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BRE Trust Review 2012

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BRE Trust Review 2012

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Foreword

I am pleased to report that the BRE Trust achieved its principal objectives for 2012, particularly given the continuing well publicised difficulties faced by the construction sector where output was down by 1.5%. Despite that, however, 2012 was also a significant year of achievement for the construction sector, with the delivery of the infrastructure for one of the most successful Olympic Games ever. BRE played a part in this project and it is a true celebration of a great British achievement and also a legacy which will support a new and prosperous community in East London for the future.

The Trust's strategy for achieving its stated objectives for the public good are to provide targeted funding for what we believe is a world-class research organisation, working in partnership with other organisations. The Trust provides the support for our collaboration with the BRE University Centres of Excellence and for our education programmes, by providing funding for PhD students. It also funds our publications, which communicate the outcomes from our research and the research of our partners, such as WRAP. and gives them the information needed to implement change in the built environment.

The gift aid achieved for the year end was £2.7M and this enabled impressive delivery by the various BRE Trust-funded programmes. The five University Centres of Excellence continue to grow in strength and reputation, achieving collectively a total of over 130 PhD studentships, 75 staff and research associates and a research portfolio of more than £35M, in the six years since their launch.

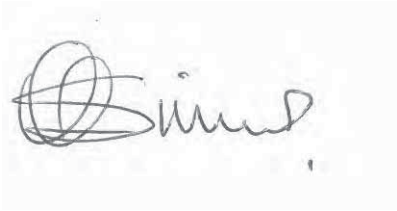
During 2012 26 new research projects were started, bringing the total number of projects in the programme to 47, which leveraged more than 2.5M cash and in-kind contributions from third parties. Twenty-five projects were completed during the year.

The successful launch of the Future cities thematic programme, with an initial investment of £775k by the Trust, is already leveraging £3M of other funding and has attracted over 45 new partners.

Dissemination of outputs, from the research projects, through the launch of over 50 new publications, achieved significant outreach with nearly 20 000 direct sales and over 200 000 downloads of BRE titles to a wide cross-section of the supply chain. Recognising the increasing preference for receiving information electronically, the current development by BRE of a new digital information platform will increasingly support effective and efficient delivery of information and guidance in the coming years.

For a fourth year, BRE Trust has provided financial support for the successful online journal www.building4change.com which continues to develop, with the launch of two new supplements on retrofit and technology.

On behalf of the Trustees I would like to thank all the staff of the BRE Group for their hard work and dedication to the objectives of the Trust and, with them, I look forward to the continued success of our programmes for the future.



Sir Neville Simms FREng
Chairman
BRE Trust

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BRE Trust highlights of 2012

2012 has been another exciting year with a succession of important visitors to BRE in connection with future business development in alignment with BRE Trust objectives.

In February 2012 Edward Davey visited the Innovation Park at BRE's Watford site. This was his first official appointment as the newly appointed Secretary of State for Energy and Climate Change. Joined on his tour by the Deputy Prime Minister, Nick Clegg, Edward Davey said:

'My priorities are very simple: green jobs, green growth and getting the best deal for energy bill payers. My department is already implementing bold and ambitious reforms, including Green Deal, to unlock private investment, drive innovation and build a resilient, green competitive economy.'

BRE Trust has responded to this by supporting critical research and publications which are required to understand, communicate and deliver Green Deal.

The Minister of State for Energy and Climate Change, Greg Barker, visited the Victorian Terrace project at BRE Watford in April 2012. This flagship refurbishment project which has been part-funded by BRE Trust and the Department of Energy and Climate Change together with other partners showcases some of the latest retrofit solutions that BRE and its partners have been working on in advance of the Green Deal.

In May 2012 the Minister of State for Housing, Mark Prisk, visited BRE Watford to launch BRE's new Apprenticeship Scheme. Offering the first laboratory technician apprenticeships in the region, the programme provides participants with practical and theoretical knowledge of working in the environmental testing and fire testing industries.

Minister of State for Energy and Climate Change, Greg Barker, in conversation with Peter Bonfield during a visit to BRE Watford in April 2012

BRE's CEO, Peter Bonfield, takes the Deputy Prime Minister, Nick Clegg, and the Secretary of State for Energy and Climate Change, Edward Davey, on a tour of the the Victorian Terrace project and the Innovation Park at BRE Watford in February 2012

Minister of State for Housing, Mark Prisk (centre), and MP for Watford, Richard Harrington (left), with Peter Bonfield (right) and apprentices at the launch of the BRE Apprenticeship Scheme in May 2012

Brazilian Government delegation led by Brazilian Minister for Cities, Aguinaldo Ribeiro, and Peter Bonfield during a visit to BRE Watford in July 2012

Timeline display marks the 10th anniversary of BRE Trust

A high-profile delegation, led by the Brazilian Minister for Cities, Aguinaldo Ribeiro, visited BRE in July 2012 to explore a range of innovative and sustainable opportunities for Brazil's burgeoning built environment. The delegation which included ministry directors responsible for housing, waste management and urban mobility in Brazil met with BRE specialists in key areas relating to the essential development of the country's infrastructure. The research work over the next three years for the BRE Trust Future Cities programme will involve collaborations with researchers and city leaders from Brazil.

BRE Trust's 10th anniversary

BRE Trust celebrated its first 10 years

Over 150 projects have been funded by BRE Trust in the last 10 years through the managed and thematic programmes. Dissemination of this knowledge has been supported by the release of over 100 new technical publications which can be purchased from BRE's online bookshop (www.brebookshop.com). In 2009, BRE Trust launched a free access, online sustainability journal, building4change.com, which now has more than 45 000 subscribers, and an online archive of over 1000 historic documents.

New collaborations with key research and industry partners have also stimulated an increasing number of follow-on applied research and demonstration programmes funded by the Technology Strategy Board, the EU Commission and other private funding bodies. These have supported the effective development of products and services underpinned by knowledge initially created by BRE Trust investment to instigate transformational change in the sector.

The Trust's other activities include the delivery of a free 'Sustainability in action' course to school children in support of the national curriculum. This is presented at the BRE Innovation Park in Watford and to date more than 5400 students from 235 schools have participated in the programme.

University Centres of Excellence

A collaboration of industry and academia – BRE Trust, BRE and five BRE University Centres of Excellence – to bring rigorous science to solve the challenges facing the built environment

During 2012 BRE Trust continued to provide grants to support the following five BRE University Centres of Excellence:

- University of Edinburgh
  - Centre for Fire and Safety Engineering
- University of Bath
  - Centre for Innovative Construction Materials
- University of Strathclyde
  - Centre for Energy Utilisation
- Cardiff University
  - Centre for Sustainable Design of the Built Environment
  - Centre for Sustainable Engineering.

To date, over 40 PhD students have been funded by BRE Trust, their projects being aligned with key research areas for BRE to underpin BRE's future business objectives. An increasing number of students have been spending time working alongside BRE staff as part of their PhD project, providing access to specialist facilities and exchanging information. Collaborative working has also extended to joint bidding for other funding such as that from the Technology Strategy Board and the EU Commission, extending and aligning capabilities collectively.

The five BRE University Centres of Excellence continue to grow. Table 1 indicates their individual and collective staff and student levels and the total amount of funding won since their inception. The totals are impressive, indicating that for every £1 spent by BRE Trust, the University Centres of Excellence have attracted another £9 from other sources.

Table 1: BRE University Centres of Excellence

Organisation	Start date	Students and Staff	Total funding secured	Research priorities
University of Edinburgh BRE Centre for Fire Safety Engineering *Professor José Torero*	2004	21 PhDs 9 staff 7 research associates	£11M	FireGrid II and tall buildings, Nuclear fire safety and environmental impact
University of Bath BRE Centre for Innovative Construction Materials *Professor Peter Walker*	2007	45 PhDs 15 staff 5 research associates	£11M	Composites, Low-carbon and renewable materials, Concrete and cement, Timber, Retrofit, BPE
University of Strathclyde BRE Centre for Energy Utilisation *Professor John Counsell (until August 2012)* *Professor Joe Clarke (Acting Chair from August 2012)*	2008	15 PhDs 8 staff 6 research associates	£4.5M	Block/Element/Modifier (BEM) systems, Demand-side energy management, Phase-change materials
Cardiff University BRE Centre for Sustainable Design of the Built Environment *Professor Chris Tweed*	2007	12 PhDs 1 staff 1 research associate	£10M	Sustainable refurbishment, Human interface on energy use
Cardiff University BRE Centre for Sustainable Engineering *Professor Yacine Rezgui*	2009	35 PhDs 8 staff 10 research associates	£6M	Resilience, Assistive living, Renewable energy, Low-carbon design
		143 PhDs 41 staff 29 research associates	**£42.5M**	

Box 1: Twelve BRE Research Fellows appointed in 2012

Professor Nigel Brandon
Director, Energy Futures Laboratory, Imperial College London (Ceres Power)

Professor Brian Collins
Former Chief Scientific Advisor for the UK Government Department of Transport and Department of Business Innovation and Skills

Professor John Counsell
BRE Trust Professor in Energy Utilisation, University of Strathclyde

Professor Sir Colin Humphreys
Director of Research, Department of Materials Science and Metallurgy, University of Cambridge

Professor Tim Ibell
Vice President and Head, Department of Civil Engineering, University of Bath

Professor David Ormandy
Head, World Health Organization Collaborating Centre for Housing Standards and Health, University of Warwick

Professor Yacine Rezgui
BRE Trust Professor of Building Systems and Informatics, Cardiff University

Professor Sean Smith
Director, Institute for Sustainable Construction, Edinburgh Napier University

Professor Jose Torero
BRE Trust/RAEng Professor of Fire Safety Engineering, University of Edinburgh

Professor Chris Tweed
BRE Trust Professor of Sustainable Design of the Built Environment, Cardiff University

Professor Peter Walker
BRE Trust Professor of Innovative Construction Materials, University of Bath

Professor Jeremy Watson
Arup and Chief Scientific Advisor to the UK Government Department of Communities and Local Government, Emerging Technologies Policy Panel

First meeting of the newly appointed BRE Research Fellows in July 2012
From left, Dr Deborah Pullen (BRE Group Research Director), Professor Chris Tweed, Professor Peter Walker, Professor Tim Ibell, Professor Nigel Brandon, Professor John Counsell, BRE Chairman Martin Wyatt, BRE's Chief Scientific Advisor Doug King, Professor David Ormandy and BRE's CEO Dr Peter Bonfield

Research Fellows

BRE appointed 12 eminent scientists, including past and present Chief Scientific Advisors to the UK Government, as BRE Fellows (see Box 1 and photo above). The newly appointed Fellows will help to steer the research conducted through BRE's University Centres of Excellence and through the BRE Group of companies to ensure that the research drives innovation and change for the next generation and builds a better world. They will play a vital role in shaping and delivering the Trust's future research strategy.

A key part of their remit is to help identify knowledge gaps in a global built environment which is currently faced with a number of challenging issues, for example:

- climate change mitigation and adaptation
- technology integration
- resource scarcity
- mass urbanisation
- austerity measures
- changing demographics
- an ageing world population.

The first meeting of the BRE Fellows took place on 10 July at BRE's Watford site. A further meeting was held in November 2012 to continue discussions on maximising the impact of research outputs from BRE Trust.

