engineers' Visiting Professor scheme, chairing the committee that considered design matters in engineering.

He was a visiting professor at several universities in the UK and elsewhere. He featured in the book, *Eminent Engineers, Their 20th Century Lives and Times*, published by Whittles in Caithness, Scotland. His contribution was entitled: 'If you want God to smile tell him your plans'; his message will inspire all those who read it.

James ended his career as a Senior Partner to the multidisciplinary practice, Building Design Partnership, where he had been responsible for many highly regarded projects, not least the Channel Tunnel Terminal and the creation of the double parabolic roof of the Commonwealth Institute.

He contributed to the life and work of the Institution as President in 1989-1990, following me in that role. I note the complementary nature of my Address in 1988, 'Structural engineers, some of their wider responsibilities' and his own Address, 'An elegant profession'.

James was generous in his contribution to various educational charities which included the Higher Education Foundations, The Christian Industrial



James Armstrong: 'If you want God to smile, tell him your plans'

Movement, the Varaanasi Trust and the Maryport Heritage Trust. He was largely responsible for creating a school in India which has recently achieved Secondary status. He remained the treasurer and a trustee of the school for some 40 years, until his death.

He was Chairman of the Buildings Committee of the Harris – Manchester College in Oxford, where he was made an Hon. Fellow.

James was a devoted family man, and with his wife, Marjorie, had the joy of celebrating their 60th wedding anniversary a few days before he died peacefully. They had two children, the late Hugh, and Jane. Jane's husband, the Rev. Stephen Terry conducted the very well attended funeral service at the church of St Philips in Hove on 8 April.

The manner in which he was admired and respected by all those who knew him was exemplified by his Oxford college, which, on receiving the news of his death, raised the College flag which was then flown at half mast.

His former colleagues at BDP add:

Jim, who joined BDP in 1963, was appointed Partner in 1967 and was head of the civil and structural engineering profession at BDP until his retirement in 1989.

He had a major influence on a wide spectrum of the firm's affairs ranging from a deeply felt involvement with education and professional development to high profile engineering projects such as his early involvement in the UK Channel Tunnel Terminal.

He brought to all issues a directness of approach and made a significant contribution to the wider engineering profession not least in the year spent as President of the Institution of Structural Engineers.

In his life after BDP he continued to travel and lecture widely and was the author of numerous publications, with one book entitled *Design Matters: the organisation and principles of engineering design* published as recently as 2008.

As said of Jim at the time of his retirement from BDP 'only those who have known him can have a real understanding of the value of his work and the care and thought he has given to further our aims and strengthen our successes'. This was Jim through and through.

Viewpoint

Is CDM2007 delivering on its aims?

David Watson (M) represents the views of designers on CONIAC's working group advising the HSE on its evaluation of the regulations; here he asks for feedback

When the Construction (Design & Management) Regulations were revised in 2007, the Health and Safety Executive's (HSE) stated aim for the revision was to reduce construction accidents and ill health by:
– being clearer – making it easier for duty holders to know what is expected of them;
– being flexible and accommodating the wide range of contractual arrangements to be found in the construction industry;
– emphasising the need to plan and manage work, rather than treating the paperwork as an end in itself;
– emphasising the communication and co-ordination advantages of duty-holders working in integrated teams;
– simplifying the way duty holders assess competence.

A prayer debate on the proposed revision to the regulations was held in Parliament in May 2007 and during this debate a Government Minister committed the HSE to an early review of the Regulations. In response to this commitment the HSE recently commenced an evaluation programme. As part of this the Construction Industry Advisory Committee (CONIAC) has set up a working group to advise the HSE in respect of their evaluation of the regulations.

The group comprises representatives from various sectors / duty-holders within the construction industry. I have been appointed to this working group by the HSE to represent the views of designers and have the full support of the Institution in this role.

The terms of reference for the working group include providing industry-led views on:
– the degree to which the aims of CDM 2007 (as distinct from CDM 94) have been met;
– the perceived adequacy or otherwise of the existing HSE and industry guidance and Approved Code of Practice (ACOP) supporting the Regulations;
– the need for amendments to the existing Regulations and supporting ACOP and guidance.

Are designers playing their part?

There is a strongly held view amongst many non-designers in the construction industry that designers are failing to comply with their duties under CDM and therefore not playing their part in helping to deliver the HSE aims for CDM2007. The anecdotal feedback that I have collected over the last few years seems to polarise into two camps – the non-designers, i.e. contractors, CDM Co-ordinators, etc., who suggest that designers are not doing enough to help manage health and safety on projects and designers themselves who ask 'what more/exactly are we expect to do?'

There appears to be a drive by parts of the industry with no appreciation of aesthetics to move towards basic construction of flat-faced buildings, using construction and maintenance risk issues as the driver. If UK designers are restricted from designing aesthetically interesting buildings there is a danger that overseas designers will step in, especially with Eurocodes making this much easier.

The designer related issues being raised include:
– designers being unclear about how far to go in applying the concepts of ERIC (eliminate, reduce, inform and control) and 'so far as is reasonably practicable' to designing out or mitigating risks;
– designers failing to consider buildability and/or maintainability;
– designers being unclear about which risks they need inform other 'competent' duty holders about;
– designers being accused of failing to provide contractors with adequate information about significant H&S risks;
– designers taking their design work beyond 'initial' design without a CDM Co-ordinator being appointed;
– CDM Co-ordinators expecting designers to complete and document rigorous and/or quantitative risk assessments;
– Clients applying unreasonable pressure to ignore potential H&S issues which impact on programme and/or costs.

Other issues of concern

How many times do we have to prove that we are competent? This issue comes up time and time again in discussions about the CDM aims – the incessant corporate competence questionnaires that apply unreasonable prequalification demands and associated costs. Despite the launch of the Safety Schemes in Procurement (SSIP) initiative there is little sign of mutual recognition of industry and general H&S competence assessment schemes in respect of CDM stage 1 core criteria. How many consultancy practices, and other organisations, are forced to complete a specific Client's or CDM Co-ordinator's H&S competence questionnaire despite having evidence of OHSAS18001 compliance, CHAS accreditation, sector audit schemes accreditation, etc.?

Has the CDM-C role achieved what was intended? There are many who see this role as simply adding bureaucracy and costs to projects with little or no benefit to safety or health. A good lead designer is perhaps better equipped to co-ordinate the design from a H&S perspective, if necessary using the assistance of construction and maintenance specialists on more complex specialists.

This is YOUR opportunity to help try to influence future developments

On behalf of the Institution and other design stakeholder groups I am currently conducting an anonymous on-line survey in order to assess the perceived success of CDM2007 and provide evidence to support or dismiss the foregoing anecdotal information and views. The analysis of the data from this survey will be used as a significant part of my input into the CONIAC CDM2007 evaluation working group. The link to this survey is (https://www.surveymonkey.com/s/PLZGNH8) – please participate so that I can go back to the working group with strong evidence of the consensus views of designers in respect of the designer's role in CDM.

Whilst the HSE will be conducting its own consultation survey later this year, it is only planning to survey a limited number of each duty holders. This may therefore be the only opportunity you will have to make your views known.

Sustainability briefing

CHP: a guide for structural engineers

This briefing note provides a basic guide to the different types of CHP systems, how they are used and the design challenges they pose

Combined Heat and Power, or CHP, as it is commonly known is essentially the combined generation of heat and electrical power. Put simply, a CHP system is a system that uses fuel in a thermodynamically efficient manner to produce both usable heat and electrical energy. The effective use of both the heat and electricity generated by CHP can increase the efficiency of energy use upwards of 70% thus enabling less fuel to be used to produce the same amount of usable energy.

The CHP system can either be designed or sized to produce a set thermal output with electricity being considered as a usable by-product. Such systems are known as 'thermally led' or designed /sized to provide a certain electrical output with heat being considered as the usable by-product i.e. 'electrically led'.

CHP systems that are primary producers of heat, and from which the waste heat is recovered to generate electricity, are known as 'Bottoming cycle plants' whereas CHP systems that primarily produce electricity but then re-use the heat recovered from the process for other uses are often known as 'Topping cycle plants'.

The primary generating focus of the plant can play a major part in the location of the plant itself. The transportation of heat as hot water/liquids over long distances often necessitates costly and commonly inefficient heavily insulated pipes and pumps. Hence thermally led or Bottoming cycle CHP plants tend to be located close to the point of use of the heat as a result of the less costly and more efficient means of transmitting electricity. However electrically led or Topping cycle CHP systems can easily be placed remotely to the point of use of the electricity due to the comparatively low cost of the distribution wiring and the relatively low losses associated with transmitting electricity within a cable network.

CHP Plants are more commonly utilised on large scale industrial facilities such as steelworks, oil refineries, paper mills and chemical works.

They can also be adopted to great effect on commercial mixed use developments where differing thermal/electrical loads and the energy time demand profile promotes a balancing out of energy demand thus allowing a broad population of users to benefit from an improved effective energy generation. A classic example of such a case would be a mixed use development which consisted of a snow dome adjacent to a residential development and school; the energy expelled from the operation of the snow dome could be used to heat and power the adjacent residential development and school.

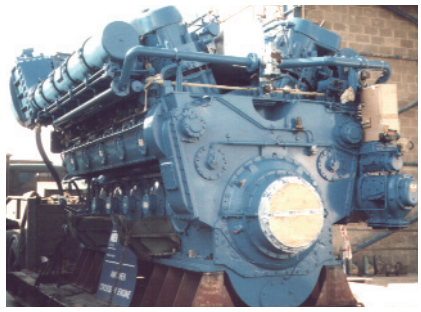
CHP systems are also well suited for use with district heating systems.

CHP can also be highly beneficial in large industrial facilities that have large electrical demands and cooling loads such semi-conductor manufacturing facilities; the excess heat generated by turbine engines generating electricity can be utilised to provide heat to meet the high levels of cooling loads by means of 'absorption' cooling.

CHP systems can vary in size and type. Common systems in use at the larger scale include:

– Gas Turbine CHP plants which utilise the waste heat in the flue gas of the gas turbines;

– Gas Engine CHP plants which use a reciprocating gas engine; this is generally considered more competitive than a gas turbine up to about 5MW.



A CHP engine awaiting installation on its foundation block within a plant room ***(Courtesy J. H. Morris)***

– Combined Cycle power plants which are adapted for CHP;

– Steam Turbine plants that use the heating system as the steam condenser for the steam turbine;

– Molten Carbonate Fuel Cells which have a hot exhaust and are very suitable for heating.

Smaller systems may use a reciprocating engine of some form to generate the electricity with the heat being recycled from the exhaust and the radiator. These systems can prove more economic for smaller demands due to the relatively lower cost of smaller diesel and gas engines.

An interesting example of a CHP system is the Masnedo CHP power station in Denmark which burns straw as its primary fuel and from which reclaimed heat is fed into a district heating system which heats adjacent greenhouses.

CHP micro-generation, which can be used in residential properties or small to medium size buildings, are considered to be a very effective means of reducing carbon. Different technologies such as micro-turbines, internal combustion engines, Stirling engines, closed cycle steam engines and fuel cells are in use in such systems to generate heat for use in space heating or hot water systems with the electricity by-product being used within the property or, if permitted, sold back to the grid.

How does CHP affect me as a structural engineer?

Projects on which CHP is adopted can add the following challenges to a project:

– Increased plant room provision, with associated increase in areas of higher floor loading, to account for in the structural design of the scheme;

– Increased demands on clear spans within plant room areas housing boilers and turbines;

– Increased provision of fuel storage areas and delivery systems within plant rooms, particularly when bio-fuels are adopted;

– The need to integrate turbines/generators into schemes with the associated provision of potentially complex foundation blocks and acoustic isolation, needing consideration of vibration and noise issues, as well as load carrying capability;

– In the case of district heating systems, the potential provision of extensive above and below ground pipeways and ducts to distribute heating pipework, and the associated design of such sub-structures.

This briefing is prepared by the Institution of Structural Engineers Sustainable Construction Panel. Further Information: contact Berenice Chan (email: Berenice.chan@istructe.org).

Issue No:10

Technical note

Importance of structural engineering in sustainable and low carbon design

Meike Borchers, Associate Sustainability Consultant, WSP, believes that the key challenge for our generation is climate change and the depletion of finite resources

The UK intends to reduce national greenhouse gas (GHG) emissions by 80% by 2050, and a similar approach is expected from most EU countries and the US. To achieve this ambitious goal, huge savings will have to be achieved in all areas, from the built environment, across all industries and in transport. Many different strategies are being put in place to achieve emissions cuts in these different sectors. In particular, the construction industry has a major role to play in environmental responsibility, particularly as far as man-made climate change and resource depletion are concerned (Fig 1).

In the UK, about 50% of all CO_2 emissions are linked to energy generation for the construction and operation of buildings[4]. Construction materials used in the UK account for about one fifth of the total national ecological footprint, and a quarter of the total national GHG emissions[5]. World-wide, approximately 5% of all greenhouse gas (GHG) emissions are linked to the annual 2.8Gt of cement production[6].

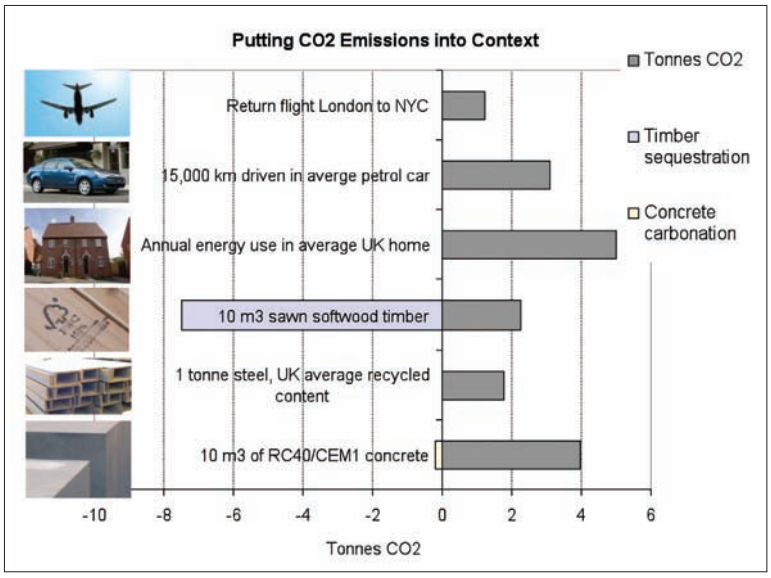
Despite these facts, design decisions taken by structural engineers are predominately driven by achieving value for money for the client. However value for money and resource efficiency can, with a little effort, co-exist, or put in other words, design decisions can be adjusted to contribute to the reduction of the environmental impact of construction without loss of value for money. A heightened awareness among informed clients and some local authorities has led to an increased focus on material choice and construction techniques which reduce environmental impact. Nevertheless opportunities are often missed, as the quantification of these impacts is difficult to demonstrate and largely unregulated. This also applies to the potential that structural engineering has for curbing GHG emissions during the design phase.

Current strategies for GHG reductions in the built environment focus heavily on emissions that occur, not through the construction phase, but during building use. These strategies are regulated through Part L of the Building Regulations and monitored through various initiatives such as Energy Performance Certificates (EPCs) and Display Energy Certificates (DECs). The aim is to make Zero Carbon homes a minimum standard from 2016, and to extend the Zero Carbon requirement to all new builds in 2019.

This approach leaves out an area with huge potential for savings: GHG emissions embedded in construction materials and the emissions arising from construction itself.

New buildings designed to meet or exceed current Part L standards consume only a fraction of the heating and cooling energy of a typical existing building. For new buildings, the proportion of CO_2 emissions attributed to the building materials over its lifetime is therefore increased significantly. This effect is even more pronounced when the reduction in operational energy demand is achieved through the use of energy intensive building materials and building services (Fig 2).