Student Summer Festival

This year's PhD Student Summer Festival, a two-day research conference for the 45 BRE Trust-supported PhD students from the BRE University Centres of Excellence, was hosted at BRE's Watford site on 9 and 10 July. It was attended by over 50 students and staff from BRE, the Centres of Excellence and other universities where BRE or BRE Trust are currently providing support. The programme included team-building and networking activities and technical workshops to identify potential research ideas for collaborative work between the University Centres of Excellence and BRE. Members of the BRE Graduate Training Scheme played an active role in shaping the agenda and facilitated many of the activities over the two days.

A group exercise at the Student Summer Festival in July 2012

BRE Trust Research Conference

The BRE Trust Research Conference took place on the morning of 15 May 2012 at the British Museum, London. The session was chaired by Dr Liz Goodwin and included the following presentations from BRE Trust-funded PhD students and BRE staff:

- Security glazing: Is it all that it's cracked up to be?
  Richard Flint, BRE
- BIM-based design adaptation of climate change resilience,
  Alexandra Cemesova, Sustainable Engineering, Cardiff University
- Monitoring of Code Level 6 Homes at Greenwatt Way, Slough
  Andy Dengel, BRE
- Fires in compartments in buildings
  Agustin Majdalani, Fire Safety Engineering, University of Edinburgh
- Dealing with difficult demolition wastes
  Gilli Hobbs, BRE
- Fabric formwork concrete
  John Orr, Sustainable Materials, University of Bath

The outputs from the event are available on the BRE Trust website: www.bre.co.uk/bretrust

Alexandra Cemesova (left), John Orr (right) give their presentations at the BRE Trust Research Conference, British Museum, 15 May 2012

PhD Award

Apeksha Gupta, a BRE Trust Knowledge Transfer Partnership (KTP) student studying at the BRE Centre for Excellence for Sustainable Design of the Built Environment at Cardiff University won the Duke of Gloucester Young Achievers' Scheme Architecture Award.

The Judges commented:

'Apeksha is an engaging person to meet, is energetic, well organised and well prepared. The judges were impressed with her determination, her modesty, and her imagination – as well as with the rigour and application which she brings to her vision for a more diverse profession focussed on sustainable outcomes.'

BRE Trust KTP PhD student, Apeksha Gupta, wins the Duke of Gloucester Young Achievers' Scheme Architecture Award, pictured with HRH The Duke of Gloucester and two of the judges

BRE Trust thematic programmes

Low impact materials, products and processes

Three-year 'Low impact materials, products and processes' thematic programme was completed in 2012

The BRE Trust 'Low impact materials, products and processes' three-year thematic programme was launched in 2009 to support the construction industry in an accelerated reduction of environmental impacts of construction materials and products by addressing critical knowledge gaps, and to help the industry avoid market failures that might otherwise arise.

BRE's capabilities in this area were already extensive and the primary outcome of the programme was to apply recently acquired knowledge to extend and create new products and services and to expedite the development of the significant new business streams available. Twenty projects were launched, covering the following topics:

- developing innovative methods for creating, manufacturing and using lower environmental impact materials
- using durability and whole life performance approaches to minimise replacement intervals and maintenance requirements
- ensuring that other key performance criteria such as strength and fire performance are not compromised in new or modified materials and products
- assessing new, high performing, advanced products such as aerogels, natural insulation and sensing materials
- developing technologies and integrating control technologies, wireless systems, photovoltaics and other energy-generating systems
- integrating low impact building products into design solutions and construction methods
- developing materials specifically for reuse or recycling to minimise waste in manufacture and construction.

The original £1.5M funding provided by the BRE Trust leveraged over £4M of additional funding, stimulated 15 new PhDs and developed four new products:

- a tool to evaluate sustainable interiors in retail environments (LIFT)
- a tool for deconstruction
- an integrated material profile and costing tool (IMPACT; an embodied environmental impact and costing tool)
- a low CO_2 cement.

Box 2: Publications resulting from the BRE Trust Low impact materials, products and processes programme

Ref. no.	Title
DG 527	Effects of chemical, physical and mechanical processes on concrete
IP 1/11	LIST (Low Impact Shopfitting Tool) for designing greener shopfitting display equipment
IP 11/12	Building-integrated photovoltaic systems: challenges and opportunities for manufacturers and specifiers
IP 20/12	Measuring the wellbeing benefits of interior materials: research programme WISER (Wellbeing: Improving Satisfaction of End users in Refurbishment)
IP 5/13	Durability of alkali-activated binder concretes: Early age performance data

In addition, over 700 products from 50 companies were validated using the new BREEAM 2011. A number of publications have already been produced with others to follow (Box 2).

Future cities

Future cities thematic programme was launched

BRE Trust launched a three-year collaborative research programme on Future Cities which aims to explore the challenges faced by the global built environment as more people migrate to city dwelling. Focus will be placed on the themes of energy, infrastructure and wellbeing, and will deliver the following outputs to BRE and its partners:

- new valued knowledge to support the development and validation of new products and services to deliver integrated cities of the future
- new business opportunities for joint exploitation in the marketplace
- leveraging additional public funding for further research and business support
- creating a wider network in the UK, EU and globally.

What is the city challenge?
Cities can be creative and productive places, generating more wealth and using fewer resources per capita than the average for that country. But as cities grow larger, population and density increase which means they will become more vulnerable to climate change, infrastructure failure and health problems, and will experience higher levels of congestion and crime. The challenge for future cities is to gain all the benefits while reducing and managing the potential problems. It is clear that new, innovative ways to support positive city living need to be found.

What do cities need?
Energy supply and demand
Cities already use approximately 70% of the world's energy and the anticipated future energy demand will continue to grow, requiring significant improvement, optimisation and expansion of the current infrastructure. The programme will extend current knowledge through real city demonstrators to address the following challenges:

- renewable energy sources with main grid integration and optimisation
- energy use reduction, operational efficiency and interoperability.

Infrastructure
As populations grow, greater demand is placed on the city building stock and infrastructures that deliver vital services. As buildings are upgraded to improve their performance, there is a need to evaluate and then monitor resource use and occupier experience to ensure buildings-in-use performance is maintained and then extended on a city scale. The programme will initially focus on:

- optimised estate management, upgrade and resilience
- digital systems integration and cyber security.

Wellbeing
Increases in both population and density of buildings in urban environments are already known to have a negative impact on health in many existing cities around the world. Increased pollution and temperatures via the heat island effect and old, deteriorating building stock can be a lethal combination, especially for the old, the young and the vulnerable. This programme will initially focus on:

- changing financial models to support healthcare for an aging population
- adaptability of building stock to support preventative and assisted healthcare
- impact of thermal comfort and air quality on health and wellbeing.

Within the first 6 months of the programme being launched, the initial £775k approved by BRE Trust in phase 1 had already leveraged a further £2.5M funding and attracted over 40 partners. Phase 2 will be launched in 2013 and further funding and partners are being sought.

International research collaboration

BRE strengthened its collaboration with Shanghai Research Institute of Building Science

A senior level delegation from the Science and Technology Commission of Shanghai Municipality and Shanghai Research Institute of Building Science (SRIBS) visited BRE to renew an existing Memorandum of Understanding (MOU) in view of the city's focus on sustainable growth.

BRE and SRIBS are collaborating on a number of key areas including the development of green building standards for eco-cities, waste management, air quality, construction process

Growth of the city

Renewing of the Memorandum of Understanding between BRE and the Science and Technology Commission of Shanghai Municipality and Shanghai Research Institute of Building Science

efficiency and sustainable refurbishment. Discussions are underway to align research work as part of the Future Cities thematic programme and to use Shanghai as a demonstrator city.

BRE Director, Jaya Skandamoorthy, who leads on BRE's initiatives in China said:

'Our renewed collaboration will facilitate a new era of knowledge exchange on the built environment between the UK and China — we are looking forward to working with and learning from our Chinese colleagues.'

With a population of 23 million and, in 2011 a GDP of $297 billion, Shanghai has become a key international, financial, trade and shipping centre which has created significant sustainability challenges for its built environment.

Professor Shou Ziqi, Chairman of the Science and Technology Commission of Shanghai Municipality, said:

'Ecological and environmental issues are vital topics for the built environment and the people who inhabit it. The collective expertise of both partners will help create a more sustainable built environment for future generations.'

Mr Zhu Lei, Deputy Director of SRIBS, added:

'I hope this Memorandum of Understanding will strengthen the collaboration between BRE and SRIBS so we can accelerate the development of greener buildings and communities in Shanghai.'

Box 3: Subject areas approved for funding from the Responsive mode research programme

- Refurbishment of empty properties
- Building information modelling (BIM)
- Treatment of underheated dwellings,
- Water use in non-domestic buildings
- Life-cycle assessment of refurbishment
- Deconstruction index: Assessing domestic buildings
- Carbon accountability in construction
- Comparison of US and European suppression codes and standards
- BREEAM-rated buildings: actual versus predicted performance
- Defining the common causes of false alarms in fire detection systems
- External fire spread and building separation distances
- BREEAM In-use: a review of the benefits from users
- Mapping the sustainability impacts in fit-out and interiors for retail and commercial properties

Responsive mode research programme

In April 2012 the BRE Trust Research Committee, chaired by Professor John Burland, approved £500k of funding for new research projects in the subject areas listed in Box 3.

Future research focus

A survey carried out in 2012 by BRE's online journal, Building4change, identified what the construction industry considers to be the current knowledge gaps. This included more forward-thinking around off-site fabrication of factory-built, machine-assembled buildings as well as their potential fire risk. Reducing the requirement for site assembly and finishing was paramount with an emphasis on the importance of finding cost-effective solutions for low-volume builds.

The life expectancy of renewable technologies was another area identified, with more information needed on the effects of environmental pollution on solar photovoltaic systems. Finding effective ways of using photovoltaics in smaller households and storing collected solar energy were some of the practical issues marked out for further investigation, together with an aspirational goal of finding a method for harnessing the kinetic energy generated from footfall.

Trialling new, innovative methods of upgrading existing buildings while occupied was a general request from most respondents who suggested that further research should be channelled into developing improved insulation solutions. Finding alternative options for solid wall insulation including small, rubble-filled cavities was listed as a prerequisite to optimising the airtightness of retrofit projects, with a preference for using natural materials to minimise the carbon footprint.

Publications programme

Forty-seven BRE Trust-funded publications were released in 2012, covering a range of topics including energy efficiency, sustainability and refurbishment. Of particular note, were three publications produced in collaboration with the Olympic Delivery Authority on aspects of the design and build on the London 2012 Olympic Park and Olympic and Paralympic Village (shown below). Details of all 47 published titles are given in the final section of this ***Review***.

The programme entered its fourth year with the BRE Trust Publications Committee, chaired by Hugh Ferguson, approving £500k of new funding to support the writing of 45 new titles, details of which are given in the final section of this ***Review***.

All BRE Trust publications are produced by IHS BRE Press and are sold through the BRE bookshop at www.brebookshop.com.

Three BRE Trust-funded publications produced in collaboration with the Olympic Delivery Authority

Building4change update

The Building4change.com online news resource continues to go from strength to strength. The resource, which was launched by BRE Trust in 2009, is a free-access online knowledge hub dedicated to sustainability and innovation in the built environment. During 2012 the website's readership grew to in excess of 55 000 unique users per month and it enhanced its profile through other social media routes including Twitter. The website promoted many industry and BRE activities over the year, including most notably the three publications covering different aspects of venue construction for the London 2012 Olympic and Paralympic Games (shown on page 7).

BRE Archive

For over 90 years, research was undertaken into a wide variety of topics at the Building Research Station, Fire Research Station and Princes Risborough Laboratory, and more recently at the Building Research Establishment now known as BRE. Annual Reports were published providing a concise guide to what was achieved each year. These reports have been scanned for the Archive from the first report in 1926 to the last to be published in the 1980s.

As well as printed material, the Archive contains hardware ranging from pin badges to items manufactured in BRE workshops including models and experimental and electronic equipment. Also in the collection are photographic material, films and videos. Purchase of 'Modes', a museum collections software program, has enabled cataloguing of items.

The value of the Archive has been demonstrated by locating information for current staff projects. A 1920's document on stone used in repairs to Westminster Abbey supported a recent presentation to the Abbey's conservation staff. Photographs from an investigation into defects in the British Embassy buildings in Brasilia in 1991 have been sourced to support an ongoing initiative to refurbish the site.

NHBC Foundation

The NHBC Foundation works in partnership with BRE Trust to facilitate research and development, technology and knowledge-sharing, and the capture of industry best practice with a focus on housebuilding. Work is commissioned that is managed independently from BRE Trust's other programmes, and in 2012 this resulted in 10 new publications which are listed in Box 4. All are available in hard copy and pdf format from the NHBC Foundation website at www.nhbcfoundation.org.

WRAP

This is the fourth year (2012/13) of an agreement between WRAP and BRE Trust to work in partnership and support industry in the area of construction resource efficiency, implementation of sector actions detailed in a number of sector Resource Efficiency Action Plans (REAPs), and other support to the construction sector. As in years 1–3, WRAP has grant-aided funds to BRE Trust to enable research and delivery in relation to resource efficiency aspects of certain construction products and issues.

This research supports the following:

- Flooring–Flooring Sustainability Partnership (FSP)
- Building Foam Insulation Resource Efficiency Partnership
- National Federation of Demolition Contractors (NFDC)

Box 4: NHBC Foundation reports published in 2012

Ref. no.	Title
NF 38	The impact of occupant behaviour and use of controls on domestic energy use
NF 39	Prospects for the UK house building industry
NF 40	Today's attitudes to low and zero carbon homes: views of occupiers, house builders and housing associations
NF 41	Low and zero carbon homes: understanding the performance challenge
NF 42	A survey of low and zero carbon technologies in new housing
NF 43	Energy efficient appliances and controls
NF 44	Understanding overheating: where to start: an introduction for house builders and designers
NF 45	The use of recycled and secondary materials in residential construction
NF 46	Overheating in new homes: a review of the evidence
NF 47	Lessons from Germany's Passivhaus experience

- resource efficiency in shopfitting through NAS (National Association of Shopfitters)
- publication of a guide on refurbishment.

A key focus in the fourth year is to continue to support work in the flooring and building insulation foam Resource Efficiency Action Plans. This will help in the transition towards these sectors becoming fully self-sustaining like the joinery sector. A key objective will be for BRE and the construction sector partners to continue working with the relevant stakeholders to identify how best to deliver the actions and see them through to delivery.

A priority sector is that of shopfitting, where large amounts of resources are used in the building and refurbishment of retail units. The initial focus will be to develop a stakeholder group and work with them to determine the key opportunities and next steps for improved resource efficiency. This will build on BRE's links in the retail sector and the NAS, as well as WRAP's work in this area, such as through the Courtauld Commitment[1].

BRE Innovation Park @Ravenscraig

The BRE Innovation Park @Ravenscraig was opened in September 2012 by Alex Neil MSP, Cabinet Secretary for Infrastructure in the Scottish Government. The Visitor Centre achieved a BREEAM Outstanding at Design Stage assessment. Since opening, it has been well used by a variety of visitors from industry and public sector organisations, and for meetings and events.

The construction of demonstration buildings began with two demonstration houses, Applegreen Homes, and the 'Resource Efficient House', which is supported by Zero Waste Scotland. Construction of two further houses, the 'Refurbished House', to be led by BRE, and the 'Curriculum House', to be led by Motherwell College, will begin in 2013.

The 'Refurbished House' will demonstrate different retrofit solutions within each of four apartments and the 'Curriculum House' will provide a 'hands-on' training experience for Motherwell College students and apprentices.

All of the demonstration houses will provide further research activities to inform the future development of the built environment.

Awards

BRE Chief Executive awarded OBE

An Officer of the Order of the British Empire medal (OBE) was awarded in the Queen's Birthday Honours List 2012 to Dr Peter Bonfield, Chief Executive of the BRE Group. The OBE recognises Peter's services to research and innovation in the construction industry.

Other construction luminaries recognised in the Queen's Birthday Honours List 2012 for their outstanding achievements in construction include architect of the London 2012 Aquatics Centre, Zaha Hadid, and Chief Executive of the National Federation of Builders, Alison Perry.

Dr Bonfield said:

'I am thrilled to receive this honour. It is a super reflection of the work we do here at BRE.'

Over the past 20 years, Dr Bonfield has contributed to the development of BRE as one of the world's leading research-based organisations, supporting the construction sector with a mission to drive positive change. BRE is respected globally for its leadership in building innovation as demonstrated by ground-breaking projects like its Innovation Park which is now being exported internationally.

Alex Neil MSP opens the BRE Innovation Park @Ravenscraig in September 2012: left photo standing outside the Visitor Centre with Rufus Logan, Director, BRE Scotland; right photo presenting Peter Bonfield with a BREEAM Outstanding at Design Stage assessment certificate for the Visitor Centre

BRE's CEO, Dr Peter Bonfield, receives an OBE for services to research and innovation in the construction industry

[1] For information on the Courtauld Commitment visit: http://www.wrap.org.uk/category/initiatives/courtauld-commitment

BRE Trust-supported AIMC4 project won at the 2012 Housebuilder awards

AIMC4 is a £6.4M project with £3.2M investment from the consortium partners matched by £3.2M from the Government-backed Technology Strategy Board (TSB). The consortium comprises five members:

- three developers: Stewart Milne Group, Crest Nicholson Plc and Barratt Developments Plc
- H+H UK Ltd
- BRE Trust.

The AIMC4 Consortium won the award for 'Best low or zero carbon initiative' at the Housebuilder 2012 Awards in London on 14 November 2012.

Following the introduction of the Code for Sustainable Homes in 2007, housebuilders have faced additional costs and greater challenges on sites to meet the Code's requirements. Often this has relied on using technologies that are expensive and complex to install. AIMC4 was set up to show that by using a fabric-first approach, the Code could be met more efficiently.

Speaking after the award presentation, AIMC4 Project Leader, Chris Gaze from BRE, said:

'We are thrilled to win this award. This shows what industry-led research can do when a consortium of this quality comes together. Through AIMC4 we have built homes that cost effectively and robustly obtain Code Level 4 using a fabric-first approach, and could be rolled out in volume nationwide.'

Each developer has now completed homes using lessons learned from the project and these homes are now being occupied. The project will be monitoring their performance and the experience of the occupants. This work will be completed in about June 2014.

BRE Trust and Worshipful Company of Constructors launched a new international research award

Natascha Readon of Turner and Townsend was presented with the inaugural Royal Charter International Research Award for Young Constructors.

Jointly presented by BRE Trust and the Worshipful Company of Constructors (WCC), the monetary award is given to an exceptional young individual from the construction sector to undertake an innovative, topical international study relating to construction.

Guy Hammersley for BRE Trust said:

'The BRE Trust and the WCC created this award with the aim of encouraging emerging talent in the construction sector to come forward. We received some exceptional submissions from which Natascha's was deemed the overall winner by the judging panel because of the quality, ingenuity and impact of her proposed study which aims to transform the way we manage the delivery of sustainable buildings.'

Natascha's study looks at creating a project performance model that gives project managers a way of managing the successful delivery of a range of required outcomes for an energy-efficient building. It will be conducted across Austria, Germany, France and the UK. She will receive £7000 towards the cost of her study which will subsequently be published by BRE Trust's publisher, IHS BRE Press.

A summary of the final report will also be published in *The New Constructor*, the journal of the Worshipful Company of Constructors.

AIMC4 Consortium accepts the Housebuilder 2012 award for 'Best low or zero carbon initiative'

Natascha Readon (3rd from left) receives the inaugural Royal Charter International Research Award for Young Constructors from BRE Trust and the Worshipful Company of Constructors

Sponsorships

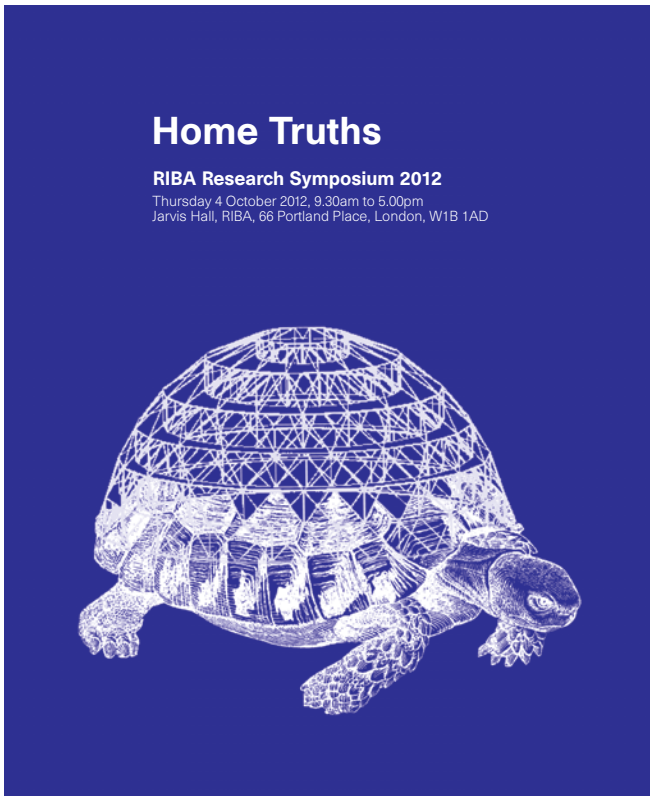
RIBA Research Symposium

BRE Trust was again delighted to sponsor the annual RIBA Research Symposium, which in 2012 was entitled 'Home truths' and was held on 4 October.

With the state of the economy halting the progress of many new-build projects, and the vast majority of our future homes having already been constructed, the refurbishment of existing housing stock presents a great opportunity for architects. With this context in mind, as well as the launch of the UK Government's Green Deal initiative, the RIBA's 7th annual research symposium asked the question: what challenges and problems lie beneath the maxim 'don't move, improve'?

Encompassing issues including conservation, sustainability and design quality, the symposium explored whether old houses can become modern homes. The keynote speech entitled 'The triple challenge of retrofit: Technical, behavioural and financial' was given by Jeremy Watson, Chief Scientific Adviser to the Department for Communities and Local Government. The event included case studies from both architects and academics, as well as the presentation of an exciting student design charrette showcasing how schools of architecture came together to tackle the challenge of retrofit.