At the moment, almost no attention is paid to energy embedded in the materials, or the associated CO_2 emissions for that matter. In fact, the only time this is looked at is within the BREEAM and Code for Sustainable Homes materials section. But here the transparency of the data is lacking. Eco-labelling of materials to the BRE Green Guide incorporates a whole range of environmental performance criteria and a comparison of embodied and operational CHG emissions is impossible. This is about to change though. The European Committee for Standardisation (CEN) is developing European horizontal standards for the sustainability assessment of buildings. CEN/TC 350[7] is addressing indicators, methods and communication provisions for the assessment of



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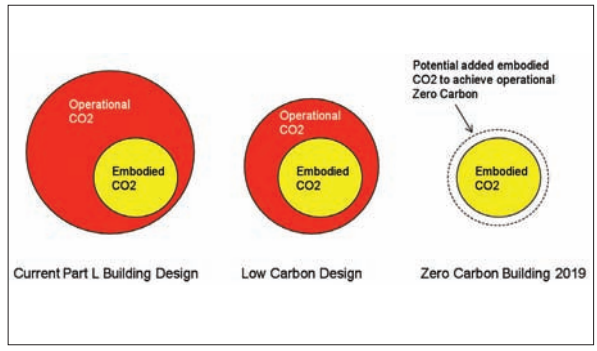
1 Putting CO_2 emissions into context, data from Refs 1, 2, 3

2 The importance of embodied CO_2 in building design



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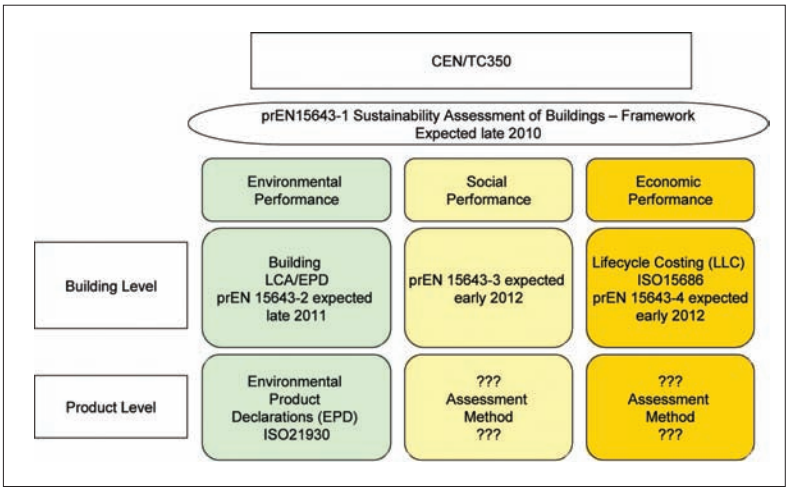

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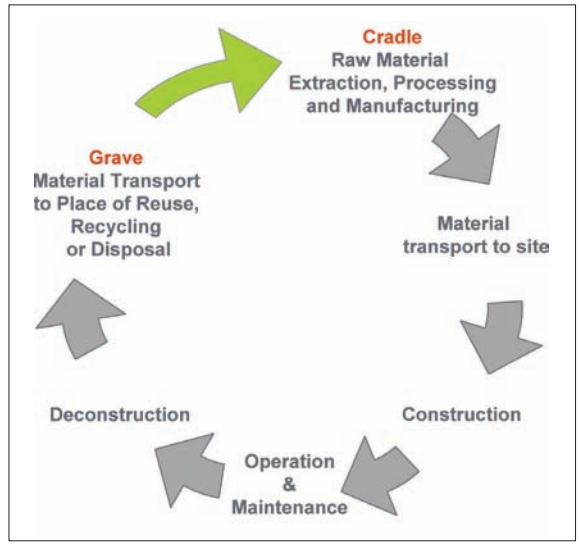

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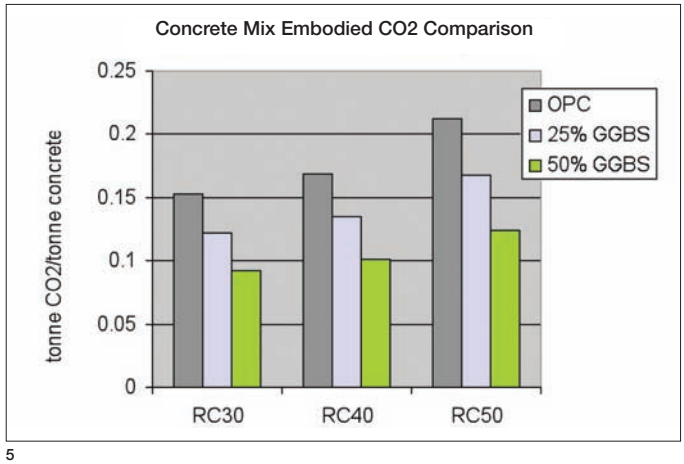
3 Future sustainability sssessment of buildings
4 Lifecycle assessment stages
5 Embodied CO_2 in concrete, based on ICE data[3]
6 Floor framing embodied CO_2 study Masterplan project in Qatar



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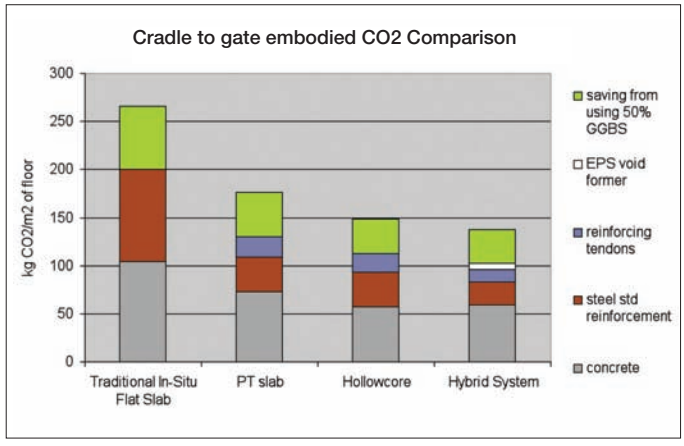

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sustainability, which uses a performance based approach in terms of environmental, social and economic performance. It is a lifecycle assessment (LCA) approach and includes quantitative indicators for performance where applicable. It is proposed that sustainability will be integrated as an assessment criteria within future versions of the Eurocode[8]. Alongside this, the development of environmental accounting standards is making good progress and Whole Life Costing (WLC) is increasingly used in building design decision making, but the quantification of social indicators remains a challenge (Fig 3).

The area that has developed the furthest is the assessment of environmental performance at the product level. The methodology is defined in ISO standards 14025 and 21930, and product manufacturers have started to assess their products using these standards. Data is still scarce but there are great opportunities for 'green' manufacturers to promote their products and indeed their business.

So in the absence of regulations, what can and should structural engineers do towards achieving low carbon design and the conservation of natural finite resources?

A LCA approach acknowledges that a building needs to be assessed over its lifespan, taking into account all aspects of its lifecycle, from planning and the extraction of raw materials (Fig 4), through construction and operation to deconstruction, recycling and disposal of materials. LCA can be used not only to evaluate environmental consequences of a development, but it can be used in the decision-making process during design. Specific criteria such as GHG emissions can be assessed individually within a LCA.

Structural engineers can then clearly see their contribution to curbing GHG emissions. Our recent lifecycle studies for low carbon and zero carbon developments such as Masdar in Abu Dhabi suggest that a building's structure can account for as much as 40% of the GHG emissions over a building's design life. Furthermore, it strengthens the environmental case for refurbishment over demolition and rebuilding if embodied CO_2, resource use and waste arising are all taken into account.

The embodied carbon calculation for structural elements involves quantifying the amounts of materials used and applying carbon factors for each material type. Sadly there is not one commonly acknowledged embodied carbon database, but the most used data source is probably the Inventory for Energy and Carbon (ICE)[3]. This data does enable calculations to be performed to compare the initial embodied carbon investment for various considered framing options. For example, for the Strata building In London's Elephant & Castle district, we estimated the savings for PT construction over conventional concrete framing to be 1800t of CO_2. This is equivalent to the CO_2 emitted by 360 UK homes over 1 year.

But the devil is in the detail. The conscious specification of concrete strength and cement types, for example, can lead to great embodied CO_2 savings as Fig 5 above illustrates.

Eventually, the structural engineer can compare a variety of framing options in terms of their embodied CO_2 contents. Fig 6 summarises a study that WSP carried out for a masterplan project in Qatar, informing the client of the options with lowest embodied CO_2.

However important the threat of climate change, we should not focus on embodied carbon in isolation. There are many other sustainability aspects that are important and should be considered. One way of assessing these impacts is to study the various lifecycle stages that a building will go through. As an example and by no means a complete list, Table 1 summarises key environmental indicators for the classic three materials that are

	Concrete	Steel	Timber
Embodied CO_2 by weight, based on ICE data	RC35, 100% OPC: 0.161kg CO_2/kg RC35, 50% GGBS: 0.091 kg CO_2/kg	Average 1.77 kg CO_2/kg	Sawn softwood: 0.45 kg CO_2/kg Plywood: 0.81 kg CO_2/kg
Embodied CO_2 by volume, based on ICE data	RC35, 100% OPC: 380 kg CO_2/m^3 RC35, 50% GGBS: 215 kg CO_2/m^3	Average 13,800 kg CO_2/m^3	Sawn softwood: 230 kg CO_2/m^3 Plywood: 570 kg CO_2/m^3
Recycled content	Potential for cement replacement e.g. with GGBS, PFA, recycled concrete aggregates	On average contains about 45% recycled steel, with rebar usually near 100% recycled content	Engineered timber products can contain recycled timber, e.g. plywood and OSB
Responsible sourcing	Environmental impacts during raw material extraction and processing can be high, specify supplier EMS certification	Environmental impacts during raw material extraction and processing can be high, specify supplier EMS certification	Important as global timber use is not sustainable, specify FSC or PEFC certification
Transport impacts	Can be kept low by local sourcing	Can be kept low by local sourcing	Can be kept low by local sourcing
Construction impacts	High unless prefabricated elements are used	Low due to high level of prefabrication	Low due to high level of prefabrication
Maintenance impacts	Low	Low to medium (e.g. painting)	Low to medium (e.g. preservatives, painting)
Acoustic performance	High	Low, typically requires added acoustic elements	Low, typically requires added acoustic elements
Thermal performance	Medium, but good thermal mass properties	Low, poor thermal mass	Good, poor thermal mass unless solid timber construction
Fire Performance	Good	Low, requires added protection	Low, unless solid timber construction, mostly requires added protection
Building adaptability	Medium to low (PT construction)	Medium	Medium
Potential for reuse	Low	Medium, potential reuse of steel sections	Medium, potential reuse of beams, columns and joists
Potential for recycling	Medium, can only be down-cycled and used as aggregate	High, near 100% recyclability	Medium, can be shredded and used as filler
CO2 emissions after useful life	Low	Low	High, from decomposition, but can be combusted for energy generation

Table 1 Consideration of lifecycle performance of various framing materials

considered for low and medium rise construction, namely concrete, steel and timber.

One aspect that is worth pointing out specifically is the recycled content of materials. While it is typically environmentally beneficial to specify recycled content to use waste products that would otherwise go to landfill, most metals are an exception.

For some projects attempts are made to maximise the recycled content in steel and other metals in order to lower embodied CO_2 for a particular building to a minimum. This approach is problematic. Due to the high value of the material, recovery rates are high and nearly all scrap metal is put to use. Therefore if we specify very high recycled content in metal for a specific product, we are simply taking it away from other products. A distortion of the market is the result, with no environmental benefit, as no additionality is achieved[9].

Another highly debated issue is that of 'carbon sequestration' in timber, which leads to timber being sometimes referred to as 'carbon negative'. Although timber stores huge amounts of carbon as it is grown, this sink cannot be regarded as something that lasts forever. If timber is disposed of, its decomposition process not only releases stored carbon but it releases methane which is 24 times more potent as a greenhouse gas than CO_2. If it is combusted for energy generation, the stored carbon is released into the atmosphere. Thus carbon storage in timber is only a temporary solution and should not be relied upon to offset building lifecycle CO_2 emissions.

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Project

Combining sustainability and innovation at Harlow Carr

Peter John Corbett, structural engineer at Gifford describes the Royal Horticultural Society's new Learning Centre and Library in the gardens of Harlow Carr

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2

1 Artists' impression of the building (*Tom Stuart Smith)*
***2* The finished building (*Courtesy RHS*)**

Sustainability lies at the core of the design of the RHS's recently completed Learning Centre, dictating everything from the way the building sits in the landscape to the choice of building materials and servicing strategy, providing an inspirational educational resource for generations of current and future gardeners. From inception through to construction, many challenges were overcome and the finished building is set to achieve one of the highest ever 'Excellent' BREEAM 'Bespoke' 2006 ratings of 88.53%, leading to the building being featured on the Carbon Trust's website as an exemplar of sustainable building design. Due to open in the summer of 2010, the Centre is expected to provide an environmental and horticultural educational resource to around 10 000 schoolchildren a year. Construction was completed within a 10-month timeframe under a £2.12M partnering contract.

Sustainable design

An important aspect of the building's sustainable design lies in its response to the landscape which also dovetails with its environmental performance in use. It lies within the RHS Gardens of Harlow Carr, sloping away from the car park towards the gardens (Fig 1). The Learning Centre responds to this setting by being partially earth-bermed; this not only reduces the visual impact of the two-storey structure from the approach road and car park, but also enhances the thermal strategy.

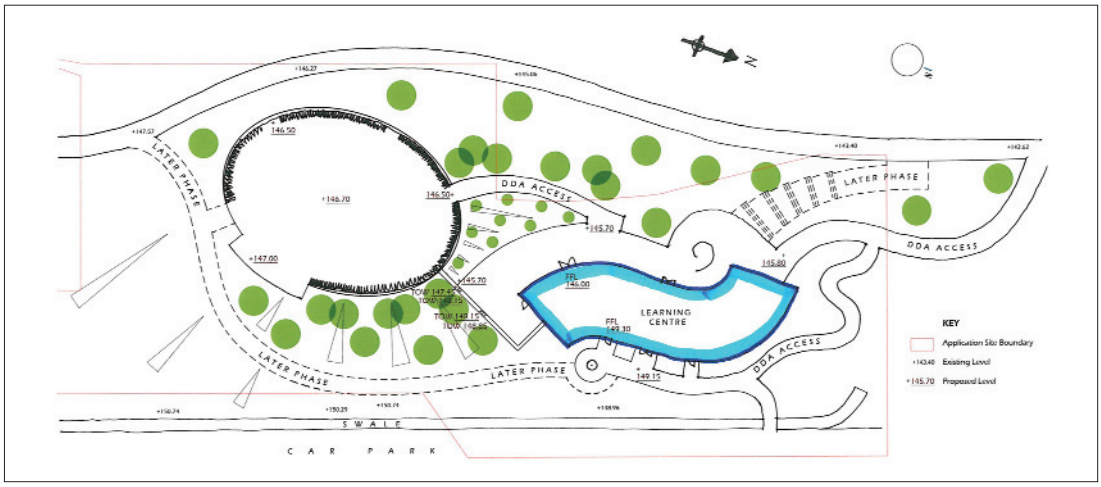
Utilising the natural site topography in this way necessitates that the building faces west and so, in order to increase the potential for beneficial solar gain during the winter, an S-shaped building plan was selected to maximise the extent of south elevation (Figs 2, 3). This S-shape is repeated in the roof profile, which is clad with a living, bio-diverse green roof enabling the building to blend in with the surrounding Yorkshire landscape. Further benefits of the green roof system include providing a natural habitat for wildlife, decreased rainwater run off and improved thermal performance providing cooling in summer through evaporation.

The building is naturally ventilated and utilises PassivHaus principles, placing particularly onerous demands on the external building envelope in terms of insulation and air tightness. The exposed flat reinforced concrete slab and dense blockwork walls provide thermal mass, and a fully glazed front elevation maximises natural daylighting and beneficial solar gain. In principle, the glazed front elevation draws in the heat which is then retained by the thermal mass in the floor slabs and rear walls (Fig 4).

Sustainability is also built into the building fabric through the specification of recycled and responsibly sourced building materials. The reinforced concrete frame extends from foundation to first floor level and contains 50% GGBS cement replacement; the timber used for the roof structure is sourced with FSC and full chain-of-custody certification. The internal non-load bearing partitions are constructed using either unfired clay bricks or dense concrete blocks manufactured using 100% recycled aggregate, and plastered with a clay-based plaster which assists in the regulation of both temperature and humidity, making it ideal for 'breathing' constructions. The clay bricks are included to passively absorb moisture during the winter months, whilst hydrating the air during summer. An eco-screed is used to embed the underfloor heating, incorporating 100% replacement of natural sands with recycled amorphous glass, using 1.2t of recycled glass per cubic metre of screed applied. The binder part of the screed is derived from desulphurised gypsum (DSG), a by-product of the emissions cleaning desulpurisation process carried out at coal-fired power generating stations. Thus the specification of the eco-screed allows a saving not only in the quantity of quarried sand but also in the reduction of glass to landfill.

The result of this stringent specification of materials meant that we achieved seven out of the seven credits available in the materials section of the major building elements in our BREEAM rating (BREEAM Bespoke 2006).

To reduce the building's carbon consumption over its lifetime, renewable energy sources have been included. A 15kW, 20m high wind turbine has been erected adjacent to the building, supplying



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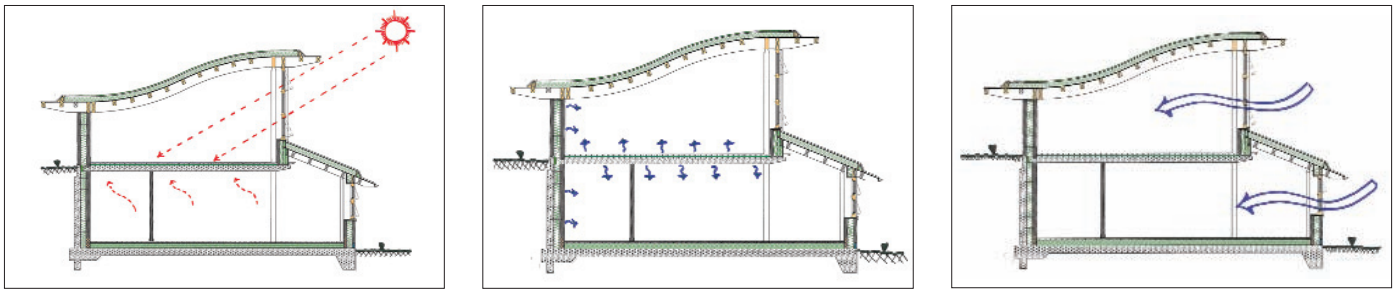
3 Site plan: the curved building footprint was reflected in the surrounding landscaping

4 Natural ventilation and heating strategy



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a Solar gain and the building occupants heat the building's inherent thermal mass on a winter's day

b On summer days, the first floor slab and dense partitions have a cooling effect on the internal building environment

c Natural ventilation is BMS activated and assisted by fan assisted louvres when required

18MWh per year of renewable electricity and channelling any excess electricity generated into the National Grid.To reduce the building's demand on conventional energy sourced for heating water, solar thermal panels have been fixed to the roof, ground source heat pumps with deep boreholes have been installed to provide a renewable source of space heating and rainwater harvesting reduces the building's water demand.