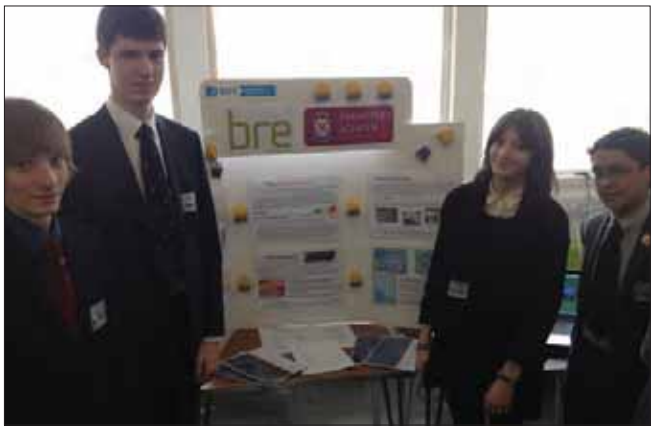
More information on the symposium can be found at www.architecture.com/TheRIBA/AboutUs/InfluencingPolicy/ResearchAndDevelopment/ResearchSymposium/ResearchSymposium2012.aspx



Researchers of the future

For the seventh consecutive year, BRE Trust has provided Parmiter's School in Watford with support and financial assistance to enable a group of sixth-form pupils to participate in the Engineering Education Scheme (England), which is part of the Royal Academy of Engineering's 'Best' programme.

The scheme gives pupils the opportunity to work on a project, guided by a mentor, which allows them to experience science, engineering and technology first-hand. This year's team worked on a project entitled 'Design for interactive software/hardware training tool for fire panel companies' with the fire safety and engineering section of BRE. As in previous years, they again won a gold CREST award in the British Association for the Advancement of Science CREST scheme.



Team from Parmiters School wins the gold CREST award in the British Association for the Advancement of Science CREST scheme with mentoring support from BRE and a grant from BRE Trust

Foreword to the BRE Trust Research Programme

In the introduction to ***Issue 1*** of the magazine for the Foundation for the Built Environment (FBE, now BRE Trust) dated April 2001, the Chairman, Hugh Try, wrote:

'If industries in the built environment sector are to adapt to the needs of tomorrow, they must have new and improved processes, make effective use and re-use of materials and adopt and adapt other developing technologies for built environment applications. FBE intends to help our industries meet these goals through sponsoring research at BRE and elsewhere. When reviewing how best to go about this, the FBE Council concluded that strategic research should form an important component of the Foundation's research programmes.

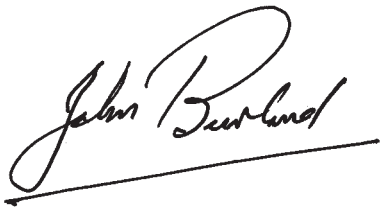
FBE's research programmes aim to deliver results that will assist both the industry and its clients to improve the sustainability and quality of the built environment. Research on enhancing functional and whole life performance, improving processes and underpinning technologies and reducing waste will help produce cost benefits for clients, the industry and wider benefits for society generally. We will work with other centres of excellence where possible, particularly universities, and avoid duplicating the work of other funders.'

Twelve years after Hugh Try set down this plan we can look back and appreciate the importance and value of his strategic vision which has resulted in many of the tools that underpin the drive to improve sustainability and reduce waste, such as BREEAM, the Code for Sustainable Homes and SmartWaste, and the tools such as SAP and SBEM which are used to help reduce carbon dioxide emissions under the national building regulations. One of the first BRE Trust Reports to be produced 12 years ago was ***Potential implications of climate change in the built environment***.

In the intervening 12 years, new challenges for the building industry have emerged but the strategy remains the same. BRE Trust continues to look forward. Now the built environment is faced with new challenges as our populations become older, more than 50% of people live in cities and resources are becoming scarcer. At the same time, advances in IT redefine the nature of communities and the way that services such as health care can be delivered in the home. Embedded sensors can monitor our buildings and control energy demand and supply without our intervention. Innovative materials, novel processes and construction techniques are being adopted without perhaps realising the full implications on the future durability and adaptability of buildings and the wellbeing and safety of the people who use them. Rigorous evidence-based research is essential to improve the quality of the built environment.

I am delighted to say that at the time of writing this Foreword a total of 64 research projects are being funded by the Trust. This includes the 13 integrated research projects which are included in the Future Cities programme but does not include the Research studentships being supported by the Trust at the BRE University Centres of Excellence and elsewhere.

The following pages contain summaries from a selection of recently completed research projects supported by BRE Trust. You will see that BRE Trust, together with their industry and government partners, supports a broad range of research into the built environment using the combined resources and skills that are available at BRE and the BRE University Centres of Excellence.



John Burland CBE, FREng, FRS
Chairman
BRE Trust Research Committee

PS If you would like to suggest ideas for research or would like to know more about the research programmes run by BRE Trust please look at the BRE Trust website at www.bretrust.org.uk

Materials

High-value, low CO_2 alkali-activated concrete products

Andrew Dunster

Building Technology Group, BRE

This project was one of a group of inter-related BRE projects assessing the potential for using alkali-activated materials as binders in the manufacture of concrete products. The project demonstrated that concretes made using alkali-activated binders can have excellent performance relative to that of Portland cement concrete.

Background

Alkali-activated ash, clay and slag binders present significant opportunities for reducing CO_2 emissions associated with cement and concrete manufacture in the UK. Portland cement manufacture in an efficient plant emits about 0.83 tonnes of CO_2 per tonne of CO_2 produced. Consequently, a number of alternatives to Portland cement (PC) are being developed. The current project has focussed on one of these alternatives, alkali-activated binders, in which industrial by-products such as slags and ashes are mixed with a high pH chemical activator.

If these materials are to be used on a large scale, work is needed to optimise the mix formulations for different sources of raw materials and product applications and to demonstrate robustness, durability and performance in a range of exposure environments. The objective of this BRE Trust funded project was to generate performance data for concretes made using a range of alkali-activated binders.

Figure 1: An industrial trial being conducted with an alkali-activated binder concrete pump concrete mix

Research programme

Binder sources considered likely to be available on a consistent basis in the UK (both in terms of quantity and composition), were selected for the study. Durability and performance tests (to 2 years of age) were set in place, with the possibility of longer term monitoring of concrete specimens under future projects. The main tests conducted were as follows.

- Early age tests (such as setting times, heat of hydration)
- Compressive strength development under sealed conditions in water at 20 °C and in air
- Durability tests
- Chemical attack: storage of cubes specimens in sulfate solutions and acid waters
- Protection of reinforcement: carbonation in air, accelerated carbonation, chlorides, corrosion rates
- Dimensional stability, freeze/thaw

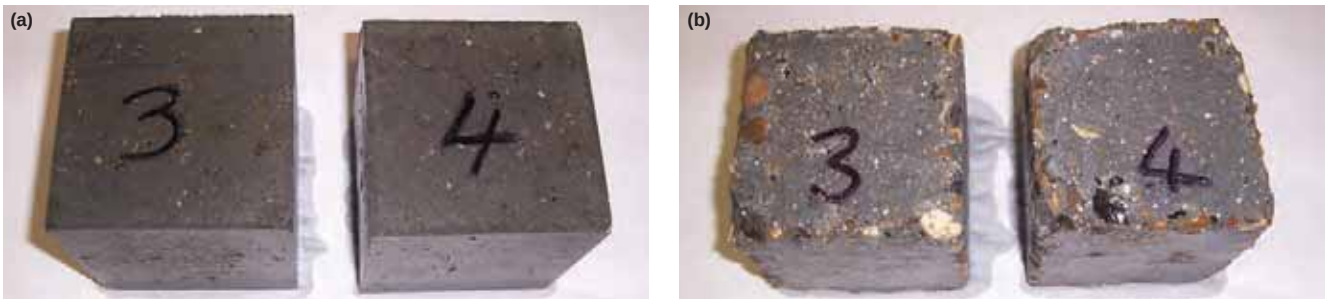


Figure 2: Appearance of concretes exposed to Class 4a sulfate solutions for 24 months: (a) alkali-activated binder concrete, (b) Portland cement control

The project also identified the critical next steps for codes and standards development for the binders and conducted indicative life-cycle assessments (LCA) and estimates of embodied CO_2 on prototype products.

Successful manufacture of concrete components and ready-mixed concrete using alkali ash binders (including concrete block pavers, architectural masonry and pump mix concrete; Figure 1) has been completed by industrial partners under a parallel project. An assessment of their fitness for purpose in short-term performance tests has also been carried out.

Project outcomes/Conclusions

The project has demonstrated that concretes made using alkali-activated binders have good performance relative to that of PC concrete (Figure 2). Other work has shown that these concretes have good durability performance in the context of a wider range of common deterioration mechanisms (eg Figure 3). The results of the work have been published in conference proceedings[1].

Figure 3: Reinforced concrete test specimens for ponding with chloride solution and monitoring for reinforcement corrosion

Work on the environmental impact of alkali-activated concretes has shown that reductions in embodied CO_2 of over 50% relative to conventional PC concrete can be achieved[2]. The results from the project have been included in a BRE Information Paper and Digest directed at the construction industry and their clients.

Publications/Research output

Dunster A, Quillin K and Abora K. Alkali-activated binder concretes in construction. BRE Information Paper IP 4/11.

Dunster A. Durability of alkali-activated binder concretes. BRE Information Paper IP 5/13.

Dunster A. Performance characteristics and environmental benefits of alkali-activated binders. BRE Digest (in preparation).

References

1. Abora K, Paine K, Quillin K and Dunster A. Properties and performance of alkali-activated fly ash/hydrated lime concrete. Paper presented at 8th International Conference on Concrete in the Low Carbon Era, Dundee, 9–11 July 2012.
2. Dunster A, Abora K and Quillin K. Alkaline ash binders: Reduced environmental impacts for precast concrete products. BRE Information Paper IP 9/10.

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Novel advanced cellulose composites from landfill waste

Ed Suttie

Building Technology Group, BRE

The purpose of this project was to build on successful work on a black bin bag source of cellulose fibre (sterile waste-derived fibre [SWDF]) and address two critical gaps in technical knowledge concerning refinement and development of higher value composite material for construction:

- **processes for classification and clean-up of fibre product**
- **production of a minimal clean-up fibre product.**

After 9 months, the main aims of the project have been achieved and a strong position for future activity has been established by:

- **identifying technologies that could be used to clean up the fibre**
- **producing sample boards and testing them for use in chosen markets (hardboard, sponge insulation, temporary flooring)**
- **utilising key strategic industry partners.**

Background

In 2005, BRE Trust funded a project to make construction boards (similar to medium-density fibreboard) from cellulose fibre derived from autoclaved black bag waste (waste that would normally go to landfill). This led to two patents and follow-on work funded by the Technology Strategy Board which not only focused on boards but also on the use of this cellulose for insulation and as an additive for cement products and packaging.

The challenge of this project was to address two critical gaps in technical knowledge concerning the refinement of a recovered cellulose fibre stream (sterile waste-derived fibre [SWDF], Figure 1) and development of higher value composite construction products. The two gaps were:

- to improve classification of the autoclaved output and thereby improve the quality of fibre for use as a substitute raw material for existing construction product processes (ie as an alternative to wood fibre)
- to investigate whether a viable construction product can be made with minimal classification of autoclaved output.

Figure 1: Sterile waste-derived fibre (SWDF; left) compared with virgin wood fibre (right)

Research programme

The research programme was divided into four stages.

- *Market requirements and existing platform of low-performance product*
  The market requirements were established in the context of international expertise and experience. This led to development of a strategic plan which included key stakeholder input.
- *Fibre classification*
  Classification systems were reviewed, including selective surface modification of constituent parts, modified water absorbency, material stabilisation, tagging materials, modification to the autoclave process.

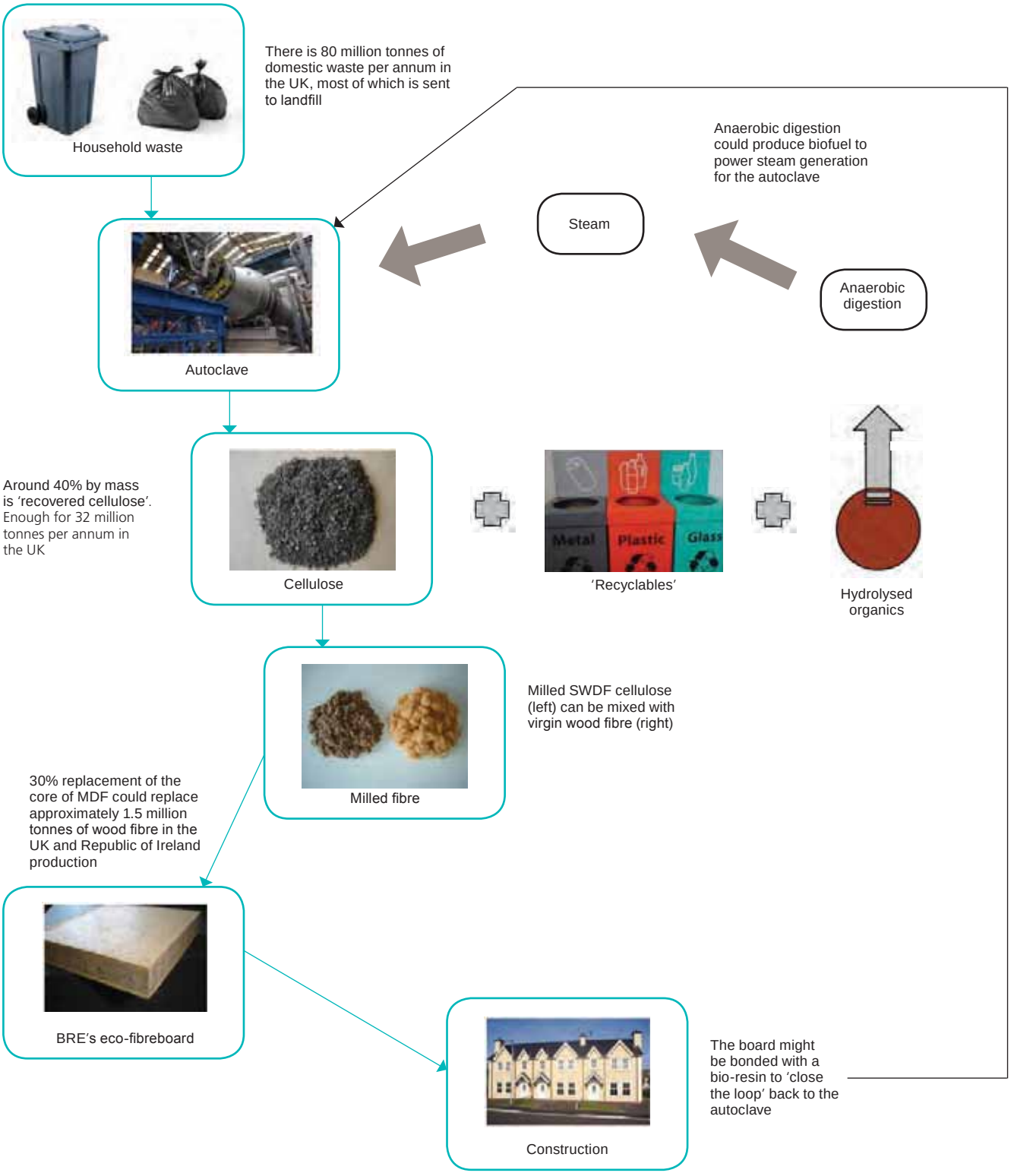

Figure 2: Schematic diagram showing production of the BRE eco-fibreboard from cellulose recovered from household waste. The applications are as diverse as for existing fibreboards, including construction

- *Fibre modification and stabilisation*
  Fibre modification technologies were reviewed. Trial products that had potential as viable construction products were produced with minimal classification of autoclaved output.

- *Production of prototype boards*
  Drawing together the evidence from the previous stages, demonstration boards were produced for specific applications. Boards were manufactured at BRE's pilot plant for panel products and included:
  - hardboard-type products (Figure 2)
  - insulation materials
  - temporary flooring products.

Project outcomes/Conclusions

There are multiple existing sorting and classification processes and technologies that can be employed to address the issue of SWDF clean-up; many are used in the paper industry. In addition, chemical modification technologies offer great promise, including acetylation, with which BRE has considerable experience, eg for wood and flax fibres.

A multitude of end-use applications and potential product interfaces are emerging as industry partnerships are explored.

Further classification technologies captured in this study will be considered to unlock the use of SWDF in mainstream medium-density fibreboard manufacture.

Three product prototypes have been manufactured:

- a hardboard-type product manufactured using SWDF (Figure 2)
- a prototype insulation type product
- a temporary flooring product based on the hardboard-type product.

Throughout this project, relationships with manufacturers have been developed to secure wider development funds for the prototypes. In addition, connections and spin-off research and licensing and equity opportunities are being investigated, including links with the paper industry, overseas board manufacturers and UK universities.

Publications/Research output

Suttie E. Recovered cellulose as a raw material for composites in construction. BRE Information Paper (in preparation).

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BRE Centre of Excellence for Innovative Construction Materials, University of Bath

Peter Walker

BRE Trust Professor of Innovative Construction Materials

In 2012 BRE Centre for Innovative Construction Materials (BRE CICM) built on the successes of previous years to continue with a wide range of internationally leading research work in advanced composites in construction, concrete structures, low-carbon building materials, timber engineering and materials, and structural masonry.

BRE CICM continued its lead of the Engineering and Physical Sciences Research Council (EPSRC)-funded network on low-impact materials and engineering solutions (LimesNet) established in 2011. LimesNet funded 14 international missions to support collaborative engagement with leading research groups and centres from around the world. In April and May 2012 LimesNet hosted four themed research workshops with over 160 national and international delegates from both academia and industry. Following on from this, LimesNet held an international conference in July 2012 inviting the participation of speakers such as Professor Julian Alwood and Craig White, and presenting the network findings including the international mission reports by team leaders. LimesNet stimulated a number of large research proposals led by and involving BRE CICM staff, for example Drs Kevin Paine and Mark Evernden led the Bath participation in two successful associated bids for EPSRC-funded Ground & Structural Engineering Challenge projects.

BRE CICM researchers and the International Society of Fabric Formwork (ISOFF) hosted the 2nd International Conference on Flexible Formwork (icff2012) at the University of Bath in June 2012. Conference themes included:

- architectural applications of flexible formwork
- design of membrane formwork systems
- reinforcement for flexibly formed structures
- concrete durability enhancements using flexible formwork
- computational analysis of flexible formwork
- optimisation of formwork and design systems and sustainable design using flexible formwork systems.

The conference included keynote presentations by Professor Mark West (University of Manitoba) and Professor Remo Pedreschi (University of Edinburgh), technical sessions and a flexible formwork workshop (Figure 1).

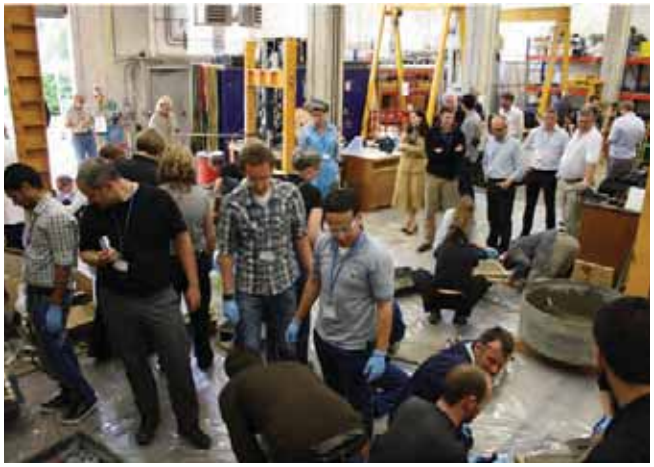

Figure 1: Workshop at the 2nd International Conference on Flexible Formwork at the University of Bath in June 2012

In November 2012 BRE CICM researchers Glavije Amirjamshidi and Victoria Stephenson organised a knowledge transfer workshop entitled 'Earth conservation approaches in practice', a one-day event at the Holburne Museum in Bath. The workshop theme explored the conservation and construction of earthen architecture, focusing on the application of conservation philosophies and holistic approaches to the preservation of earthen heritage sites. Workshop attendees included representatives from industrial and research backgrounds in a variety of disciplines around the UK and overseas. The programme included keynote presentations from Dr Louise Cooke, Dr Paul Jaquin and Professor Jean-Claude Morel. In addition, there were project and poster presentations, discussions and practical demonstrations of earth building techniques.

Formerly research officer at BRE CICM, Dr Mike Lawrence in April 2012 became a full-time Lecturer in Low Carbon Design specialising in natural building materials and in the optimisation of the fabric of buildings to minimise in-use energy consumption. Completed projects include:

- Technology Strategy Board-funded work on prefabricated straw bale panels for use in mainstream construction
- the successful development of non-cementitious mortars for use with unfired clay bricks which facilitated the use of low-carbon footprint unfired clay bricks as internal walls in mainstream construction
- a Defra-funded project with the objective of developing hemp–lime low-carbon construction for mainstream uptake.

Dr Kevin Briggs joined BRE CICM as a Lecturer in Geotechnical Engineering in October 2012. His research interests include the influence of climate and vegetation on geotechnical infrastructure. Kevin graduated with a First Class BEng degree in Civil Engineering from the University of Bath in 2006. After working as a consulting engineer he undertook an Engineering Doctorate (EngD) at the University of Southampton, sponsored by Mott MacDonald. His previous research involved the instrumentation, monitoring and modelling of railway embankments in the south-east of England. This was used to examine the influence of seasonal weather changes, extreme weather events and the influence of trees on the seasonal deformation and ultimate stability of railway earthworks.

Dr Andrew Thomson joined BRE CICM as a research officer in February 2012 to work on the European Association for Creativity & Innovation (EACI)-funded EuroCell project to research and develop prefabricated straw bale building systems for the European market. Coordinated by the University of Bath, the EuroCell consortium includes White Design Associates, Integral Engineering Design and ModCell from the UK and BB-Architecten from The Netherlands. The project will conduct research and development work on material and system performance to support certification. As part of this project, Andrew has overseen the move of BaleHaus, the prototype low-carbon straw bale panel house, to a new site at the University of Bath.