Heat loss through the external envelope is minimised through the use of masonry walls with 250mm-wide cavities fully filled with insulation. The wall ties used were made from basalt fibre reinforced polymers which are said to increase the U-value of a wall by 10-40%. (Moreover, using basalt rather than stainless or mild steel, makes sense as basalt, unlike steel, is an abundant natural resource.) Elsewhere, any structural steelwork straddling the cavity is thermally broken at the connections with isolation plates.

Structural aspects

Conceptually, the structure consists of three primary elements (Fig 5):
– a reinforced concrete 'book-end' made up of a raft slab and retaining wall;
– a RC 'table' consisting of a flat first floor slab and supporting columns and walls:
– a curved timber roof structure with planted columns to the slab below.

Lateral stability is provided by steel cross braced bays concealed within masonry walls from first to roof level, and reinforced concrete shear walls between ground and first floor levels. Diaphragm action is achieved with a RC first floor slab and plywood sheets at roof level.

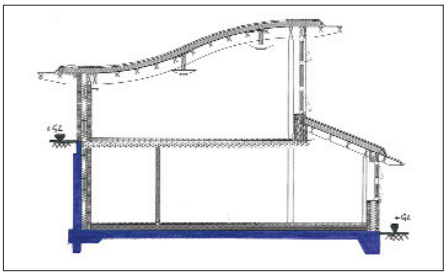
The curved and stepped retaining wall running along the building's rear is propped at first floor level by the first floor slab, which in turn is stabilised laterally by the in-plane rigidity of the retaining wall. In order to form a structural connection whilst minimising any cold bridging effects between the cold retaining wall and warm first floor slab, a proprietary insulating shear connector has been cast in. The retaining wall is backfilled with a locally sourced, recycled free-draining granular material.

The timber roof structure is made up of sawn timber purlins and specially fabricated twin glulam beams, S-shaped in elevation and sheathed with a plywood diaphragm, of which more below. As the roof is primarily exposed to view, the connection details have been sensitively detailed and fabricated, utilising steel dowel type connectors *in lieu* of conventional bolts where possible. The primary glulam beams to column connections employ specially fabricated 'pinned' connectors (Fig 6). Given the complexity of the roof geometry, a 3D computer model was built to aid the fabrication process.

A triple glazed façade runs along the south elevation of the building; the glazing system utilises stacked timber frames sandwiched between timber mullions, with a timber 'loose tongue' to create a shear connection between the two elements.

Roof diaphragm

The design of the roof diaphragm presented the design team with a number of issues. Diaphragm action needed to be achieved for global building stability, the curved plan and section building geometry dictated that a degree of double curvature was required, and the soffit was to be exposed to view. Consequently birch plywood was the preferred material, and initial calculations indicated that a thickness of around 25mm was required. However, in order to achieve the required curvatures, the maximum panel thickness needed to be 9mm, which meant that three layers of plywood would be required. Pre-fabricated, laminated curved panels corresponding to a bay's width would have been the preferred solution – gluing could then have been achieved off-site in a controlled environment. However this was ruled out on cost grounds and logistically, it would have been difficult to transport the larger panels. Thus a site-fixed solution was required and, given the vagaries of British weather and the potential quality issues associated with laminating on-site, mechanical fixings had to be used to connect the sheets together



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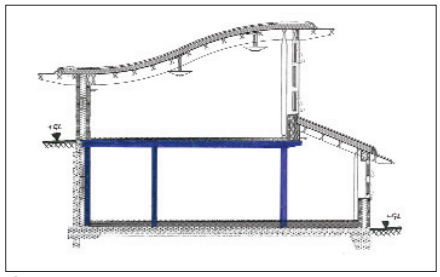

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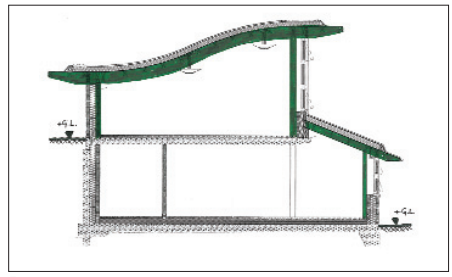

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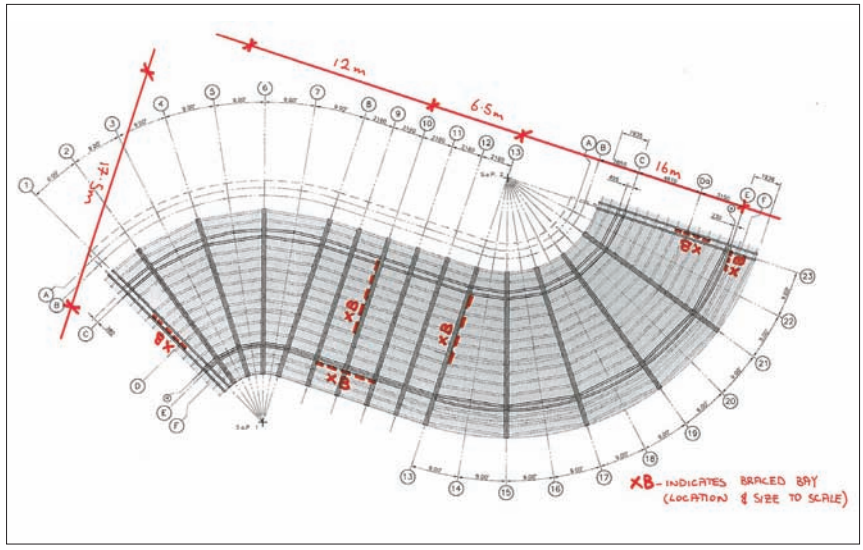

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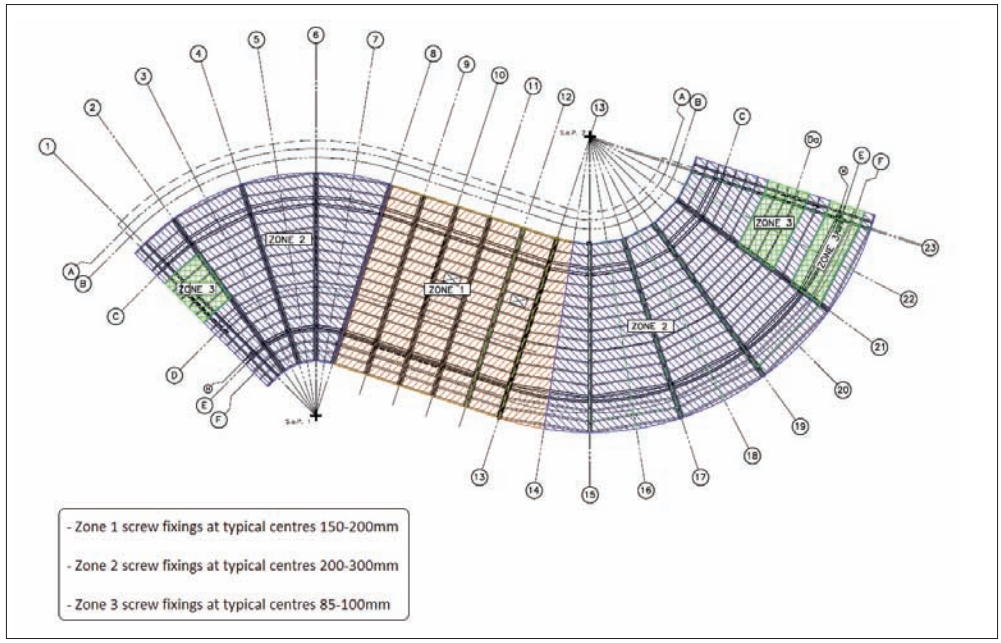
5 Structural concept
5a RC Bookend embedded in hillside
5b RC Table forming first floor slab
5c Timber roof structure
6 Construction image showing roof soffit
7 Sketch showing roof plan and braced bay setting out
8 The mechanical fixing design was informed by detailed FE Modelling



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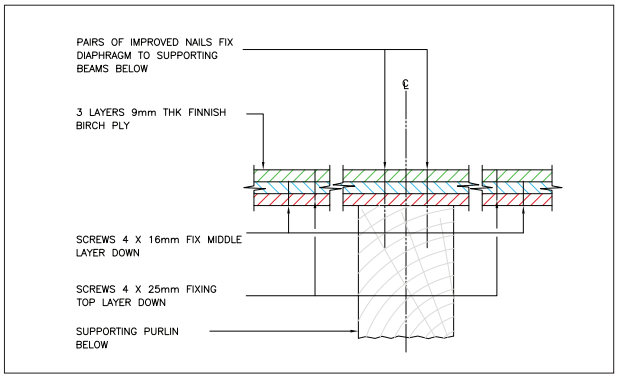
and to the supporting purlins and main beams below. Given the potential difficulty of persuading a plywood panel into double curvature, butt joints between the ply sheets were situated over the main glulam beams, reducing the residual stress in the plywood.

The structural analysis was complicated by the fact that the braced bay layout was asymmetric due to the restrictions imposed by the glazing, resulting in torsional effects on plan as well as local stress concentrations over the braced bays. Moreover, the braced bays were of differing sizes and so possessed dissimilar comparative stiffnesses (Fig 7).

To accurately predict the roof stresses and fixing requirements, a 3D Finite Element Model was generated to determine accurately the effects of in-plane forces due to horizontal wind loads. This allowed us to consider the benefits of composite action between the plywood and supporting purlins and main glulam beams to diaphragm action, as well as account for the actual stiffness of the different braced bays. The in-plane effects were combined with longitudinal shear force between the ply sheets due to out-of-plane bending.

The principal stresses varied considerably across the roof structure, from as low as 0.35N/mm^2 to peaks of 2.5N/mm^2 locally over the bracing. Thus, in order to reduce the number of fixings, we divided the roof up into three areas with different density of fixings in each (Fig 8).

The philosophy used for the fixing design assumed that wood screws would be used initially to fix the intermediate layer to the bottom layer, and subsequently the top layer to the lower two layers; self tapping screws were used to speed up the process and eliminate the need for pre-drilling pilot holes. Improved nails



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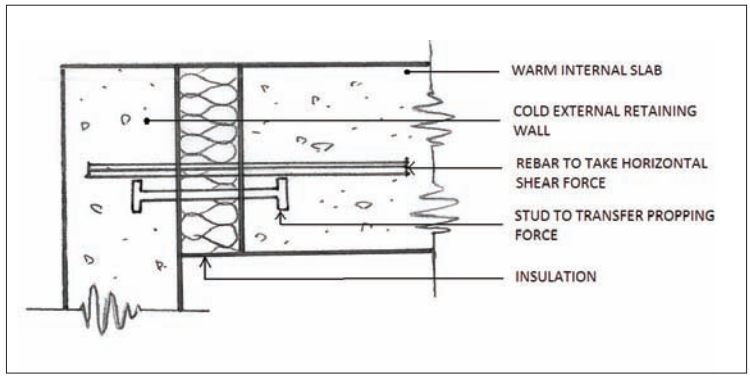

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9 Typical section though purlin
10 Section through retaining wall/first floor slab junction
11 Roof structure under construction (The lack of safety harness can be explained by the presence of a crash deck immediately below the roof beams!)
12 The finished building with the wind turbine in the foreground (*Courtesty RHS*)
13 Interior view of the roof structure (*Courtesy RHS*)

with annular shanks were used to fix the three layers to the sawn timber purlins and glulam tie and main beams. In the least stressed areas, zone 2, the required screw spacing was generally 200-300mm centres, however elsewhere this needed to be locally increased to 85-100mm centres (Figs 9, 10).

The fabricator, Dalton Joinery, built a full-scale model of a typical bay in their workshop prior to commencement on site, enabling the team to proceed with confidence that the curvature could be achieved on site (Fig 11). This also allowed a plywood sheet lapping arrangement to be agreed which was then fed back into the design of the fixings. The joints on the lower layer are expressed with a routed 10mm wide x 5mm deep groove to reduce the visual impact of the plywood cut edge in the exposed soffit.

Conclusion

The RHS' new Learning Centre is highly sustainable and geometrically complex with many bespoke details, yet was completed on programme and within budget. This was facilitated, in part at least, through close team collaboration, for example the design and detailing work that went into the roof structure meant that the doubly curved diaphragm was relatively straightforward to fix on-site. The demands of the brief required a tight specification to be accurately executed on-site, and a high level of craftsmanship was maintained throughout including working through one of the toughest winters in recent decades. Local feedback has been positive and it is hoped that the building will inspire and educate in equal measure (Figs 12, 13).

Credits
Client: The Royal Horticultural Society
Architect: EcoArc Ecological Architecture Practice
Structural engineer: Gifford LLP
M&E engineer: Gifford LLP
Main contractor: William Birch and Sons
Timber fabricator: David Dalton Joinery

Viewpoint

Quantifying the danger

Robert Thorniley-Walker (F) Director, Structural & Civil Consultants Ltd, makes the case for the inclusion of carbon emissions in risk assessments

The Engineering Council advises that risk assessments should now cover the impact of carbon emissions and should include the potential for destroying lives in distant places and in years to come. This viewpoint uses a survey of opinions, mainly amongst engineers, to consider 'reasonable' values and quantities for the probabilities and dangers to life for such a risk assessment.

As might be expected, the risks are orders of magnitude different from those usually covered in civilian projects, even when taking into account opinions from climate sceptics. More surprisingly, some common mitigation measures frequently associated with sustainable construction appear to have little relevance when assessing dangers from current emissions. The survey indicated strident opinions on how engineers need to be involved with trying to limit climate change, and the overall findings should be of interest to many disciplines and professional bodies beyond those directly associated with construction.

New responsibilities for risk assessments

The lack of 100% certainty in predictions of risks and dangers from carbon emissions, despite more than a decade of warnings from most climate scientists, has left scope for repudiation and denial of personal and shared responsibility. Even where individuals or organisations are concerned, it is usually considered 'safer' to stick with proven high-carbon products than experiment with new or historic low-carbon approaches. However, existing health and safety legislation, duties of care, contractual warranties and professional conduct requirements all suggest that construction professionals should be starting to confront the new challenge.

The Institution of Civil Engineers for example, in its 2009 *State of the Nation* report[1], recommended that carbon should become a 'key aspect' of all design. Wording on warranties often include ominous clauses such as 'The consultant warrants that no materials which are known at the time of use to be capable of causing or constituting a hazard to health and safety shall be used'. Moreover, for all those involved in construction, the overriding legal requirement under CDM[2] is either to design-out dangers, or to reduce the risks to acceptable levels.

The Engineering Council has produced a document, *Guidance on Sustainability*[3], which includes a groundbreaking and very significant chapter 'Manage risk to minimise adverse impact to people or the environment'. It states that engineers should:
1 Undertake a comprehensive risk assessment before a project begins.
2 Ensure that the risk assessment includes the potential environmental, economic and social impacts, beyond the lifetime of the engineering project or product.
3 Recognise the potential long-term aspects of risk.
4 Give sustainability the benefit of the doubt, adopting a precautionary approach where scientific knowledge is not conclusive.

There appears to have been little discussion so far on how carbon emissions might be encompassed in such risk assessments, yet the risk assessment has been a standard tool for management of health and safety in most industries. In its basic form, it has the following elements, usually laid out as a column in a table:
– identification of a hazard;
– consideration of the cause of the danger;
– assessment of the danger to life or serious injury, with say Low, Medium or High danger;
– assessesment of the likelihood or probability of the danger with say Low, Medium or High risk;
– consideration of mitigation that would reduce the probabilities and/or the dangers;
– recommendation of any actions to bring down the probabilities and/or dangers to acceptable levels.

For risk assessments to include carbon emissions, there is a need for guidance on 'reasonable' values for the uncertain risks and dangers. Appropriate categories can then be allocated to allow mitigation or other appropriate action.

Engineering opinions for risk sssessments

This article considers figures for probability and numbers of people at risk that could be considered 'reasonable' using opinions from a questionnaire survey[4] aimed at members of both the Institution of Structural Engineers (IStructE) and the Institution of Civil Engineers (ICE) and their associates in the Northeast of England. The author prepared a range of questions associated with carbon emissions in the autumn of 2008 and this was distributed with the help of the regional officials of both institutions, in advance of an oral paper addressing the question 'Should engineers lead on climate change?' Responses to many of the questions are relevant to assessing the risks.

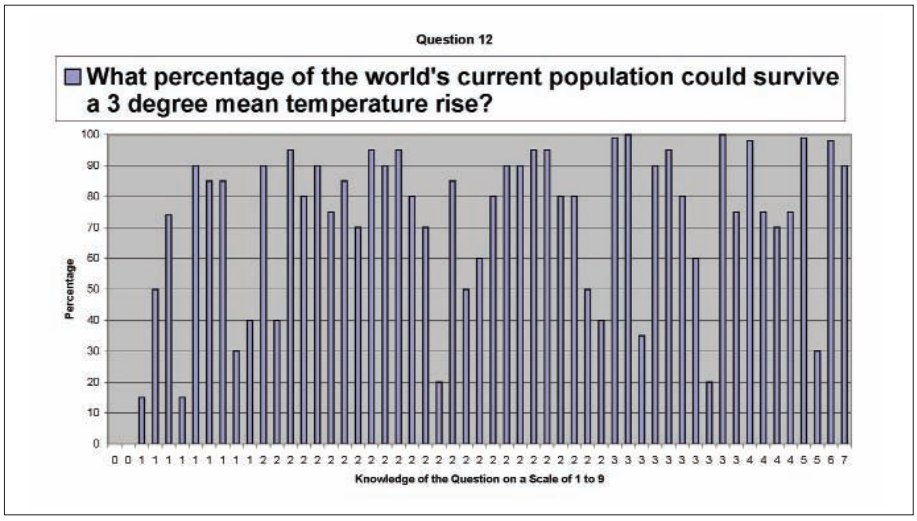
The questionnaire survey[4] requested respondents to quantify their opinions based on the current response to climate change. It also asked them to indicate their knowledge of each question using a marking system effectively ranging from 1– no real knowledge of the topic and 2 – basic understanding, to 6 – studied a range of papers and 7 – top 10% expert, while a '0' under knowledge indicated not answering. The raw statistics from this questionnaire with basic graphs and tables are available at the web site indicated[4].

Some representative graphs below illustrate the responses and these are generally ordered by the level of knowledge claimed by the respondents. Although it is more usual to employ graphical techniques to illustrate statistical data, these graphs have been kept simple to indicate actual individual responses.

Effort was made in the survey to reach experts as well as all engineers in the region. The opinions of climate sceptics were particularly sought, as their responses were considered very relevant when defining the lower-bound values of risk. Up to 20 out of the 55 respondents could be considered 'climate sceptics' based on Question 4 (outlined below), but responses were not necessarily consistent from question to question. Half the respondents appeared to hold senior positions and 20 out of the 55 respondents were Chartered Engineers. Only one respondent appeared to be working outside the UK. The group included three young people and one surveyor, while everyone else appeared to have some current or previous association with engineering.

The hazard

With risk assessments, hazards and the causes are initially



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1 Graph of individual results for Question 12 from the questionnaire survey, ordered by level of expertise, covering the percentage of the world population that could survive a mean 3° rise

2 (Opposite) Atmosphere-Ocean General Circulation Model Projections of Surface Warmings (IPCC Fourth Assessment Report (AR4). Climate Change 2007: Synthesis Report, Pachauri RK and Reisenger A (eds). IPCC: Geneva, section 3.2.2, fig 3-2)

3 (Opposite) CO_2 Emissions and Equilibrium Temperature Increases for a Range of Stabilisation Levels (IPCC Fourth Assessment Report (AR4). Climate Change 2007: Synthesis Report, Pachauri RK and Reisenger A (eds). IPCC: Geneva, section 5.4, fig 5-1)

considered before assessing the likely probabilities and dangers, along with mitigations or required actions. The build-up of carbon dioxide in the atmosphere has two main potentially harmful effects: increase in acidification of the oceans, and warming of the planet through greenhouse effects. While the risks from acidified oceans would ideally be included, they will be set-aside in this article, and only the number of lives in danger from climate change will be considered.

From Question 1 '*What is the percentage risk that mankind is effecting temperatures?*' all 55 respondents thought there was at least a 5% chance that the hazard was real. This is a particularly significant probability considering the strongly anti-climate change opinions of some of the respondents.

Quantifying the danger

There are radical opinions in society as a whole when considering the degree of danger from climate change. The points below are intended to cover this range of views.

– The questionnaire survey[4] did not ask a specific question on how many people might be at risk if temperatures were allowed to increase without control. However, Question 12: 'What percentage of the world's current population could survive a 3º mean temperature rise? gave a mean answer of 72% (Fig 1). It is deduced that at least 28% would be in danger if temperatures increased by 3°C and that this percentage would increase if temperatures continued to rise beyond that figure.

– Some engineers and a few scientists believe that there are no hazards from climate change. The questionnaire survey for Question 12 had two out of 52 respondents who held the view that there would be 0% loss of life around the world with 3°C warming (Fig 1). Another four respondents indicated less than 3% of the population were at risk.

– Other scientists warn that the whole planet is at risk from runaway heating, which would imply that there are nearly 7bn people in danger. The best-known scientist expressing such concerns is Dr James Hansen of NASA[5] who has a consistent track record of spotting the various threats from climate change far in advance of other scientific bodies. From the questionnaire[4], Question 12 had 13 out of 52 respondents who believed that up to 50% of the world would be at risk from just a 3°C rise (Fig 1). It is again considered reasonable to assume that the number of respondents with that view would have increased if say 5°C or 6°C rises were had been used in the question.

– The IPCC (International Panel on Climate Change) brings together a range of scientists to form a consensus. The IPCC(2007)[6] report indicated that warming of between 3°C and 6°C is a real possibility (Fig 2), and that such temperature rises would have disastrous effects on crops and water supplies. The number of lives at stake was not quantified for the higher temperature range in IPCC(2007), but it indicates that many of the most-populated countries in the world would face temperature rises that would disrupt or prevent cultivation. While peaceful resettlement and sharing cannot be ruled out, the risk is that whole populations would either starve or trigger major wars over land and resources. Consideration of just the populations in the most severely threatened countries such as China, India, Bangladesh and Pakistan would yield a figure of around 3.5bn people in danger.

There would be logic in using the worst figures that need to be addressed for the risk assessment. It is however, suggested that a figure of 50% of the world's population, (approximately 3bn people), should be considered under major threat from unchecked temperature change.

There may be questions over the relevance of dangers elsewhere to British engineers and no specific question in the survey covered the indirect dangers to places such as the British Isles, which might be relatively unaffected. However, as discussed below, Question 11 indicated that mass migration would be necessary for 27% of the world population with just a 2°C rise, so few countries could remain unscathed from much higher temperature rises. Moreover Questions 16,17 and 18 (which are discussed below), indicate that British engineers believe that they should be very involved with climate change.

It would be reasonable to assume that the hazards to whole populations from forced relocation, war or starvation should be classified 'Extremely High'.

Quantifying the cause

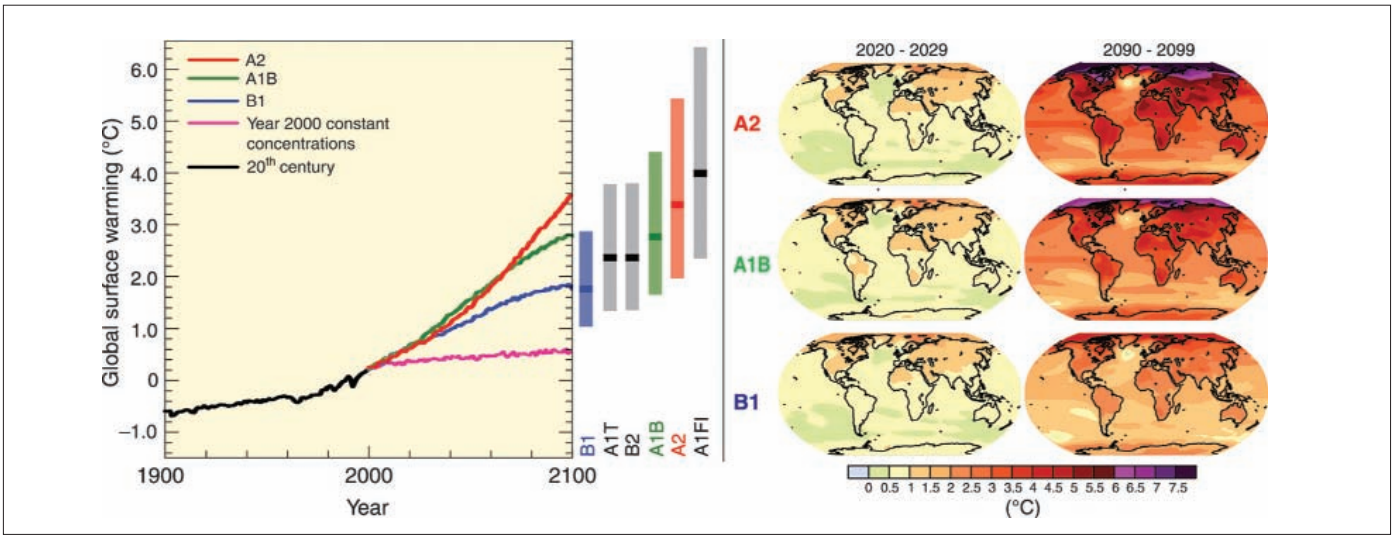
The underlying cause of global warming dangers is associated with greenhouse gases in the atmosphere and in particular the levels of CO_2. It is the excess that causes the danger, so there is first a need to suggest a 'safe limit' to temperatures and a quantity of the world's CO_2 emissions that is endangering this 'safe limit'. The likelihood of these dangers can then be considered.

A possibly relevant question for a 'safe limit' from the survey was Question 4: '*What is the percentage chance that we could reach a new equilibrium at 4°*?' Only seven out of 47 respondents thought there was more than a 50% chance of stability, so it is deduced that engineers believe that temperatures must be kept well under a 4°C rise.

As discussed above with Question 12[4], engineers gave a mean figure of 28% of the worlds population at risk if temperatures rise 3°C, so that figure would again pose a major danger.

At the 2009 Copenhagen Summit, several developing countries thought that even a 1.5°C rise would cause major suffering. The majority however agreed an upper target of 2°C mean temperature rise to avoid the major dangers to the world. For such a rise Question 11 '*What percentage of the world's current population will need to move to survive a 2° mean temperature rise?*' still yielded a mean figure of 27%. A 2°C rise will however be assumed to be a pragmatic upper target.

Using IPCC(2007) figures again (Fig 3), world emissions of CO_2



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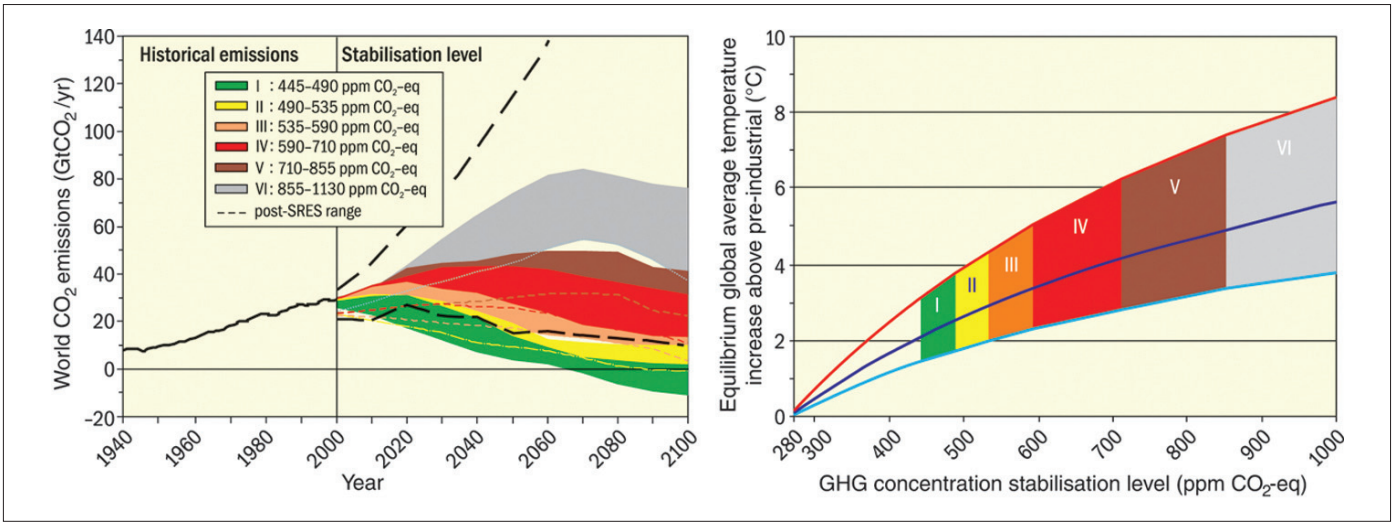

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would need to be cut from 30Gt to 20Gt per year to keep temperatures below a 2°C target. The worst dangers might then possibly be avoided if 10Gt per year were cut from current world CO_2 emissions.

For the risk assessment, it could be stated that 10 000Mt of carbon dioxide emitted per year, could be endangering 3000M people. There is therefore some possibility that every 10t of carbon dioxide released per year may be contributing to the loss of life of three people. It is necessary to consider the likelihood of this danger and the timescale so that this can be used per project for isolated projects.

Timeframe

The significance of the 'per year' aspect of the 10Gt could easily be applied to running emissions or annual phases of a large project, but the danger from each individual project also needs to be assessed. The timescales for emissions in the IPCC graphs (Figs 2, 3) indicate that CO_2 concentrations need to start dropping by 2020, giving a timescale of 10 years.

The problem of the lingering effects of each emission was also illustrated from Question 2: '*What percentage of CO_2 emissions currently released do you think will not be absorbed by the sea, forest, soils, etc and will add to concentrations of greenhouse gases over the next 10 years?*'. Engineers across the spectrum of expertise gave a mean value of 38% to this difficult question, and only three respondents indicated more than 90% of carbon dioxide would be absorbed in 10 years. Ten years is therefore a very upper bound limit.

From Question 9 (asked in 2008) '*What is the probability that the future of our civilisation will be determined by our actions to resolve climate change in the next 5 years?*' A value of 38% was given for the mean, with quartiles of 10% and 60%. As 23 out of 53 opinions gave a probability of 50% of more, many engineers appear to think that the timescale is very short.

A reasonable figure might therefore be taken as 6 years from 2010. If 6 years of emissions at 10Gt per year endangers 3bn people, this would indicate that there is a chance that every 20t of CO_2 emitted before 2016 could result in a loss of a life.

Likelihood

As already mentioned when assessing the hazard with the help of Question 14, even the most ardent sceptics believed there was a 5% chance that our actions are affecting the planet.

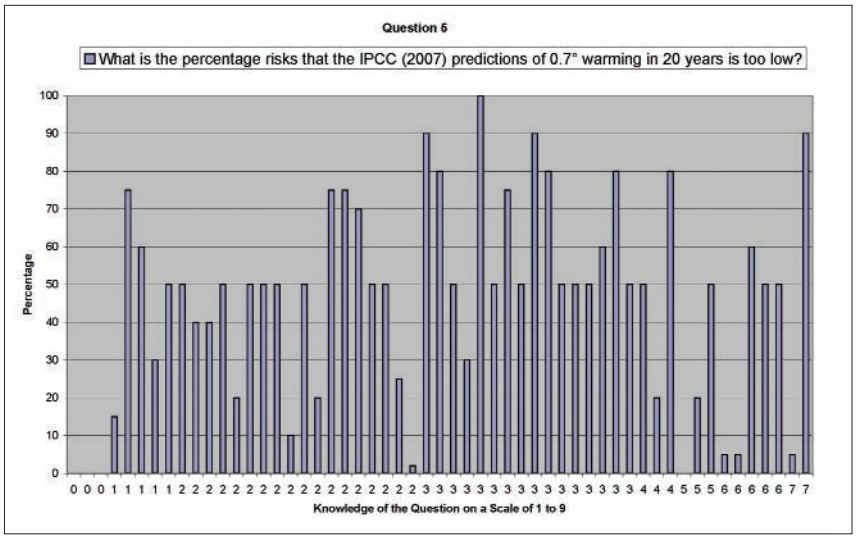
More precise statistical probabilities have been prepared for risks of local flooding, temperature change etc. in the UK, but these figures are generally based on IPCC2007, with little advice on how flaws in the basic data from IPCC 2007 would effect the results. Similarly, the graphs used in Figs 2, 3 which link temperature and emissions were carried out by environmental scientists for IPCC 2007.

An oblique, yet relatively robust and simple alternative to assessing the likelihood of the above specific dangers would involve examining:

– What are the probabilities that concerns over global warming may have been over-estimated?

– What are the probabilities that IPCC 2007 may have under-estimated the dangers?

– What is the percentage chance that new technology will prevent major loss of life from climate changes?



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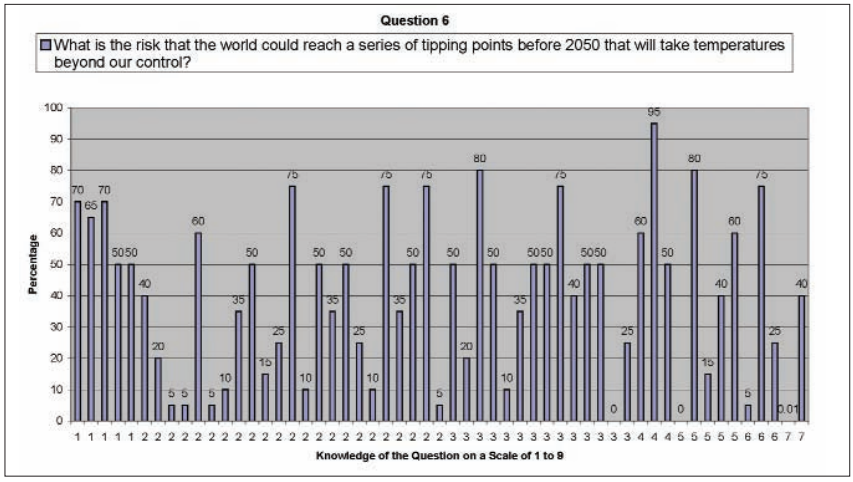

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4 Graph of individual results for Question 12 from the questionnaire survey ordered by level of expertise on the probability that IPCC predictions of warming are too low

5 Diagram indicating individual results from the questionnaire survey on the probability that the world would reach a series of tipping points that would destabilise temperatures before 2050

6 (Opposite) Thames Barrier Construction – 'The Race to Save London' by Jane Thorniley-Walker illustrates an engineering project that was initiated in time to reduce a perceived risk and is now needed several times a year. It is also one extreme of a high-cost and high-carbon project that could be easily justified. Society will need to make many positive and negative decisions on the value of many projects of all sizes, based on the assessed probable risks and benefits

7 (Opposite) Responses to Question 18 asking how involved professional engineers should be with trying to limit climate change – (mean response 77%, with 22 out of 52 respondents giving 100% involvement)

In the questionnaire survey[4], four questions yielded relevant data on these subjects.

a) For the Question 4: '*What is the probability that global warming is within the range of normal solar cycles and that predictions of warming significantly over-estimate the problem?*', the mean value was given as 35%. It is therefore deduced that there is around a 65% probability that concerns over man-made global warming are justified.

b) The converse Question 5: '*What is the percentage risks that the IPCC (2007) predictions of 0.7° warming in 20 years are too low?*', yielded a mean 48% (Fig 4). On this question 45 out of 52 thought there was a 20% or more risk that IPCC underestimated the danger.

c) Similarly on Question 64: '*What is the risk that the world could reach a series of tipping points before 2050 that will take temperatures beyond our control?*', the mean result was 43%. Within this, 27 out of 55 respondents, across the complete spectrum of knowledge on the subject, believed that there was at least a 50% chance of tipping points (Fig 5).

d) For Question 10: '*What is the percentage chance that new technology will prevent major loss of life from climate changes?*', the mean was 40%.