In March 2012 Dr Juliana Holley joined the University of Bath as a research officer working on the European Commission FP7-funded FIBCEM project. The FIBCEM Consortium consists of 10 project partners from five European countries. The FIBCEM material will consist of a cement-based sandwich composed of a foam cement core and fibre-reinforced cement skins. The foam core will be produced using a nano-scale foaming agent to ensure the formation of an optimum closed-cell foam structure having a micro-scale cell size with a narrow cell size distribution. Both the foam and the skins will be reinforced with nano-clays to improve both the mechanical and transport properties of the material. By using a foam core and replacing part of the cement with materials such as fly ash and silica fume, the CO_2 footprint of the material will be significantly reduced compared with existing fibre-reinforced composites.

New visiting staff appointments in BRE CICM include Visiting Professor Julie Bregulla (BRE), and Visiting Research Fellows Sam Stacey (Skanska UK) and Judith Sykes (Useful Simple Trust).

Two new BRE Trust-sponsored PhD research projects commenced in 2012:

- *Daniel Brandon* is conducting a study to develop theoretical and experimental understanding of non-metallic mechanical connections in structural timber members. The work builds on previous work conducted at BRE CICM and is focusing on fire and creep performance characteristics.

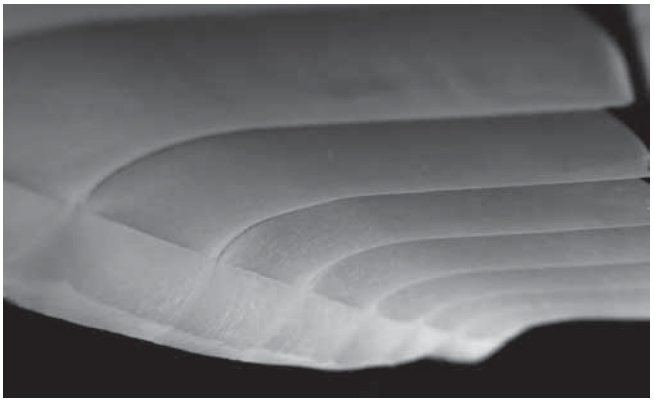

Figure 2: Flexible formwork concrete beam

- *Neal Holcroft* is working with Dr Andy Shea to further develop the use of natural fibre insulation products in building retrofitting applications. Natural fibre insulation materials, such as hemp and flax quilt, sheepswool and hemp–lime, have been gaining market share in the new-build market, offering the combined benefits of a low-carbon content and hygrothermal performance, but to date have had relatively little use in retrofit applications.

Other new PhD students starting this year included Alistair Bradley, Eugene Duffy, Sarah Ellis, Mark Hang Hu, Styliani Papatzani and Abbas Tajaddini.

PhD graduates in 2012 included Jonathan Bawcombe, Chris Gross, Xan Gai, Socrates Ioannou, John Orr and Zhaoxia Zhou.

The journal paper 'Concrete structures using fabric formwork', published in ***The Structural Engineer*** and authored by Dr John Orr, Dr Antony Darby, Professor Tim Ibell and Dr Mark Evernden of BRE CICM, together with Professor Mike Otlet of Atkins Design and Engineering, was awarded a diploma of the Henry Adams Award by the Institution of Structural Engineers. The paper demonstrates how fabric formwork can be used to create architecturally interesting, optimised concrete structures that use up to 40% less material than an equivalent-strength prismatic section, thereby offering the potential for significant embodied energy and carbon savings in new structures (Figure 2).

Visiting Research Fellow, Dr Paul Livesey, received the Institution of Civil Engineers Howard medal for the best paper in the ***Proceedings of the ICE: Construction Materials*** journal for 2011. His paper 'Building limes in the United Kingdom' presents the development of lime as a building material throughout history, from its introduction by the Romans to its modern use in low-carbon buildings. Paul is a world-renowned cement chemist and having previously worked for Castle Cement Ltd he is now in private consultancy. He provides expert advice on a range of research projects on lime, cement and concrete to the BRE CICM.

For further information on any of these projects, contact Professor Peter Walker
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Assessment of calcium sulfoaluminate and supersulfated cements for use in concrete

Socrates Ioannou*, Kevin Paine*, Peter Walker* and Keith Quillin†

BRE Centre for Innovative Construction Materials, University of Bath*

Building Technology Group, BRE†

There is increasing pressure for the cement industry to reduce the energy and embodied carbon dioxide (eCO_2) emissions associated with the manufacture of Portland cement. Among other technologies, the substitution of Portland cement with alternative, low-carbon cements is one of the key routes in established roadmaps for achieving the desired eCO_2 reductions. The research undertaken in this study aimed to explore the potential of using two non-Portland low-carbon cements for structural concrete in the UK: calcium sulfoaluminate cements and supersulfated cements.

Background

The needs of global construction could never be met without concrete. It is the most widely used construction material with approximately three tonnes being used per capita globally annually. However, the manufacture of cement (concrete's key binding ingredient) is an energy-intensive process responsible for the liberation of CO_2 emissions to the atmosphere. This is mainly the result of both the energy consumption required for manufacture and the calcination of the raw materials (decarbonation of limestone). It is estimated that the manufacture of 1 tonne of Portland cement (PC) causes approximately 930 kg of CO_2, rendering PC responsible for approximately 5% of all global manmade CO_2 emissions.

An incentive roadmap for achieving target CO_2 reductions in the cement sector by 2050 was established in 2009 and several approaches were set for achieving the target reductions. Currently, and for the immediate future, these targets can be met by blending PC with other constituents [for example, fly ash and ground-granulated blastfurnace slag (ggbs)] and by reducing cement contents. However, in the longer term an alternative way to reduce the eCO_2 of concrete is through the use of non-PC-based systems. These lower carbon cements (LCC) may be based around a number of technologies, some of the most promising of which include: calcium sulfoaluminate cements (CSAC) and supersulfated cements (SSC).

However, for a LCC to be considered as a practical candidate for commercial-scale use and standardisation within the UK framework of design rules and procedures, several issues need to be addressed as given below.

- In a given region, the availability of raw materials needs to be at least sufficient for achieving large-scale production.
- LCC hydration mechanisms and chemical stability need to be thoroughly understood.
- Fresh, engineering, permeation and long-term durability properties of concretes based on LCC need to be studied and compared with those of PC concretes upon a valid basis of comparison.
- The associated eCO_2 emissions for achieving equivalent performance and for satisfying durability recommendations should be lower than the emissions associated with PC concrete.
- LCC product market prices (or associated costs for achieving equivalent performance) should be at least comparable or lower than that of PC.

Research programme

The research initially involved the development of chemically and dimensionally stable CSAC and SSC combinations selected from a range of formulations with varying constituent contents. Following the selection, the hydration mechanisms of the selected combinations were investigated using tests such as x-ray diffraction analysis, scanning electron microscopy, thermogravimetric analysis, isothermal conduction calorimetry.

It was observed that ettringite was the main hydration product in CSAC, forming within the first 24 hours of hydration, and that it was responsible for the strength and performance of CSAC. In SSC, ettringite and calcium silicate hydrates co-existed in the hydrated cement albeit that hydration occurred at slower rates and ettringite was formed from the third day of hydration onwards.

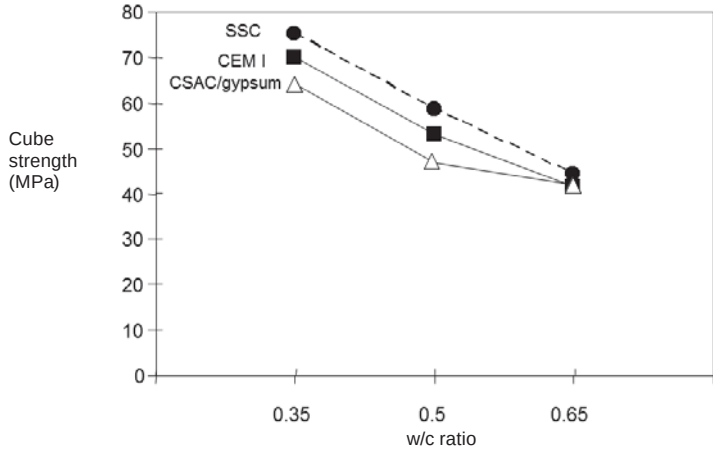

Figure 1: Relationship between w/c ratio and 28-day cube strength of tested concretes

The engineering, permeation and durability properties of concretes at three different water–cement (w/c) ratios based on the selected combinations were then studied. These were compared with those of reference PC concrete. It was observed that CSAC concrete, relative to PC concrete, had:

- higher early cube strengths
- lower permeability
- less moisture dependency
- fewer load-dependent deformations
- better sulfate and chloride resistance.

While concrete from commercially available SSC exhibited higher cube strengths (Figure 1) and generally better durability characteristics than any other concrete, it was noted that a custom-developed SSC concrete exhibited poor performance and that this was associated with the unsuccessful formation of sufficient hydration products and a sparse microstructure. It was concluded that the quality, hydraulic activity and state of constituents were the key parameters that affected the overall performance of SSC.

Of concern, but not unexpected, was that the carbonation resistance of both CSAC and SSC concretes was found to be lower than that of PC concretes at any given w/c ratio. It was found that in addition to the porosity and optimal composition of both combinations, the absence of alkali hydroxides in the pore solution was an additional driving parameter.

Following a critical assessment of the results, a series of enhancements were undertaken to improve the physio-chemical properties of CSAC- and SSC-based cements. The enhancement approaches for CSAC involved the use of pozzolanic additions and fillers and alternative forms of calcium sulfate, while for SSC, casting techniques and the incorporation of alkaline admixtures and synthetic products were adopted.

It was shown that that limestone fines could be used as both a chemically and mechanically active component of the CSAC, and that it benefited the combinations chemically by partially restricting the formation of monosulfate, and carboaluminate phases in minor amounts were observed by theromgravimetric and x-ray diffraction analyses. Furthermore, there was evidence that the use of fly ash could improve certain properties of CSAC.

While on its own, calcium sulfoaluminate clinker was not a good activator of fly ash, it was found that ternary systems comprising calcium sulfoaluminate clinker, calcium sulfate and fly ash gave promising strength, durability and permeability properties, such as low absorption rates (Figure 2). This was because the addition of fly ash, resulted in pozzolanic reactions between fly ash and calcium hydroxide resulting from belite hydration, and because the fly ash aided particle packing and provided a beneficial synergistic effect with ettringite (Figure 3).

The enhancements to SSC concrete showed that the use of fabric formwork substantially decreased chloride diffusion coefficients, carbonation depths and absorption rates. It was shown that the use of fabric formwork gave the beneficial effect of a minimised pore volume and reduced w/c ratio near the surface of the concrete. The incorporation of alkaline admixtures and synthetic products for enhancing hydration mechanisms of the systems were found to have little or no effect on the overall performance of the system. It was concluded that the main factor underpinning the SSC performance was the inherent physio-chemical properties of ggbs, the main constituent.

Based on the experimental results, an environmental impact assessment was conducted and the applicability of CSAC and SSC to current standard practice was assessed through design examples. Optimum balance between associated eCO_2 emissions, cost and equivalent performance of concretes to meet exemplary design requirements was determined.