The opinion survey generally indicated that the probability of IPCC2007 being correct, one way or the other, appears to be in the range of 35%-65%. It is worth mentioning that at the time of writing the IPCC has apologised for over-exaggeration of the rates of glacial melt in the Himalayas, and has been unable to produce all raw research data for some of their findings. Conversely, data prepared for the December 2009 Copenhagen Summit[6] indicated that current statistics on key data such as CO_2 levels and Arctic summer melt are already at, or even worse than the worst-credible IPCC2007 predictions.

It is common for many construction projects to have such difficulties in defining the exact risks, as failures and multiple deaths are relatively rare. In projects where multiple deaths might be expected, engineers tend to work with probabilities in the range 0.1% to 0.001%. As millions or billions of lives are at risk from global warming, and as the probabilities appear to be around 50%, the likelihood would need to be regarded as 'Extremely High'.

Mitigation

Common mitigations for use of high carbon materials in projects are sometimes based on:
– the ability to recycle materials in decades to come;
– a steady saving of carbon emissions during the long-term use of the facility;
– a prolonged life expectancy;
– offsetting schemes, such as tree planting, based on future absorption of CO_2.

For the risk assessment however, the results from Questions 2, 6 and 9 (discussed above), indicate that the dangers under consideration emanate from the current year or so. Any mitigation associated with potential future long-term benefits will usually have little or no direct bearing on current emissions. Risk assessments should not therefore generally consider beneficial effects that might accrue beyond the next few years. Attention thus needs to concentrate on achieving a low carbon footprint during construction and in the short-term running life.

Similarly the payment of a licence or tax that allows the richer countries, companies or individuals to pay for the right to pollute might not necessarily be considered reasonable mitigation when analysed carefully on a project by project basis.

In previous decades, methods such as cost-benefit-analysis have been used where, for example, a notional value of £1M per life might be weighed against expenditure for various options.

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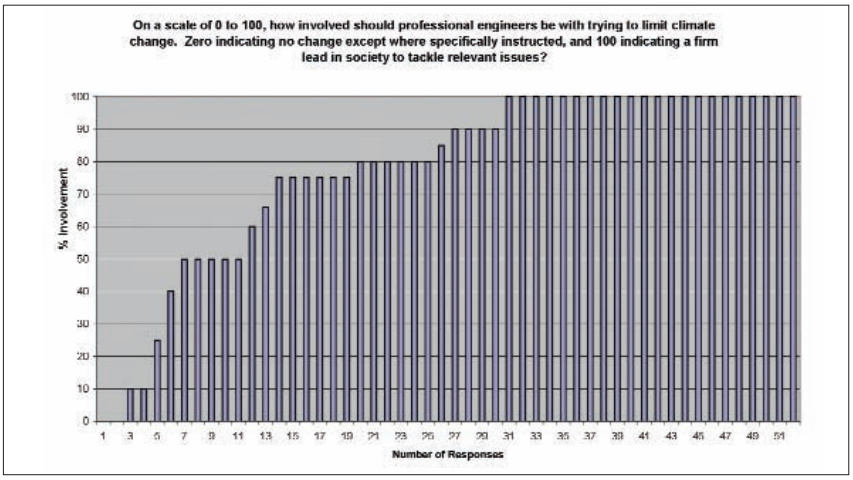

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		Mean Opinion	Median
Question 16	'If there is a looming crisis from unsustainable development of the earth, what % of their duty do engineers owe to society rather than to their clients?'	69%	75%
Question 17	'What percentage of previous risk assessments, codes of practice and legal requirements need to be revised to meet the challenges of the next 50 years?'	73%	80%
Question 18	'On a scale of 0 to 100, how involved should professional engineers be with trying to limit climate change. Zero indicating no change except where specifically instructed, and 100 indicating a firm lead in society to tackle relevant issues?' (Fig 7)	77%	88%

Table 1 Results from last three questions to the Questionnaire Survey[4]

Issues from climate change are more complex and mitigation might need to be based on the benefits to society offsetting the likely cost in lives. This might be clear-cut for projects such as the Thames Barrier (Fig 6), but the risk assessment framework should at least allow serious discussion and debate to be initiated.

Action

The risks and dangers associated with climate change are clearly immense when compared with other engineering hazards. It might therefore be expected that future risk assessments will precipitate major changes to the philosophies of all parties in construction and design, as well as in other fields beyond these sectors.

As many projects will struggle to find mitigation or justification in their risk assessments, robust actions will be needed by clients, design teams and construction staff to cut their contribution to the hazards, even if this appears insignificant on a global basis. The form of appropriate action will again need careful and specific consideration and might not necessarily conform to current 'sustainable' standards.

Such changes were apparently anticipated in the engineer-based survey, as indicated by the surprisingly high mean percentages to the last three questions of the survey (Table 1). The median figures were even more emphatic, and for Question 18 with 22 out of 52 respondents for wanted 100% involvement (Fig 7).

Conclusions

All projects should have risk assessments that include the effects from carbon emissions. The lack of 100% certainty on any hazard is no reason for exclusion, and British engineers, who helped initiate the mass burning of fossil fuels from the mid-C19, now appear keen to be involved with taking on this responsibly.

The engineer-based opinion survey has proved a useful source of quantifiable data. It suggested that even relatively sceptical values for the probabilities and hazards from carbon emissions indicate that the danger to life, and the likelihood, are both exceedingly high when compared with usual risks in civilian engineering and industrial activities. The questionnaire evidence, coupled with data from IPCC (2007), suggests that every 20t of carbon dioxide emitted will probably cause the death of one person from global warming.

There is scope for much discussion about the various factors, opinions and interpretations of the sample study group, and another larger survey might provide a slightly different perspective. However, it appears unlikely that further data will adjust the high probabilities or the dangers down to 'normal' acceptable levels.

When considering mitigation, it is the current emissions that are precipitating the danger. It is therefore recommended that risk assessments should not generally consider return periods or future benefits that may accrue beyond the next decade. Other established approaches to sustainable developments might also fail to provide proper mitigation or action to the specific risks identified.

The findings and opinions in this article endorse the Engineering Council's recommendations on the need for risk assessments to include climate change. The findings also confirm the advice from ICE that a key part of all design should involve minimising the carbon footprint.

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Verulam

Sheer loads on slab

John Botterill, writing from Chessington, Surrey, seeks guidance on the design of rc slabs carrying concentrated loads.

The question of what width of a slab can be considered to carry a concentrated load, has always had some uncertainty.

For bending moment in an *in situ* simply supported slab, BS 8110 clause 3.5.2 – figure 3.6 provides us with a figure for the width as being generally width of the load plus (up to – depending on load position) 0.6 times the span. The Institution *Manual for design to Eurocode 2* offers the same formula, and in fact not restricted to just simply supported slabs, though as usual the Eurocode itself gives no guidance.

But for shear there seems to be no information. Indeed, neither is there information on bending moment, or shear, for a concentrated load on a continuous nib.

Does anyone have any guidance to offer please?

John's query is more commonly associated with load distribution analysis of bridge decks. Unless any member out there wishes to respond, I suggest that John refers the question to The Concrete Centre which offers assistance on the implementation of Eurocode 2 (website: wwweurocode2.info).

Construction standards

A regular correspondent, Richard Harris, writing from Dorset, has developed the issues raised by Satish Desai (Verulam 2 February) concerning design standards, remuneration and client satisfaction etc.

Satish Desai recently raised the issue of lower construction standards. He referred to a report, based on snagging surveys, by Terry Williams that revealed 'a distinct lack of care and diligence in new home construction'. This report concluded that 'the existing control systems and policies for quality and consumer protection within the UK new house building industry are not effective'. He cites, amongst other causative factors, the potential lowering of standards of education and training, the role of competitive tendering, and the lack of regulatory concern for achieving an acceptable level of quality. (I would imagine that this must all be just as applicable to the refurbishment market.)

From my own experience of other engineer's work, the sometimes-poor quality of conceptual design is also a factor in quality issues and consumer protection. This is something that may not be apparent in a snagging survey, which can visually identify poor workmanship, but may not pick up unnecessary or excessive use of structural steelwork, for instance. When I was checking Building Regulations applications under Part A, I sometimes saw structural designs that were of such poor conceptual quality that it made me quite cross. They often passed the requirements for safety, but would have been unnecessarily expensive to build, or would have poor serviceability or aesthetic qualities, etc. These designs were obviously quick to produce, so that the engineer's fee was probably cheap, and turnaround quick, but they did the client no other favours. Clients often would be none the wiser, because there was nothing with which they could make a direct comparison. (In my experience, the worst offenders, usually, were not members of this Institution.)

When we initiate a structural design, especially in competitive tendering situations, we take an ethical stance. We do so, whether we consciously realise it or not. Perhaps this is not something to which we, or our clients, or even regulatory agencies, give much recognition? Our ethical stance is, in part, an accumulation of attitude, derived from our development as engineers, according to the dictates of our mentors and managers. For instance, when I started out, there was an attitude that engineers should not be concerned about remuneration, and that we should want to do the job for its own sake. Perhaps this was a legacy from the days when articled pupils paid to work for a practice? As we progress through our careers and take on more responsibility for our work, our ethical stance might be influenced by discussions with our peers. In my own case, I took a mandatory course at university on Professional Practice that focused on ethics, for registration with Professional Engineers Ontario, which grants licences to practise professional engineering in that Province. Its statutory mandate is to serve and protect the public interest, where engineering is concerned, with a Code of Ethics that puts the public first. Also, with somewhat less emphasis, the Institution of Structural Engineer's Code of Conduct requires that, 'Members of the Institution in their responsibility to the profession shall have full regard to the public interest'.

There is also, of course, a component of our ethical stance that derives from our individual personalities; in other words, there is a contribution from both genes and environment.

To put it bluntly, some engineers undoubtedly put more emphasis on getting their reward (maximising their fee for the number of hours worked) and less on achieving the client's objective's (the conflicting requirements of safety, economy, sustainability, serviceability, aesthetics, etc.). In a competitive tendering situation, this is unlikely to be apparent to some clients. They may think that in retaining the engineer offering the cheapest fee, they are getting a good deal for the design service, but they are not necessarily going to get a good design out of it. They have no means of evaluating quality, except perhaps through the builder's comments, by which time it is too late. And the builder's comments may or may not reflect an informed understanding of the engineer's judgments and decisions.

Those of us working as sole practitioners, for instance, are selling a service that cannot be properly marketed by using the usual marketing tools. (These involve identifying quantifiably superior benefits to the purchaser, such as: proven reliability of the products used or supplied; ready availability of spare parts saving downtime; size of advertising budget; range of financing deals; proven safety record of the products used or supplied, and so on.) We are left, effectively, with competing on price or promised turnaround alone. And my experience is that potential clients often do not react well to the idea that they should not be seeking the cheapest price for structural engineering services. It is sometimes difficult, or impossible, to explain that the longer the engineer spends on a job, within reason, the better he or she can refine the design, to the client's advantage. They have no way of assessing whether a design is optimal or not, because they have no concept of either the art or science of structural engineering. We operate in what economists call a failed market, due to the effects of information asymmetry between the client and service provider.

Under competitive tendering there is little, or for some engineers, no incentive to produce good design, where the conflicting demands of safety, economy, serviceability, etc. are carefully balanced for an optimal solution. A reputation for good design is, by its nature, difficult to achieve, and would not travel far. It would also be difficult to educate clients on this issue. As a well-established competitive tendering regime appears to be with us for the foreseeable future, we, as a profession, seem to have reached, or been forced into, an *impasse* over the issue of good design. Where good design does exist, I suggest that it largely depends upon the good will and benevolence of the engineer.

Except perhaps for prestigious projects, frequently the only incentives for a structural engineer to produce optimal designs derive from endogenous volitions such as altruism or pride. I think that this prevailing situation is unlikely to have significant safety implications, particularly where designs are checked by experienced engineers acting for a Building Control Body. But I am sure that it must adversely affect economy, sustainability, and other important aspects of the building, not only to the detriment of the client, but also for society at large.

I thank Richard for this assessment of professional practice in today's competitive environment.

Beech hedges

Philip Gasson writing from Banstead, Surrey, expresses his frustration in seeking agreement with his local Building Control Officer on the building of foundations adjacent to trees and hedges.

I provide structural engineering designs to local architects, mainly in relation to extensions to housing. Subsoils in my area are often clays with high shrinkage potential and as such trees and vegetation frequently determine the safe depth of foundations.

Building Control Officers always refer to NHBC Chapter 4.2 for guidance and generally this leads to a reasonable solution, however when it comes to established hedges in my view logic is not followed. Not for the first time I recently raised an issue over a mature beech hedge which is 2.5m high. The proposed extension will be approximately 1.5m from the hedge. The Building Control Officer's stance is that the hedge, which consists of beech planted at approximately 900mm centres, is to be treated as beech trees growing to a mature height of 20m! Consequently the Building Control Officer will only accept 2.3m deep foundations or piles as the foundation solution.

I pointed out to the Building Control Officer that the beech hedge was well established and clearly it is intended by adjoining owners that the hedge will remain a hedge. It is in any event physically impossible for the hedge to ever become a row of 20m tall trees. I proposed to Building Control that we assume the hedge be treated as if 4m tall (unlikely to occur but this gives a margin of safety) and provide foundation depths thereafter as per NHBC guidelines (1.7m) but they would not accept this.

I consider this unreasonable. The point I would make is that the situation is controllable. If the hedge remains at 2.5m or even grows to 4.0m the adopted foundation depth will be fine. If however for some bizarre reason the hedge is allowed to grow towards mature tree height and subsidence damage consequently occurs the hedge/trees can be cut back to their former height thereby returning the *status quo*. (It's always comforting for engineers to have an alternative plan.)

I have also experienced similar Building Control problems with regard to *Leylandii* hedges but with legislation limiting the height of such hedges I assume the proposed hedge height, plus a margin, could be adopted for such situations rather than assuming the hedge grows to mature tree height.

I would be very interested to learn members views and experiences on this issue.

One can understand Philip's frustration at having to take foundations down excessive depths in order to comply with the BCO's somewhat conservative prediction of further possible growth.

Whilst such disputes may ultimately be referred to the Secretary of State for a determination, perhaps it would be advisable to ask the BCO to reconsider his ruling taking account of the following ameliorating factors:
i) The low probability of the hedge being allowed to grow to 20m in height.
ii) Assuming the building being of traditional domestic construction, any movement of the foundation resulting from the presence of hedge roots is likely to manifest itself in serviceability cracking, not structural cracking of a nature that may impair the stability of any part of the building. Regulation A2 refers.

Young engineers/graduates not appreciated

Rebecca Marr is an enthusiastic graduate from Edinburgh who experienced a less than respectful welcome when attending a recent Institution seminar.

I recently attended an Institution seminar in Edinburgh on the subject of temporary works. The presentation was very interesting and covered things that I didn't know much about, being a fresh graduate who has only been in work for 6 months.

The subject of experience came up which was followed by a bit of a rant from the presenter (who shall remain anonymous), on the subject of graduates, their general uselessness, lack of experience and basic knowledge and the fact that undergraduates spend their entire time at university getting drunk.

Everyone has a good time while studying; I did, my friends did. However, I object to being tarred with the same brush as all students are, often wrongly. My course was difficult; challenging both in the level of knowledge and study required and in the shear volume of work that had to be put in. If I had been out drinking constantly I doubt I would have passed!

Besides this though, I found it off putting that being one of a tiny minority of people who seemed around graduate vintage, and one who had voluntarily come to this presentation without coercion from my employer, that my contemporaries and I were disparaged.

It seems that many experienced members of the profession think of graduates and students as lacking common sense, engineering judgment and a basic understanding of structural behaviour. But whose problem is this?

Is it the problem of the person who has attended their classes, listened and done the amount of study required to get a pass grade in their university exams and eventually acquire a degree?

Or is it the problem of the university which sets the exams, delivers the lectures and awards the degrees?

Or is it the problem of the institution that accredits the degree course?

If people, with a lot more experience and knowledge than I have, think that the quality of graduates is poor then it must be the case. But is that the graduate's fault or is it the fault of the authority? Whichever is the case, I certainly feel less inclined to attend any more of these seminars where 'all are welcome' and I'm tired of the constant 'graduate bashing' that happens within the more senior circles of structural engineering. Everyone has to start somewhere.

I trust that such unfortunate remarks are not repeated at other professional meetings or seminars given that, apart from being largely unfounded, we need to give our graduates every encouragement during their formative years. My thanks to Rebecca for reporting this unfortunate exchange.

Continued Professional Development

Neil Rigby writes from Peru expressing his support of Angelo Manesero's novel recommendations (See Verulam 16 March) for presenting training seminars to members.

In relation to Mr Manesero's letter regarding 'webinars', I wholeheartedly support this proposal. Having live in Brazil for a number of years and recently moved to Peru, I have long bemoaned the lack of action from the powers that be in the Institution in tackling this issue, particularly in light of the apparent push towards compulsory CPD.

I can recommend the Institute of Engineering in São Paulo, Brazil as an example of how well it can be done. For any Portuguese speakers, please see: http://www.iengenharia.org.br/videos/. Here you will find a wide range of subjects presented.

I would appreciate if those responsible for CPD and communications from the Institution can provide us with some feedback on plans, if any, to implement such a proposal. This has been a subject of discussion for some time among contributors to Verulam. But has seen little action from those responsible within the Institution for promoting these activities.

A vote of thanks also to Verulam for publishing Mr Manesero's letter and helping to keep this issue in the forefront of people's minds.

I thank Neil for his contribution to this issue.

Video courses and seminars

Peter Jackson writes to explain that the technology for delivering video courses and seminars, as referred to by Angelo Manesero in his letter published on 16 March, is already available.

I have just read yet another letter, this time from Angelo Manesero (16 March), advocating the use of video. If you will forgive me for saying so, I was appalled by your patronising 'thanks for drawing attention to this facility which sounds quite promising'. In fact it is a well established technology which the Institution should have embraced long ago. We have Skype for phone calls, Elluminate (as used so successfully by the Open University) for discussions/seminars, Audacity for audio recording which can be output as MP3, and what about Utube[sic]. The software for most of these is free. Come on Institution, get into this century and provide a decent service for your members, and this is me as a 74-year old suggesting it!

My thanks to Peter for bringing myself (and no doubt others) up to date on the current situation regarding the latest equipment for presenting distant learning CPD etc.

Emails can be sent to Verulam via: (verulam@istructe.org).
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Paper

Going for green – the search for a green design for a striking new building for Curtin University's engineering department

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How Curtin University of Technology's Engineering Pavilion vision rubbed off on the design team

Curtin University of Technology, Western Australia's largest university, wanted to create a multipurpose facility for the engineering departments to be the focal point of activities for the engineering students and encourage them to come together to learn. The brief for the building was therefore to provide space beyond the current lecture theatres, laboratories and classrooms that exist for the students and allow them to engage in informal learning and teaching, while enabling the university to develop more self directed learning and create more flexible spaces on the campus that cater for unknown future needs as technology changes with time.

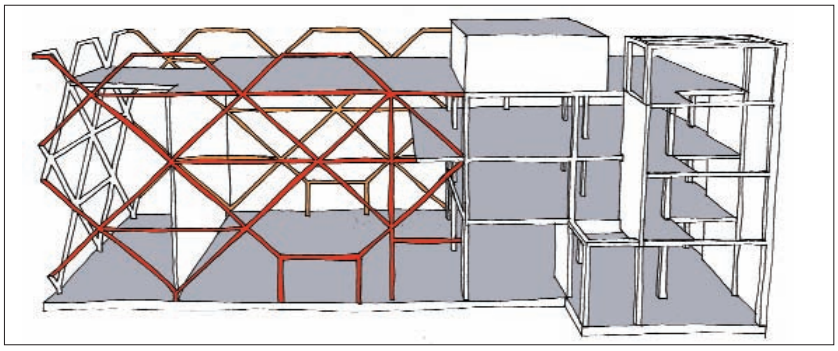
This resulted in the brief encompassing the following activities: 300m^2 of exhibition area; an industry and careers space (40m^2); a common room of 100m^2; project rooms (60m^2); 300m^2 of self-learning and project rooms and structured learning areas totalling 300m^2 (Fig 1).

Having set the brief as a gateway for students into the engineering departments and a building where they should learn for themselves it quickly became obvious to the design team that we had to rise to the occasion to produce a building capable of inspiring the students. To do this we decided the engineering for the building should go on display. We wanted this to stand out in the design, but were also cautious not to make it too busy with ideas, so we chose a few specific aspects of the engineering principles to display and worked hard to integrate them well. The building services responded to this by the introduction of a building operation and energy usage display panel in the exhibition space to promote educational awareness about the building's energy usage. Occupants will receive feedback on:

- total building energy usage;
- specific system energy usage / generation (HVAC, lighting, photovoltaics etc);
- net carbon dioxide emissions;
- building operating mode (heating / cooling, economy); and
- space temperature and humidity.

With the structure we chose the stability system and the long span structure for the roof of the open exhibition hall as the components to emphasise. Wrapping the three-storey exhibition space in a steel diagrid frame on three sides we combined the steelwork we would require for the support of the three storey height façade with the lateral stability system for the building. Combining the exhibition hall wall support system with the bracing system in this way has removed some structural shear wall elements from the design, Fig 2.

As we discussed the options for the support of the roof structure across the 19 × 17m exhibition space we were also presented with our next challenge by the university. Keen to promote sustainable design on the campus, Curtin decided to champion the Engineering Pavilion as a green building and seek to achieve a 5-star rating on the Green Star rating system. It also turned our mind to using timber in the structural form. We therefore started looking at glulam solutions for the main roof trusses. Starting with a deep glulam beam crossing the space, we were keen to display the use of material in the roof space. But conscious of the quantity of timber that entailed, we sought to reduce its required bulk. The glulam beam was therefore adapted to a flitched plate beam using a pair of glulam beams either side of a steel plate. The wind uplift loads from suction on the roof surface giving rise to higher design loads than the live loads on the roof,



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1 Architectural images of the Engineering Pavilion (*Courtesy Taylor Robinson Architects*)
2 Schematic of the new Engineering Pavilion
3 (Opposite) Architectural images of the Engineering Pavilion (*Courtesy Taylor Robinson Architects*)

and with a relatively light self weight this seemed to be a reasonable conclusion. But when you consider the deflection, which in timber structures is frequently the critical design criteria the emphasis changes to the creep deflection of the timber. Our final design therefore combined a bow string truss using a small, fabricated cruciform steel strut holding off a tension cable with the timber flitch plate top chord to optimise the truss design.

Concurrent to the development of the Engineering Pavilion project, the University's Department of Electrical and Computer Engineering had been planning to set up a Green Electrical Engineering Park (GEEP). In their search for an appropriate space for this facility the University decided to investigate incorporating it into the Engineering Pavilion. It seemed appropriate for the university in striving to achieve a 5-star rating for the building to also include facilities for the establishment of world class teaching and applied research in the area of renewable energy (Fig 3).

And so the brief was complete and our objectives clearly set to achieve a 5-star rating on the building and promote the engineering principles. But what is the Green Star system all about?

The Green Star system

In Australia there are now six tools established for rating the green credentials of a building:

Green Star™	Green Building Council of Australia (GBCA)
NABERS	Australian Government – Department of Environment and Climate Change, NSW
EcoSpecifier	Royal Melbourne Institute of Technology and Natural Integrated Living
EcoDesign Score Card/Ecoselector	Royal Melbourne Institute of Technology and VicUrban
Australian Life Cycle Inventory Database (AusLCI)	Australian Life Cycle Assessment Society (ALCAS)
NatHERS	Nationwide House Energy Rating Scheme

The two main systems most commonly used are The Green Star system and NABERS. Here's what they say about themselves:

'GBCA is a national, not-for-profit organisation that is committed to developing a sustainable property industry for Australia by encouraging the adoption of green building practises. It is uniquely supported by both industry and governments across the country'. So somewhere between a government department and a private organisation. That's interesting, let's hope it has a positive effect in pushing forward green policies that take in to account the latest, most up to date knowledge and green technologies and doesn't get hung up on any one party or organisation's preferences. When you pick up the Green Star Rating Education tool the first thing you notice is that it does seem to cover a lot of aspects surrounding the building's future from energy consumption to public transport. They also split 'As built' from 'As designed' recognising that it is more difficult to realise all the design ambitions once you are on site.

'NABERS is a performance-based rating system for existing buildings. NABERS rates a building on the basis of its measured operational impacts on the environment, and provides a simple indication of how well you are managing these environmental impacts compared with your peers and neighbours'. Well, in fact they also provide the tools to rate a new building too although this doesn't make that clear. It is, however focused on the operational impacts of the building so NABERS doesn't cover sustainability related to structure unless that structure has an impact on the energy used for the running of the building.

So with the Green Star Rating being a more encompassing system for the whole design of the building, that is where we headed and down an 'As designed' route.

Will the Green Star rating help to guide our design to a more sustainable building? We hope so and perhaps we'll pick up a few more ideas along the way. Let's see, as we set about reviewing the design of Engineering Pavilion Building for Curtin on a retrospective journey of discovery.

Whatever system you might use to compare the green credentials of buildings, one thing is for certain – there are only two

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ways in which we are likely to see more sustainable solutions being adopted. One is legislation that forces it to happen and the other is market forces that make having a greener building a desirable prospect for developers. Change, after all, will often come with a new price tag attached. Being able to market a building as having a Green Star rating is now starting to be recognised as adding market value and the more this is the case the more it will be used. What is important now is that the system is developed and not abandoned for a new rating system so that it becomes more and more understood, recognised and sought after.

Finding out how Green (Star) our building is

The Green Star system is currently split into 10 tools:

- Retail Centre
- Education
- Office
- Office Interiors
- Industrial
- Multi Unit Residential
- Mixed Use
- Healthcare
- Office Existing Building
- Convention Centre.

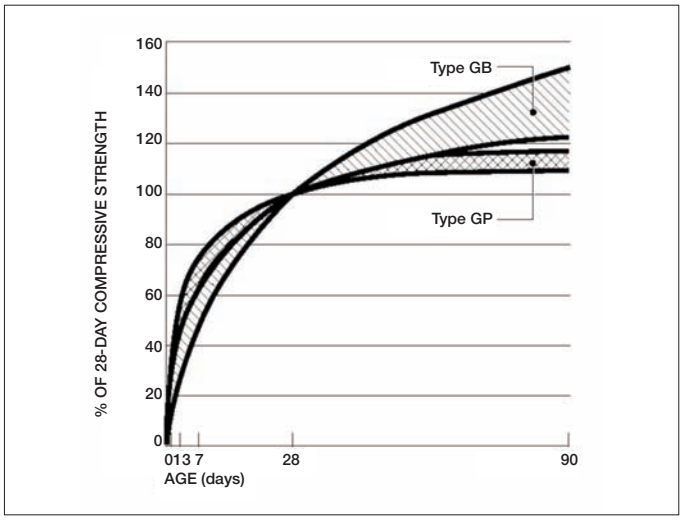
So that's good, we can start straight away with the Education tool. The Green Star was only a pilot scheme for the Education tool when we started, so we had to use the pilot together with the full Office tool to check our work against and then reconfirm the point scoring once the final version was released. The Green Star rating system is changing fast – at the time of writing five of these tools are still pilot schemes. There are now 235 Green Star accredited buildings, 13 of which are in Western Australia (WA) and are all office buildings.

In order to achieve Green Star points the designer must identify improvement in environmental performance relative to industry standard against nine environmental categories as listed below.

- Management
- Indoor Environment Quality
- Energy
- Transport
- Water
- Materials
- Land Use and Ecology
- Emissions
- Innovation.

The categories are weighted with Energy and Indoor Environment Quality getting the highest weighting and all other categories being largely on a par.

We first looked for any areas of the scoring system where structural aspects of design featured. My first impressions were that the system is fairly comprehensive, except on those structural aspects we were looking for. It picks up on many good ideas that I have come across over the years, such as the point that can be gained for making the building occupants aware of the energy consumption that they are using in the building. By displaying at



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4 Typical development of concrete strength with age

least three of the buildings' environmental attributes in a manner that can be readily understood by building users, with at least one attribute relating to energy use and one attribute relating to water use we gained a point.

The emphasis on indoor environment quality is interesting and not something that immediately jumps out as being the most important green factor in rating a buildings' green credentials, but this section actually serves as a check against all the other measures that a design team or client is likely to introduce to achieve a high Green Star rating. So it rewards good lighting levels, ventilation rates, thermal comfort and external views. It also checks the efficiency of achieving those and the ability for the occupants to vary conditions locally to suit circumstances. The other aspect of this is that buildings that work well for the occupants are more likely to have a long life without the need for major refurbishment or redevelopment and that in itself is good for the environment. As we know one of the best ways of cutting down on energy consumption in construction is not to have to construct at all the 'Reuse' in the three Rs: Reduce, Reuse, Recycle.

Looking on through the sections on Energy, Transport and Emissions I was expecting to find reference to the embodied energy from extraction, production, fabrication, transport and construction of the building, but surprisingly, found nothing. I contacted the GBCA to find out why and they said, '*The GBCA is a partner in the Australian Life Cycle Inventory Project. Once this project is completed, Australian national life cycle data collection and reporting protocols will be established. Currently, the lack of such agreed national methodologies is a barrier to the GBCA adopting lifecycle decision making tools. The Green Star rating tools do include operational energy, which over the life of the building is more significant than the energy embodied in materials and construction. Should the Aus LCI fail to achieve its goals, the GBCA may look elsewhere in an effort to incorporate life cycle assessment decision making in Green Star tools. Prominent LCA experts in Australia support the GBCA position.*'

So that really leaves the structural designer with the section on Materials to consider in detail (as you would of course expect).

Green concrete?

As I'm sure the reader knows, concrete contributes significantly to the amount of greenhouse gases we produce each year with around 0.9 to 1t of CO_2 liberated into the atmosphere in the manufacture of 1t of cement. 6–8% of the world's CO_2 emissions come from the manufacture of cement.

The process to produce Portland cement clinker involves heating a mixture of raw materials, usually limestone ($CaCO_3$) mixed with secondary materials such as clay shale, sand, iron ore, bauxite, fly ash and slag in a kiln to around 1450°C. This requires the burning of coal and gas to run the kilns, which, together with the fumes exhausted from the process results in the release of CO_2.

One way to reduce the environmental impact of concrete production is by the replacement of Portland cement with industrial waste products in the concrete mix and the Green Star recognises that. One Green Star point can be gained if the absolute quantity of Portland cement is reduced by: 30% *in situ* concrete, 20% precast concrete, 15% prestressed concrete.

Two points can be gained if these quantities are doubled. The percentages are taken as an average across all the concrete mixes used on the project, so the designer must consider the implications of using these mixes in all aspects of the concrete design.

There are several types of industrial waste product used to replace ordinary Portland Cement (OPC), the most common of which are: pulverised fly ash (PFA), ground granulated blast furnace slag (GGBS) and silica fume.

The most attractive of these from a design perspective is PFA. Despite its common use as a cement replacement in the Eastern States PFA has not been widely used in concrete in WA. Locally available fly ash has generally been considered of poor or inconsistent quality and found to cause brown discolouration of the concrete. To comply with AS 3582 (the Australian Standard on supplementary cementitious materials) PFA must conform to certain quality criteria which include fineness and loss of ignition. Western Australia's PFA was until recently not adequate for widespread use in concrete. In 2007 one of the largest coal fired power stations in WA at Collie, 3h south of Perth, finally started to produce PFA of a quality suitable for use in concrete mixes following a outage and overhaul in 2006. By increasing the burn temperature and efficiency of the burners and reducing the water content of coal going into the burners they were able to get the loss of ignition down to between 0.4 and 0.9%, which is well under the limit of 4% given in AS 3582 and means that there is significantly less unburnt carbon in the PFA to cause a discolouration and affect the properties of the concrete. They also improved the fineness and, with conformance testing in place, now achieve 82 to 86% fines less than 45µm. PFA is less dense than GGBS or OPC cement and the silos required to store it for production therefore need to be twice the size for the same quantities of cement material. As a result many producers are still not currently prepared to invest in the capital outlay required for the new silos they would need to produce concrete with PFA replacement. If they were to use their existing silos they would have to cut production. At present Hanson is the only company we know of set up to provide concrete with PFA cement replacement as a ready mixed product in regular quantities. We therefore looked for a more widely available solution until the point at which the contractor is on board to maintain competitive procurement options.

GGBS is widely available in WA as part of a premixed cement (GB cement). It is supplied with a 30 to 35% GGBS, 65 to 70% OPC content cement pre-mix and then mixed at the concrete plant with more OPC (GP cement) to create the required mix design. The maximum content of GGBS that can therefore be relied upon is 30% using GB cement. It is also available in LH cement mixes in quantities up to 65%, however the issues discussed below can be more pronounced so we stayed with GB cement mixes and aimed for one Green Star point. GGBS improves the durability of concrete, however the introduction of GGBS into concrete can lead to significant disadvantages:

– Concrete with a GGBS content gains strength at a slower rate than OPC concrete, Fig 4. Rapid strength gain is required to achieve the early floor strengths necessary for the nominal floor-to-floor construction cycle. An extended construction period may need to be accepted with GGBS concrete mixes.
– Concrete with a GGBS content leads to increased creep, which results in greater long-term deflections. Excessive long-term deflections in slabs and beams could lead to serviceability problems with the finishes and as a result the design needs to be adjusted to accommodate the change in mix design (usually by slight increases in structural depth or increases in the reinforcement quantities used). Some of this increased creep is

due to the higher shrinkage rates seen in concrete mixes using GGBS (around 700 microstrain) compared to around 600 microstrain in concrete mixes with 100% OPC. These values are average shrinkage rates expected, and the actual shrinkage values observed could be ±150 microstrain.

The increased creep and slower strength gain are consequently significant concerns when considering GGBS in concrete floors.

Silica fume, a by-product of silicon and ferro-silicon metal production, is a highly-reactive pozzolan and is generally used to produce high strength and highly durable concrete. If silica fume is used in combination with GGBS (referred to as a triple blend cement) the silica fume tends to counteract the additional creep caused by the GGBS. Unfortunately, silica fume is expensive, which is why we did not consider its use for this project. Instead it was felt to be more cost effective to design for the slightly increased shrinkage rate in the concrete and ensure that the strength gain with age is factored in to the construction programme for stripping formwork and stressing slabs.