Project outcomes/Conclusions

It was concluded that concrete made from ternary combinations consisting of CSAC, anhydrite and fly ash had low eCO_2 emissions and costs, and satisfied exemplary durability recommendations and equivalent performance, comprising the most sustainable cement replacement solution. The particular combination appeared to have a considerable potential for use within the standardised design procedures. Although SSC concretes were associated with the lowest eCO_2 emissions for achieving equivalent performance, associated costs were found to be high.

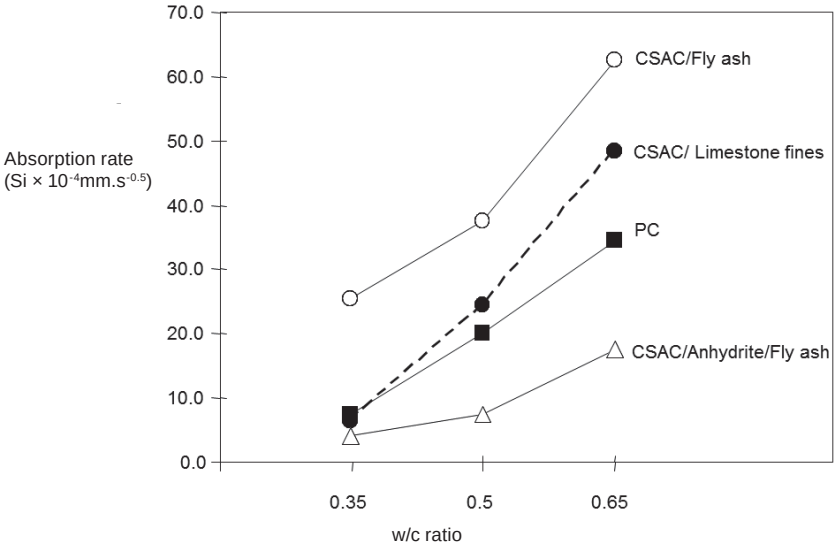

Figure 2: Relationship between w/c ratio and absorption rates of tested concretes

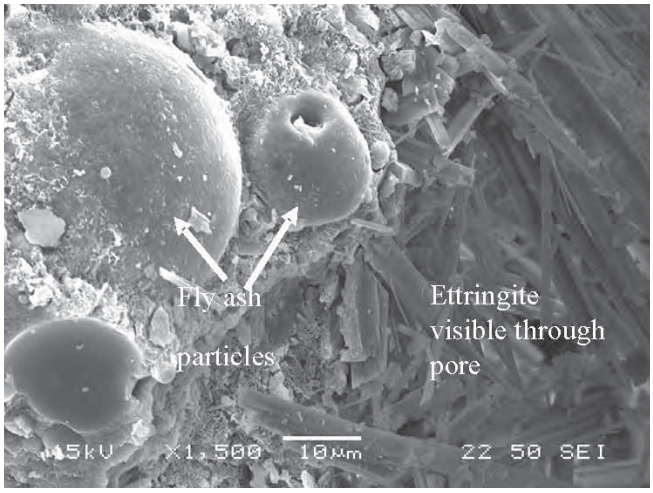

Figure 3: Scanning electron microscope image of CSAC-anhydrite-fly ash cement at 28 days of hydration

Publications/Research output

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Energy

Fourth generation district heating

Robin Wiltshire and Ciro Bevilacqua

Building Futures Group, BRE

The fourth generation district heating concept envisages the reduction of supply temperature to as low as 50 °C on the basis that low temperature operation:

- **improves the efficiency of the network by reducing distribution heat losses**
- **widens the scope for potential usage of renewable and residual heat streams**
- **may reduce the capital cost of the network by enabling the use of plastic pipes.**

This concept has particular relevance to the UK where district heating is one of the choices for high-efficiency new-build developments. Early experiences with fourth generation district heating are promising, although *Legionella* control is one of several issues that requires further research.

Background

District heating (DH) networks have an important role to play in sustainable and smart towns and cities of the future. However, to benefit from synergies with energy-efficient buildings and smart energy grids, district heating technology will need to gradually migrate towards lower temperature operation. In this way, there will be better matching between demand and supply.

The development of district heating has evolved from systems using steam as the energy carrier (1st generation DH) to systems using pressurised water at above 100 °C (2nd generation DH) and finally to systems using pressurised water below 100 °C (3rd generation DH). The vast majority of modern, efficient schemes fall into the latter category, and they already deliver environmental, social and long-term economic benefits. However, along with other energy grids, future heat networks will deliver energy even more efficiently. Hence the further notional development to 4th generation DH (4GDH).

In the 4GDH framework, sources of heat at temperatures of 70 °C and less, and even as low as 50 °C provide heat, specifically to new-build highly energy-efficient buildings through a network with low energy losses. The 4GDH paradigm aims to match the requirement for energy and exergy with the supply and by doing so to increase the overall efficiency of the system. The benefits arising from low temperature operation also include improved diversity and flexibility of energy supply.

Figure 1: Greenwatt Way, Slough, operates as a 4GDH scheme

The deployment of 4GDH entails an increased potential for utilisation of low exergy energy sources (eg low-grade heat from industrial processes that otherwise would need to be upgraded). The potential for the deployment of renewable energy sources such as geothermal and solar heating plants at large scale may also increase. Hence, these networks could significantly contribute to the penetration of both residual and renewable heat sources.

Savings in the capital cost of the distribution network may be achieved if plastic pipes can be deployed. Heat losses, which are

proportional to the temperature differential between pipe and external environment can be significantly reduced.

Research programme

The research has focused on two main areas:

- the heat loss reduction achieved through engineering measures such as temperature reduction and connection via twin and (conceptual) triple pipe to the end-user point
- the way the ***Legionella*** risk has been addressed in the Danish cases.

As 4GDH is in its infancy, only a few early experiences have so far been analysed:

- Lystrup (Denmark)
- Greenwatt Way (UK; Figure 1)
- Drake Landing Community (Canada)
- Kırşehir (Turkey).

The Lystrup case study is an example of an existing 3rd generation network that has an extension operating at very low 4GDH temperatures. The Greenwatt Way scheme in Slough comprises 10 houses that were built to the Code for Sustainable Homes Level 6. Several renewable energy technologies supply low temperature heating to the houses by means of a small heat network. Drake Landing Community and Kırşehir are examples of two 4GDH networks where the low temperature energy source is supplied by solar energy and geothermal energy, respectively. The Turkish case study is unique in that the low temperature energy source is used to supply heat to existing buildings.

Project outcomes/Conclusions

The research has highlighted that, with appropriate technical solutions, DH can remain a technical option even for low energy buildings. From analysis of the case studies, it appears that it is feasible to provide heat at low temperatures in a robust, efficient and economic operation that delivers environmental and economic benefits and does not compromise the level of service to the end user.

The application of 4GDH is, however, at early stages and more experience needs to be reviewed and analysed. The concept of 4GDH requires research and development in many areas.

- ***Heat losses.*** Energy losses in the network need to be minimised to increase the system's efficiency of performance and therefore its profitability.
- ***Heat interface units and heat exchangers***. These need to be optimised for the new low temperature regime.
- ***Domestic hot water arrangement and health.*** Health issues such as ***Legionella*** risk need full investigation.
- ***Controls.*** Intelligent controls are required to deal with balancing the network if synergy with the electrical smart grid and the successful integration of various heat sources is to be achieved.
- ***Relation with the existing building stock***. Research is required to explore how the concept can be successfully applied to the existing building stock, eg to what extent existing heating systems could be operated at lower temperatures.

The vision is that future heat networks could be operated with smart controls to enable the balancing of highly integrated infrastructure comprising multiple points of supply, storage and demand and to allow for integrated operation with the power grids.

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BRE Centre of Excellence in Energy Utilisation, University of Strathclyde

Joe Clarke

Professor, BRE Centre of Excellence in Energy Utilisation

The first phase of operation of the BRE Centre of Excellence at Strathclyde ended on 31 December 2011. BRE Trust granted a one-year extension to provide continuity while a business case for a second phase of operation was developed and agreed during 2012. Professor Joe Clarke assumed the role of Centre Director when Professor John Counsell left in August 2012 to take up a new post closer to his home.

Highlights for the year are as follows.

All PhD project students progressed satisfactorily and three graduated: Gavin Murphy, Matt Stewart and Yousaf Khalid. Collectively, the BRE student cohort produced 3 journal papers, 5 conference papers and a book chapter. Two of the outcomes associated with the graduating students had immediate impact.

- The ***IDEAS*** system (developed by Gavin Murphy) for SAP-equivalenced dwelling simulation was used within a Technology Strategy Board-funded project (involving BRE at Watford, PassivSystems Ltd and University of Strathclyde) as a virtual test bed for the design and testing of a market-ready, smart controller to ensure optimum domestic heat pump operation under varying weather conditions and loads.

- The ***BIEN*** system (developed by Matt Stewart) for delivering power over the Ethernet was filed for Patent. Internet provider arrangements were agreed between BRE Ventures and University of Strathclyde. A prototype system was established and subsequently relocated to BRE's Watford site as a result of the loss of the engineering building at Strathclyde to a serious fire. The intention is to use this prototype to attract investors.

One PhD student, Alastair Scott, who is at the writing-up stage, was appointed as Assistant Financial Director of the Baxi Trust while another, Yousaf Khalid, secured employment with BRE. Joseph Brindley's Viva is imminent while James Johnston and Obadah Zaher will submit their theses in early 2013.

Support was provided to BRE Scotland's Low Carbon Built Environment (LCBE) initiative funded by Scottish Enterprise, most significantly to help attract investors to the BRE Innovation Park at Ravenscraig and assist the Clyde Gateway regeneration company to shape plans for the redevelopment of a large part of the east end of Glasgow, including a new Innovation Park at Shawfield.

Figure 1: A LCBE workshop exploring regeneration options

A performance assessment of the Visitor Centre at the BRE Innovation Park at Ravenscraig was undertaken in support of a BREEAM Outstanding rating.

An Engineering and Physical Sciences Research Council (EPSRC) project, in collaboration with Newcastle University, addressed energy demand reduction through digital innovation and explored the role that pervasive digital networks can play in facilitating novel approaches to energy use reduction. The project developed and deployed real/virtual sensors for environmental conditions and occupant behaviour monitoring, employing the high-frequency data so collected in two modes:

- to provide real time information feedback to building operators and users on disaggregated energy use and best efficiency action
- to populate the user-related portion of the data model required by dynamic building simulation tools as a means to further reduce the gap between predictions and observations.

Figure 2: A low-energy demonstration home under construction at the BRE Innovation Park, Ravenscraig

The sensors were deployed within the Visitor Centre at the BRE Innovation Park at Ravenscraig to demonstrate ultra-low-cost monitoring as a means of delivering ubiquitous energy-related services in future cities. The sensors are being deployed as a base monitoring solution within all demonstration houses at the Innovation Park, with bespoke monitoring solutions appended depending on the specific technology being showcased (eg for heat pump performance demonstration).

A Scottish and Southern Energy (SSE)/Ofgem-funded project explored the use of domestic demand management as a means to enable the prioritised use of renewable energy assets within electricity networks. The project entailed the monitoring and subsequent modelling of 'quantum' electric space and water heaters within a large housing estate comprising approximately 750 dwellings located in Shetland. The results were used to establish optimum charge schedules for heating appliances and provide day-ahead demand forecasts to enable optimum generation dispatching.