The design mixes for the engineering pavilion building were therefore aimed at achieving the Green Star point with 30% GGBS cement replacement in *in situ* concrete, 20% in precast concrete and 15% in prestressed concrete. It's interesting to note however that GGBS is shipped in from Japan for use in WA, but the environmental effects of this transport is not part of the Green Star

Steel Building Product Type	Size Range	Recycled Content > 50%	Post Consumer Recycled Content
Angles (Equal and Unequal)	Equal 25 x 25 to 75 x 75 Unequal 65 x 50 & 75 x 50	Yes	77%
	Equal 90 x 90 & 100 x 100 Unequal 100 x 75 & 125 x 75	Yes	97%
	Equal 125 x 125 to 200 x 200 Unequal 150 x 90 to 150 x 100	No	5%
Beams (Tapered Flange)	100 TFB and 125 TFB	Yes	81%
Channels (Parallel Flange)	75 PFC to 125 PFC	Yes	97%
	150 PFC to 380 PFC	No	5%
DuraGal® Profiles	Angles 30 x 30 to 150 x 150 CA	No	6%
	Channels 75 x 40 to 300 x 90CC		
	Flats 50 to 300 CF Thickness		
	Range: 2.5mm to 8mm		
Flats	Width 20mm to 150mm SEF	Yes	87%
	Slit Flats	No	7%
Hollow Sections -Tubeline® CHS,RHS & SHS incl. DuraGal®	CHS 26.9mm to 457.0mm RHS 50 x 20 to 250 x 150 SHS13 x 13 to 250 x 250 Thickness range: 1.6mm to 12.7mm	No	6%
Rounds	Diameter: 12mm to 20mm	No	5%
	Diameter: 22mm to 90mm	No	5%
Universal Beams & Columns	Beams -150 UB to 610 UB Columns - 100 UC to 310 UC	No	5%
Welded Beams & Columns	Beams -700 WB to 1200 WB	No	6%
Reinforcing Bar	All OneSteel Supplied	Yes	89%
Reinforcing Rod for Mesh	All OneSteel Supplied	Yes	66%
Plate	BlueScope Steel Pt Kembla Supply (OST estimate)	No	7%
Purlins, Guttering, Steel Roofing and Steel Decking	BlueScope Steel Pt Kembla Supply (OST estimate)	No	7%

Important Notes:
1 Recycled Content percentages for OneSteel produced steel are estimated averages based on data for a previous financial year (2007/08). Accordingly, future Recycled Content percentages have the potential to change.
2 For products produced using primarily BlueScope steel (Coil, other steel building products and plate) figures are based on OneSteel estimates. BlueScope steel is used in the manufacture of DuraGal® Profiles, Hollow Sections and welded beams and columns. These figures may be superseded later by further BlueScope Steel published data.
3 Some OneSteel products can use alternate steel feed sources from both within and external to OneSteel depending on scrap availability, operational constraints and market demand.
4 Recycled Content refers to average post-consumer scrap which according to the GBCA definition excludes internal to site scrap.
5 OneSteel's Laverton, Waratah & Sydney Steel Mill operate Electric Arc Furnace scrap based steel-making processes, whilst OneSteel Whyalla Steelworks operates a Blast Furnace/BOS steel-making process.
6 Data relating to overall average scrap content refers to the overall proportion of scrap consumed in the total production of that product group

Table 1 OneSteel Product Green Star™ Points Eligibility

system. So the use of locally available PFA will therefore be revisited once the contractor is on board.

Sourcing timber from managed forestry practices

The next thing we considered was the use of timber, which, provided the timber is sourced from forests that are certified by the Forest Stewardship Council (FSC), gains recognition for its use in a project.

We looked at the elements of the building that were reasonably lightly loaded and considered whether they could be timber. In this way our roof structure and canopy elements were framed up in timber where earlier designs had considered light gauge, cold formed steel purlins. Laminated Veneer Lumber (LVL) joists were used for the longer spans because they exhibit much better stress and strain properties than a standard softwood joist. LVL is manufactured from veneers that are peeled from a rotating log, dried and laminated together under heat and pressure with an adhesive. This process makes efficient use of the log when compared to the cutting and planning process used to make joists and means that even larger sizes of joists can be produced without requiring large diameter trees. The grain on each ply is oriented in the same direction as the length of the member and knots can be offset so that they don't coincide in the joist at one section. The veneers are typically around 3 to 4mm thick so stress grading can be done with confidence on the whole section. So with higher stress and strain properties in the timber compared to standard softwood joists a smaller joist can be used to perform the same function and as a result some of the energy required in the manufacturing process is offset by a reduction in the quantity of timber used and the size of tree required to produce it. We were keen not to take the change to timber too far because the building was already employing efficient designs in its steel and concrete elements, which we felt would become less efficient if we changed to a timber frame.

Steel's sustainability rating

Steel is dealt with in the Green Star system by looking at the post consumer scrap content in the steel products used or the quantity of steel recycled from previous structures. Without an appropriate demolition occurring nearby and a deliberately custom design to use that steel, reusing steel from a previous building is extremely unlikely, so to obtain a point you really need to consider whether more than 60% of the steel members used in the project achieve the >50% post consumer scrap content asked for or whether the overall post consumer scrap content percentage is greater than 30%. One of the primary suppliers of steel sections in Australia, OneSteel does not agree with this differentiation of steel based on the steelmaking method or the level of recycled content as a useful environmental strategy. The application of this approach may create market distortions, environmental inefficiencies and cost impacts within the steel and scrap industries with no net improvement in global sustainability. Specifying a minimum level of recycled content in steel can lead to re-routing of products resulting in increased environmental, freight and cost burdens through the transportation of steel scrap within Australia, compared to the current export of Western Australian and North Queensland scrap which is still recycled by offshore EAF mills.

The market for steel scrap is already well established, with recycled steel being of great value. So stipulating minimum recycled content in steel products does not drive the recovery of steel materials. Steel recovery rates are instead, a function of deconstruction methods and recovery equipment, with recovery rates in Australia are already at around 95% for structural steel and between 70% and 80% for reinforcing steels.

As a result of the location of OneSteel's manufacturing plants and the availability of scrap steel in those areas, versus offshore recycling and production from raw materials their products lay out as shown in the Table 1.

So rather than stipulating post consumer scrap content requirements for the steel the designer in fact needs to check the latest published scrap content table from the supplier (produced annually) and to see if the project gains a point in this scrap content lottery. It could be possible to adjust the design to meet the content if the structure could be fabricated from the small section sizes that have the scrap content, but that would not create an efficient, environmentally friendly building.

The Engineering Pavilion's steelwork quantities were as per Table 2, so the project gained a point with the overall scrap content being 38%:

Innovate to get ahead

In the Green Star rating system there is also a section on Innovation 'To encourage and recognise pioneering initiatives in sustainable design, process or advocacy.' as they put it. Being a University known for its Science and Engineering subjects, Curtin had approached us to include in the building geopolymer concrete as part of the building fabric.

Geopolymer concrete is a product similar to traditional concrete, but which uses as different chemical reaction process as the basis of the curing of the material. The constituents of the mix are SiAl rich source materials, the alkaline liquids. The source materials should be rich in silicon (Si) and aluminium (Al) and could be natural minerals such as kaolinite and clays, or byproduct materials such as fly ash, silica fume, slag and rice-husk ash. Due to the availability of fly ash from the Collie power station South of Perth, this is the preferred source material for WA. The alkaline liquid used for geopolymer concrete is a combination of sodium hydroxide (NaOH) and sodium silicate solution ($2 \times SiO_2 + Na_2O + H_2O$). The reaction is then created by the silicon and aluminum oxides in the low-calcium Fly Ash reacting with alkaline liquid to form a polymer that binds the aggregates and other unreacted materials together. No cement is required in the mix design and only a small quantity of water is required (usually around 1%) as this does not form part of the curing reaction and is only there for additional workability.

There are a number of issues that need to be addressed with the use of geopolymer concrete, as follows:

- The concrete needs to be heat cured to prevent excessive shrinkage after construction taking place.
- It takes longer to reach the prescribed 28-day strength, which means striking times are extended.
- The concrete industry is not set up to produce it and would have to install specific storage and mixing facilities to produce it. It also has different material storage requirements and different workability characteristics to traditional concrete, so people are nervous of using it.
- To date geopolymer concrete has only been produced on a research laboratory scale at Curtin University.

Due to the requirement to heat cure geopolymer concrete it is really only suitable for production in precast yards, which means we are looking at its use for the facade panels and paving. At this stage we have not been able to get any precast companies on board to produce such a product, so it looks unlikely that geopolymer concrete will be used.

Investigating where we could pick up points in the Green Star system also lead us to research a number of cutting edge material technologies for use in the structure of the building. Biaxial hollow core floors have only very recently been marketed in Australia and offer savings in the amount of concrete used to achieve a particular span by creating spherical voids at the centre of the slab where concrete is not required for strength. Unfortunately we missed out on gaining a Green Star point for incorporating this technology in our design because it would have to be the first use of that technology in Australia and a project was already underway when we looked into it. Instead we stayed with the post-tensioned slab design which offers significant efficiencies in material use and had been designed to work very hard.

The wider perspective on greenhouse gas emissions in Australia

Currently the breakdown of greenhouse gas emissions in Australia attributes around 3% of direct emissions to commercial services and construction and of the 35% of direct emissions attributed to electricity, gas and water some 23% of that is caused by commercial services and the construction industry's use of electricity. This means that around 11% of the total greenhouse gas emissions from Australia can be attributed to commercial

services and construction from both direct emissions and use of electricity.

The figures given above and in the pie charts presented, Fig 5 & 6 are based on the Government's Department of Climate Change report: Australian national greenhouse accounts national inventory by economic sector 2007):

What was the point of this point again?

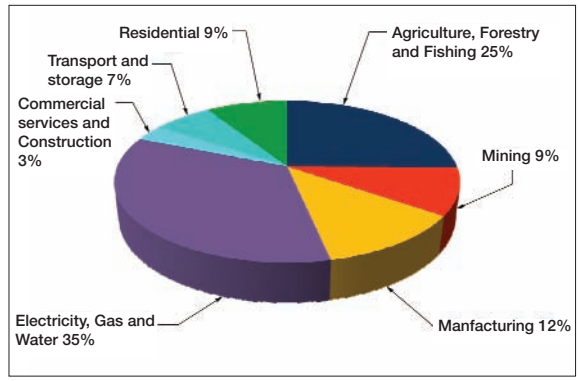
As we went through our possibilities for scoring points we came across some glitches in the rating system that could lead to points being achieved while the environmental advantages are lost.

Steel gets a point for its post consumer scrap content, but that steel could be shipped from Japan with the energy use associated with the shipping. Our project gained a point in this category and included large size RHS sections that are typically bought in from Japan or shipped over from the Eastern states on special delivery. Timber and replacement cement in concrete have the same issue as steel if they are shipped from overseas. Forest Stewardship Council (FSC) certified timber from Sweden? Ground Granulated Blast furnace Slag (GGBS) cement replacement from the steel mills in Japan? Why is the energy used in transporting materials not taken into account? The true values for embodied CO_2 may be hard to calculate, but no one will try until there is some reward for doing so. The GBCA says it is awaiting the finalisation of the Australian Life Cycle Inventory Project, so hopefully this will be resolved in the near future. It also says that as projects adopt the Green Star rating system the demand for locally produced sustainable materials increases and this in turn helps to develop and encourage those industries, and we are already seeing the results of that. FSC certified timber was not widely available in Australia 4 years ago. While some supply issues may remain, more and more domestically-grown FSC certified timber is becoming available. Ready-mix concrete producers are also starting to produce concrete with locally available PFA as well as the previously commonly available GGBS from Japan. GBCA also points out that Life Cycle Assessment conducted in Australia and elsewhere often reveals bulk sea transport as low impact, and most of Australia's population and built environment is located close to sea ports, so we need to be careful about our assessment of which products are more sustainable.

If a technology or process is worthy of an innovation point, but only if they are the FIRST use of that technology or process (either in Australia for one point or the World for two points), what incentives does a client or designer have to use that technology or process when it is the SECOND or subsequent use? How do you avoid this point scoring encouraging one off unique systems that do not become popular and thus end up with a lot of buildings that are difficult to manage, with the knock on effects of possible

Steel Product Type	Size Range	Recycled Content > 50%	Post Consumer Recycled Content	Total Tonnage Used on Project	Recycled Content Tonnage
Angles	Equal 25 x 25 to 75 x 75 Unequal 6 5 x 50 & 75 x 50	Yes	77%	0.16	0.12
	Equal 90 x 90 & 100 x 100 Unequal 100 x 75 & 125 x 75	Yes	97%	0.81	0.79
	Equal 125 x 125 to 200 x 200, Unequal 150 x 90 to 150 x 100	No	5%	2.98	0.15
Channels	75 PFC to 125 PFC	Yes	97%	0.21	0.20
	150 PFC to 380 PFC	No	5%	8.13	0.41
Flats	Width 20mm to 150mm SEF	Yes	87%	0.01	0.009
	Slit Flats	No	7%	13.43	0.94
Hollow Sections	CHS 26.9mm to 457.0mm RHS 50 x 20 to 250 x 150 SHS13 x 13 to 250 x 250, Thickness Range: 1.6mm to 12.7mm	No	6%	39.44	2.37
Universal Beams & Columns	Beams -150 UB to 610 UB Columns - 100 UC to 310 UC	No	5%	13.39	0.67
Reinforcing Bar	All	Yes	89%	50.20	44.68
Reinforcing Mesh	All	Yes	66%	2.31	1.52
Post Tension Cables	12.7mm diameter cable	No	0%	4.57	0
Totals:		Total Steel Tonnage =		135.64 t	51.86 t
		Overall % Scrap Content =			38%

Table 2 Curtin University Engineering Pavilion Points Eligibility



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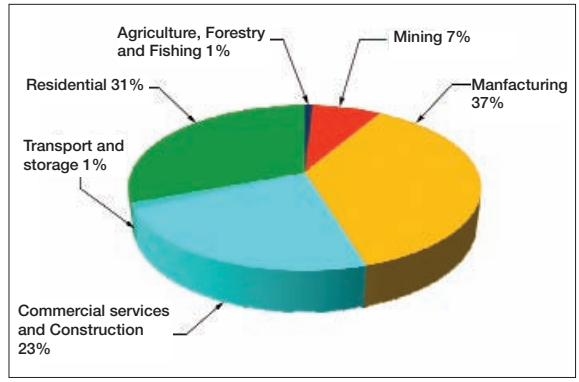

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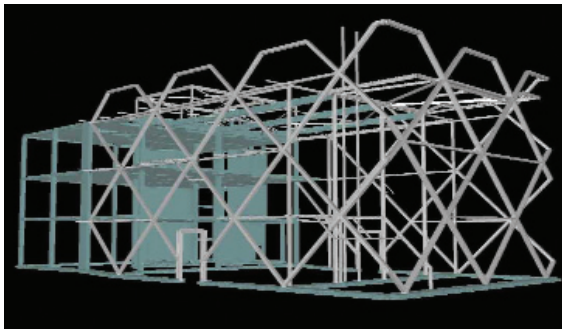
5 Australia's direct greenhouse gas emissions by economic sector 2007

6 Australia's indirect greenhouse gas emissions from generation of purchased electricity 2007



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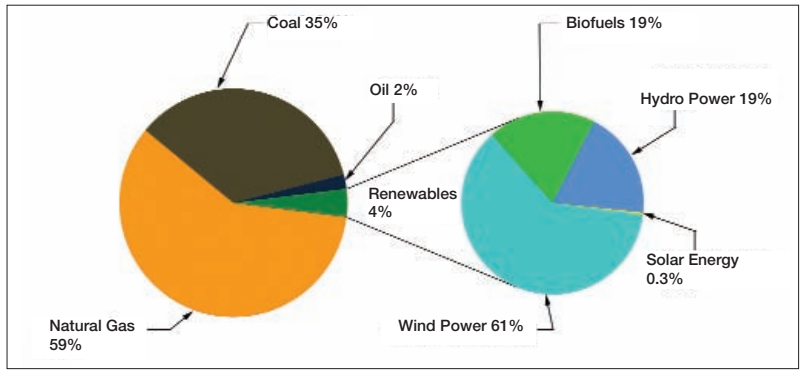

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7 Structural analysis model for steel and concrete frame
8 Shares in Western Australian electricity generation in 2006/2007 by energy source

refitting or refurbishment prematurely as a result? GBCA says it is currently considering changes in the credit to reflect this.

It seems, as schemes get submitted they are also picking up problems with the scoring system. This gradually gets fed back to help the Green Star rating develop, but this process is slow. At the same time designers are effectively lobbying suppliers as they work their way through the list of possible points to be gained and ask the suppliers if they can achieve the criteria. Hopefully the niggling issues that we found will be gone within a year or two and the scheme will be pushing boundaries on other fronts (with the inevitable teething problems that it will face).

Settling on the solutions for the design, a design guide

So after a lot of research and analysis of the structure the basic result followed some simple rules:

- Use the three 'Rs': Reduce, Recycle, Reuse.
- Use timber (provided it is FCS certified, from sustainably managed forestry practices).
- Check to see if more than 60% of the steel you are using has a post consumer scrap content of > 50% or the overall post consumer scrap content of steel used on the project is >30%. If the majority of steel in the building is in the form of reinforcement you are probably in luck.
- Specify concrete with high levels of cement replacement. But be careful to incorporate this in all aspects of your design. Make sure you understand the implications of doing so and design for them.
- Innovate where appropriate.
- Design for adaptability and disassembly and design with dematerialisation in mind.
- Most importantly, make your structure efficient and make it work hard.

With the Engineering Pavilion only 40% of its steel is reinforcement and not many small structural sections were used so we did not have the high percentages of post consumer scrap content in many of the sections used, although the overall scrap content was enough to gain us a point. We did have an efficient use of steel for the three-storey façades. Where we might have used vertical structural mullions the diagrid members braced each other and shared the loads giving us an estimated saving of around 20% on the façade support around the exhibition hall (Fig 7). They also formed the lateral stability on three sides of the building replacing *in situ* concrete shear walls that would otherwise have been needed. Overall we feel that the design was efficient and that makes it more sustainable.

The key to the green credentials in terms of the structure of this building is the appropriate use of the structural materials in places that suit their strengths.

Where to from here? Anywhere else?

Yes, of course, lots of other places (provided they get us Green Star points, that is). Well OK, we know that they won't always, and perhaps that isn't the most important thing on the agenda even though it is definitely firmly on that agenda as it should be. At BG&E what we always aim to do, above all, is make sure that the building fits the client's needs, and often that means being a part of discovering what those needs might be. From refining designs to make them as economic as possible so that clients can spend their money in other areas that add value to a project to creating structures that are flexible enough to cope with changing uses, development and reuse. The emphasis should be on making our buildings last and adapting those that won't.

The Green Star system recognises this approach and is happy to reward you with a few tasty points for reusing land, but like any developing score system, it needs more time before we can truly say that Green Star represents the greenest system for rating buildings. I'd like to see the scoring for steelwork change. It currently doesn't seem to make much sense given what we know about recycling in the industry. I would have thought that the embodied energy of materials must be an important issue to include. Can GGBS cement replacement from Japan be better for the environment than blended cement from Australia? And how about if we were to specify some steel beams that were recycled from 100% post consumer scrap, but they came from the UK (2 points)? Or some timber from sustainably managed forests in Finland (2 points)? OK, this one is not so easy to sort out, but if a design is worth a point for innovating will that innovation catch on if there are no points for anyone who follows suit? There are a few creases to iron out, but in general I felt it was fairly all encompassing and buildings that achieve a 5-star rating have reason to be proud.

Carbon Monitoring for Action estimates that Collie power station emits 2.39Mt of CO_2 each year as a result of burning coal, and the Government of Western Australia, Office of Energy calculates that coal accounts for 35% of electricity generation, Fig 8.

So clearly PFA will be available in quantities for some time to come and with the increasing use of the Green Star rating system and other Ecologically Sustainable Development (ESD) initiatives becoming more attractive to developers looking for additional ways of marketing their properties in a harsh financial environment, we are certainly going to see the industry demanding more sustainable products like this.

We're definitely going on a journey further into a sustainable built environment. Are you coming with us? Green is marketable and green is now for sale, would you like to buy some (it's quite expensive)?

References/Bibliography

- Green Building Council of Australia website: www.gbca.org.au
- Department of Environment and Climate Change, NSW website: www.environment.nsw.gov.au
- Australian Government department of Climate Change website: www.climatechange.gov.au
- Government of Western Australia, Office of Energy website: www.energy.wa.gov.au
- Carbon Monitoring for Action (CARMA): www.carma.org
- Concrete Institute of Australia (CIA)
- Ash Development Association of Australia (ADAA)
- OneSteel product sustainability information sheet available from: www.onesteel.com
- Timber resource and information web sites: www.timber.org.au & www.trada.co.uk

HEADQUARTERS

Meetings are at the Institution's international headquarters, London, unless indicated otherwise.
Evening meetings are free and start at 18.00h unless otherwise stated.
Refreshments from 17.30h. (More information: http://www.istructe.org/courses/meeting.asp)

Institution courses & seminars

For the latest information on courses please see the Institution website.

HISTORY STUDY GROUP

Contact Sarah Okoye at the Institution (email: Sarah.Okoye@istructe.org).

Monday 10 May
Brunel's timber bridges and viaducts
Brian Lewis
17:30 for 18:00

Monday 7 June
How did engineers calculate (their designs) before computers?
Bill Addis
17:30 for 18:00

Branches & sections

Further details on branch meetings see website: (http://www.istructe.org/region/uk.asp?bhcp=1).

Branches that have not informed us of upcoming events are not included.

Beds & Adjoining Counties

Tuesday 18 May
Daventry iCon
Nigel Greenhalgh
(Joint meeting with ICE East Midlands)
Sunley Management Centre, University of Northampton, Northampton
18:00 for 18:30

Secretary: Nick Ball
(tel: 01908 669 898; email: balln@rpsgroup.com).

Cangen Cymru/Wales

Tuesday 11 May
Cardiff City Football Stadium
Chairman's Lounge, Cardiff City Football Stadium
17:30 for 18:15
(Due to limited numbers at the venue pre-registration is required – a tour of the facility will follow the talk)

Tuesday 8 June
Cardiff Canoe Slalom Centre
Steve Davies
Cardiff Canoe Slalom Centre, Cardiff Bay
17:30 for 18:15

Secretary: Matthew Evans
(email: matthew.evans@arup.com).

Devon & Cornwall

Thursday 20 May
AGM followed by Award winning wood
Peter Ross
Arundel Arms
Lifton, PL16 0AA
18:00 for 18:30

Secretary: David Bray
(tel: 01395 567 175; email: davidbray@robsonliddle.com).

East Anglian

Monday 10 May
A visit to the new library at Wymondham
Oliver Edwards
18:30
(N.B. places are limited to 30 – visit followed by a buffet at Park Farm Hotel – tickets – from branch secretary)

Friday 11 June
Branch Summer Ball
Park Farm Hotel, Hethesett, Norwich
19:30 for 20:00
(Contact: Jason Stordy tel: 01603 664 499 or Phil Stroud tel: 01473 327 072).

Secretary: Paul Wilson
(tel: 01603 614 834; email: paul.la.wilson@ntlworld.com).

East Midlands

Tuesday 8 June
Seismic engineering
Speaker – tbc
Yew Tree Lodge, Kegworth
18:00 for 18:30

Secretary: Mike Baker
(tel: 0870 600 6090; email: mike.baker@hspconsulting.com).

Lancashire & Cheshire Branch

Tuesday 11 May
Building Information Modelling
Dan Clipsom
Clifford Whitworth Conference Suite, University of Salford
17:45 for 18:30

Secretary: Catherine Darby-Roberts
(tel: 0161 228 2331; email: secretary@istructe.com).

Midland Counties

Tuesday 11 May
Birmingham New Street Gateway project
Martin Chambers
Birmingham Medical Institute
18:00 for 18:30

Secretary: Andrew Worship
(email: andy@ghwconsulting.co.uk).

North Thames Branch

Monday 24 May
Development of nuclear energy
(Joint Technical Meeting with Hong Kong Institution of Engineers UK Chapter)
Richard Coackley
Institution of Structural Engineers HQ
18:00 for 18:30

Secretary: Peter Tyler
(tel: 07770 667 136; email: cwt@cwtpartnership.co.uk).

Scottish Branch

Thursday 20 May
Structural glass – CPD Stirling Seminar
Chris Jofeh
14:30 for 14:55
Stirling Management Centre, Stirling University

Friday 28 – Sunday 30 May
Summer Weekend
St Andrews Golf Hotel
(contact Alex Tait for details; email: alexntait@aol.com)

Secretary: Ian Barton
(tel: 07801 386 530; email: ian.barton100@btinternet.com).

South Eastern Counties

Thursday 20 May
Seminar – Site investigation and foundation design to EC7
Croydon Park Hotel, 7 Altyre Road, Croydon
(Near East Croydon Station)
13:00 for 14:00, close 17:00

Tuesday 1 June
Belvedere energy from waste project
Mike Waller
Fairfield Room, Fairfield Halls, Croydon, Surrey
18:00 for 18:30

Secretary: Dan Farquhar
(tel: 0208 774 2690; email: dan.farquhar@mottmac.com).

Southern Branch

Monday 17 May
Designing a low impact stadium for the Olympic event
Fergus McCormick
University of Southampton
18:00 for 18:30

Secretary: Will Duckett
(tel: 02380 817 620; email: will.duckett@gifford.uk.com).

Surrey Branch

Monday 10 May
Sheet piling
Tim Dawson
Lecture Theatre M, Surrey University, Guildford
18:00 for 18:30

Secretary: Miles Trenly
(tel: 01276 473 855; email: tren@milesia.co.uk).

Thames Valley

Thursday 27 May
EC2 exposed
Robin Atkinson
Court Gardens, Pound Lane, Marlow

Secretary: Parmindar Mann
(tel: 020 8564 6567; email: parmindar.mann@taylorwoodrow.com

Western Counties Branch

Thursday 20 May
The UoB Nanotechnology Building – The quietest building in the world
Iain Martin, John Wormold & David Williams
Time and venue – tbc

Friday 4 June
Branch Annual Dinner
Goldney Hall, Clifton, Bristol
Time - tba

Secretary: Steve Holmes
(tel: 01275 371 333; email: SteveHolmes@craddypitchers.co.uk).

Yorkshire Branch

Wednesday 19 May
Performance venue design
Philip Heselton
School of Civil Engineering, University of Leeds
18:00 for 18:30

Secretary: Steve Garrity
(tel: 0113 343 5388;
email: s.w.garrity@leeds.ac.uk).

Please send all your diary information to Ian Farmer at *The Structural Engineer,* Institution hq Tel: 020 7201 9121: Email: ian.farmer@istructe.org.

Products and Services

Added bonus for flagship sustainability centre

Lincolnshire's flagship new Epic Centre for sustainable building has received an unexpected cost-saving solution using earth retaining technology from Tensar International.

The originally planned conventionally-sloping green embankment abutting directly against the new building at the Lincolnshire Showground, meant it needed to be able to withstand a considerable imposed lateral earth pressure. However, by using an alternative Tensar design with Tensartech TR2 earth retaining technology to relieve lateral thrust, a 'value engineered' self-supporting earth structure was achieved.

The design saved the costs, materials and construction time associated with the original structural steel frame and reinforced concrete infill panels. The revamped proposals also made use of site-won aggregates to substantially reduce the quantity of imported materials.

The Epic Centre's first floor overlooks the showground arena, with a 115m long, 3.65m high viewing terrace over a grassed embankment, which also carries access steps and ramps down to the arena floor.

The Tensartech TR2 solution comprised earth fill reinforced with layers of Tensar's uniaxial geogrid, securely connected to specially-designed steel mesh units to form the vertical face adjacent to the building. This enabled the embankment to stand off from the basement wall by 150mm, thus relieving all earth pressures from the building. An attractive vertical face was achieved for the access ramp using split faced, dry laid concrete blocks as part of the Tensartech TW3 geogrid system.

The creation of a 150mm void between embankment and building faces enabled a cost effective ventilation system to be used for radon ground gas.

Further information: Tensar International, Cunningham Court, Shadsworth Business Park, Shadsworth, Blackburn BB1 2QX (web: www.tensar.co.uk).

LABC approval for joist connector

Simpson Strong Tie's latest steel connector, the JES (Joist End Support), has been approved for use by the LABC (local authority building control). The two piece metal-work system allows modification of I-joists to fit into the eaves of the roof, enables the use of engineered timber I-joists in loft conversions. A video demonstration is available from www.i-loft.co.uk.

Further information: Simpson Strong-Tie (web: www.strongtie.co.uk).

Product items on these pages are selected and edited in good faith from press releases supplied by the companies, and the Journal accepts no responsibility for the product information supplied.

Low temp epoxy coatings for ventilation shafts

One of North America's biggest hydroelectric tunnelling schemes, being undertaken by Ontario Power Generation, required five vertical fresh air shafts to be bored to the tunnel 459ft below ground. The vertical access shafts, 36in. in diameter, which will also be used for equipment and water pump access for emergency water evacuation, were bored down to the tunnel below and the vertical steel pipes were lowered down using cranes. The pipes were protected on their exterior surfaces by Protal 7250 and Protal 7125 epoxy-based liquid coatings from Winn & Coales International subsidiary, Denso North America Inc. Before being lowered into the shaft, each section of pipe, which had been precoated with Protal 7250 at the factory, was in its girth weld area, painted with Protal 7125, which is specially formulated for low temperatures, down to –20°C.

Further information: Winn & Coales Denso Ltd, Chapel Road, London SE27 0TR (tel: 020 8670 7511; fax: 0202 8761 2456; email: mail@denso.net; web: www.denso.net).

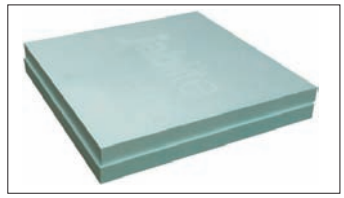
New website has NBSplus specs for raised floors

Eurodek® Raised Access Floor Solutions has launched a new service on its website for National Building Specification documents. Logging into the Eurodek® website at www.accessfloors.net will enable users to create specification documents using the company's products.

The company manufactures a range of products, tested and certified to meet stringent PSA and BSEN standards, which are available either with a bonded floor covering or supplied bare to accept loose lay finishes. Both standard and specialist systems are offered to satisfy all types of projects, from offices and data centres to clean rooms and airports. The range of accessories includes pedestals, adhesives, tools, outlet boxes and a fire, smoke and acoustic barrier for use in the floor void.

Further information: Ria Goddard, CPD Distribution plc, Hillsborough Works, Langsett Road, Hillsborough, Sheffield, S6 2LW (tel: 0114 231 8030; fax: 0114 231 8031; email: marketing@eurodek.co.uk).

New inverted flat roof EPS insulation



Jablite's latest innovation, Flat Roof Inverted, has been specifically designed to give a greener choice for standard and green inverted roofs. Inverted, or protected membrane, roofs place specific demands on the insulation's water absorption, water vapour transfer and compressive strength. The new A+ rated Expanded Polystyrene (EPS) flat moulded insulation board can be used for inverted green roofs because the boards protect the waterproof membrane, whilst the planting provides necessary ballast. The boards also protect the waterproof membrane on all standard gravelled and paved inverted roofs from wide temperature variations, degradation by weather and mechanical damage during construction, use and maintenance. The panels are 1.2 × 1.2m (1.44m²) in size, for ease of handling from a single person on site, whilst thicknesses up to 230mm mean a single layer system is suitable for most applications. The boards also have a 15mm lipped top to prevent uplift during installation and to eliminate thermal bridging.

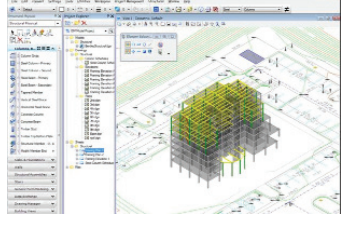
Further information: Jablite (tel: 0870 444 8769; email: marketing@vencel.co.uk; web: www.jablite.co.uk).

ISM heralds integrated project workflows

Bentley Systems, Inc., has launched its Integrated Structural Modelling (ISM) methodology for creators and consumers of structural project information. With ISM – and new no-cost software apps available for download from Bentley – structural engineers can fully participate in multidisciplinary, integrated project workflows.

It means they can also take advantage of innovative Building Information Modelling (BIM) best practices to reap significant business benefits for their projects and organisations. ISM's flexible workflows support design review of various structural assets, such as buildings, bridges, towers, and industrial structures, by aggregating information-rich content, in both proprietary and interoperable formats, from multiple data sources.

The new apps – consisting of Structural Synchronizer V8i and Structural Dashboard V8i – lets structural engineers immediately and quickly employ ISM in their integrated projects. Both can be downloaded free on the Bentley website (www.bentley.com/getISM).



Further information: Bentley Systems Inc., (web:www.bentley.com).

All in one gas and damp membrane

Z-Led Ltd's new Protect GDB10 Gas and Damp Barrier is designed to stop any methane, carbon dioxide and radon from entering the building, and simultaneously provides a damp-proof membrane.

When installed with Z-Led's Cavity & Slab Edge Protection System, the multi-layer reinforced polyethylene/polypropylene membrane with integral continuous aluminium foil provides barrier protection of buildings against both gas and damp. When used as an oversite membrane below floor slabs or suspended floors, it provides a complete solution to compliance with Building Regulations Part C and BRE Report BR 414 2001 'Construction of buildings on gas contaminated land', without any need to install an additional damp proof membrane, helping reduce both labour and material costs.

It has been independently assessed as a gas and damp barrier by BRE certification and it meets the requirements of both the NHBC RSK '*Guidance on Evaluation of Development Proposals on Sites where Methane and Carbon Dioxide are present*' and CIRIA C665 '*Assessing Risks Posed by Hazardous Ground Gases to Buildings*'.

It is easy to cut and weighs 17.5kg/roll. Each roll is 40m long and 2.5m wide.

Further information: Z-Led Ltd (tel: 0161 905 5700).

New sealant tape has curtain walling covered

A new EPDM (ethylene propylene diene monomer) tape system from foam sealants specialists ISO-Chemie provides long term sealing of construction applications including curtain walling and architectural aluminium.

The ISO-CONNECT Inside EPDM is a system with alternative fixing options and provides a high performance internal sealant for metal, glass and façade constructions, which can compensate for joint movements due to its high elasticity. It provides a humidity and airtight control area.

The ISO-CONNECT Outside EPDM is a long lasting, versatile exterior sealant designed for doors and windows which extend to the floor in perimeter areas, as well as the perimeter seals around architectural aluminium/curtain walling systems.

The elastomeric tape features an active, breathable membrane, providing weather protecting properties with good diffusion properties, enabling moisture trapped in the joint to dry outwards. This makes the product very effective for sealing exterior curtain walling and building façades. It is available in width sizes 100, 150, 200, 250, 300, 400 and 500mm and 25m roll lengths.

Further information: ISO Chemie (tel: 01207 566 874; email: p.thompson@iso-chemie.co.uk; web: www.iso-chemie.co.uk).