A collaborative project with BRE Scotland exploring the feasibility of embedding a simulation calculation engine within the UK Government's Standard Assessment Procedure (SAP) was completed and the outcomes widely reported. The aim was to introduce a dynamic modelling capability to SAP and thereby extend the range of technology types and combinations that can be modelled. The new tool was pre-loaded with models corresponding to the Scottish housing stock to enable investigation of the energy/emissions reduction potential of alternative approaches to refurbishment.

An EPSRC Knowledge Transfer Account award, following on from a successfully concluded Knowledge Transfer Partnership (KTP) project, enabled the Centre to continue its work with Barr Construction Ltd to develop and implement a procedure to ensure Barr's compliance with its obligations under the CRC Energy Efficiency scheme (formerly known as carbon reduction commitment).

The Centre secured a KTP award with Scottish Power Energy Networks to investigate the impact of new building regulations and low-carbon technologies on low-voltage network capacity and sizing procedures. Much of this activity is focused on the BRE Innovation Park at Ravenscraig and is enabling detailed monitoring of the impact of new technologies on low-voltage network capacity requirement.

Three grant applications were prepared and submitted (one in early 2013) as follows.

- ***EC FP7:*** a proposal in collaboration with a European consortium (including BRE) to develop a pervasive, real time monitoring capability designed to implement control action and provide feedback to support user decision-making and building operator action planning.
- ***EPSRC:*** a proposal in collaboration with two BRE Centres (Bath and Cardiff Architecture) to investigate the thermal behaviour of low/zero-carbon dwellings and in particular the interactions between thermal storage (eg phase-change materials), heat delivery systems, controls and occupancy profiles.
- ***BRE Trust:*** a proposal to develop a range of smart services for domestic-scale delivery. Examples of such services include environmental monitoring with alerts, appliance conditions monitoring and aggregate demand management. The intention is to demonstrate these services within the BRE Innovation Park at Ravenscraig.

Agreement was reached to pass control of the International Building Performance Simulation Association (IBPSA) Scotland from the University of Strathclyde to BRE Scotland as a way of ensuring the wider participation of the industry and ensure that the computational approach to design enabled by simulation is evolved through future policy and technology initiatives (related to, for example, the Energy Performance of Buildings Directive and building information modelling [BIM]) as is happening in other countries.

The Centre delivered, in collaboration with BRE Scotland, a range of CPD courses, most notably relating to SAP training, extended courses leading to the EU's Certified European Passive House Designer qualification, and practical skills training in dynamic energy systems modelling. The teaching and learning material relating to these activities was transformed into a distance-learning format to enable international delivery.

Inspired by the BRE-funded development of an interface for domestic controls assessment, a major international controls company commissioned the development of domestic home heating systems modelling, and an interface with an embedded simulation engine to carry out energy savings assessments for advanced controls solutions.

Collaboration was initiated with Glasgow City Council on its Smart Cities programme. This is expected to stimulate significant opportunities in 2013 and beyond, especially with the award to Glasgow of the Technology Strategy Board's Future Cities Demonstrator.

The year ended with the submission of a business case for the next 5-year phase of Centre operation. This case defines a new thematic programme and expanded capability through collaboration with the organisations and academic capability associated with the nascent Technology & Innovation Centre at Strathclyde. The focus of the refreshed BRE Centre of Excellence in Energy Utilisation will be on responsive demand as a means of assisting the accelerated deployment of new and renewable energy solutions at both the local and national scale. The intention is to link the social and behavioural aspects of energy end-use with research into energy efficiency and network innovation by establishing three distinct but interdependent research themes:

- monitoring and energy services
- whole systems modelling and simulation
- integrated investigations of energy utilisation technologies.

For further information on any of the projects discussed above or those that follow, contact Professor Joe Clarke
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Inverse dynamics-based energy assessment and simulation (IDEAS)

Gavin Murphy

BRE Centre of Excellence in Energy Utilisation, University of Strathclyde

A SAP-compliant dynamic modelling and simulation tool named IDEAS (Inverse Dynamics-based Energy Assessment and Simulation) was developed to enable the performance assessment of novel control systems for domestic heating/cooling equipment and appliances. The tool is implemented in a MATLAB/Simulink environment and offers plug-in support for hypothesised control algorithms, with outputs applied to the IDEAS systems models. In use, IDEAS ensures compliance with the UK Government's, empirically based, Standard Assessment Procedure (SAP)[1] so that effective control regimes might be added to equipment to gain compliance approval.

Background

Rising CO_2 emissions from dwellings advocate that properties designed in a sustainable manner will become commonplace in the future. In tandem with enhanced sustainability, dwellings will increasingly be designed with implementation of new and renewable energy generation.

The Standard Assessment Procedure (SAP) is the UK Government's approved method for assessing the energy ratings of dwellings[1]. The underlying calculation method is based on empirical relationships derived from measured data. A yearly calculation was used in SAP prior to the release of SAP 2009, which employs monthly calculations. SAP has therefore moved from a coarse to medium time resolution. To calculate energy consumption, the SAP method makes a range of assumptions including operating on the basis of a standard temperature profile that is perfectly met.

The modelling of novel supply systems in SAP (such as heat pumps and microgenerators) has been highlighted as an area where the method would benefit from further development. Modelling low carbon dwellings and systems will require a more advanced calculation method, which directly addresses system dynamics, can undertake simulations on the basis of a small time step (of the order of minutes) and can provide results that support a detailed analysis of energy performance.

Figure 1: Example of high-rise dwellings in Glasgow which could be assessed by inverse dynamics-based energy assessment and simulation (IDEAS) tool to highlight areas of heat loss and indicate where improvements in thermal insulation could be made
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Dynamic simulation methods (DSMs) already exist that are able to simulate at high temporal frequency. However, in use it is difficult to align results with those produced by SAP because of its empirical basis and the complexities of DSM user interfaces. A dynamic method is therefore required that can operate in SAP emulation mode while allowing the rapid implementation of alternative control algorithms.

Research programme

IDEAS is based on a fundamental approach to the representation of building physics[2] in which the energy and mass balance at several points in the building along with its heating system are explicitly represented. In the approach, a building zone is represented by four temperature nodes (T_{zone}, T_{si}, T_{se} and T_{im}) as follows.

- Zone temperature, T_{zone}, representing the air and furniture which are considered equal since the rate of change of

their respective temperatures in comparison to other zone temperatures is approximately the same.
- Structural temperatures, $\overline{T}_{si}$ and $\overline{T}_{se}$, referred to points located at the centre of mass of internal and external portions of the wall constructions.
- Internal mass temperature, T_{im}, representing the temperature of the non-removable internal mass associated with partition walls, struts and joists.

The relationship between these temperature nodes is depicted in the thermal resistance network given in Figure 2. Differential equations representing the rate of change of the above temperature nodes are derived from first principles and are converted to a state–space representation suitable for controllability analysis within a MATLAB/Simulink environment:

$$\begin{bmatrix} \dot{T}_{zone}(t) \\ \dot{T}_{si}(t) \\ \dot{T}_{se}(t) \\ \dot{T}_{im}(t) \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & 0 & a_{14} \\ a_{21} & a_{22} & a_{23} & 0 \\ 0 & a_{32} & a_{33} & 0 \\ a_{41} & 0 & 0 & a_{44} \end{bmatrix} \begin{bmatrix} \dot{T}_{zone}(t) \\ \dot{T}_{si}(t) \\ \dot{T}_{se}(t) \\ \dot{T}_{im}(t) \end{bmatrix} + \begin{bmatrix} b_{11} \\ 0 \\ 0 \\ 0 \end{bmatrix} \left[\dot{Q}_H(t)\right] + \begin{bmatrix} d_{11} & d_{12} \\ 0 & 0 \\ d_{31} & 0 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} \dot{T}_o(t) \\ \dot{Q}_{free}(t) \end{bmatrix}$$

Building parameters and controller algorithms are defined in a MATLAB script, while the mathematical model and subsequent numerical simulation are conducted within a Simulink model (Figure 3).

The approach supports the rapid prototyping and testing of control strategies when applied to different heating system configurations, without incurring the costs and lengthy timescales of real-life testing. The IDEAS model is therefore suitable for use as a test bed for developing and comparing controller system performance within a SAP-compliant environment.

The Technology Strategy Board has awarded funding for a project on system optimisation and control in homes to BRE, the BRE Centre of Excellence at Strathclyde and PassivSystems to investigate the feasibility of grid demand response for smart heat pump control in a domestic context. IDEAS was selected

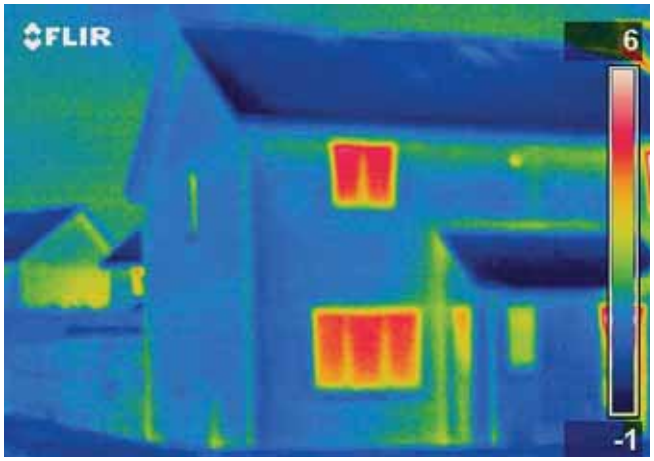

Figure 4: Thermal image showing heat loss in a dwelling constructed in the 1990s; this dwelling could be assessed by IDEAS tool to highlight areas where occupant thermal comfort could be improved
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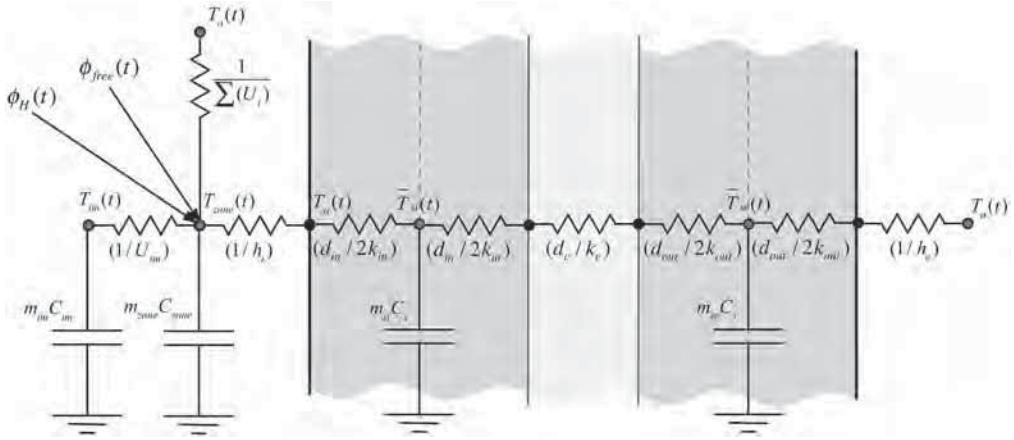

Figure 2: Thermal resistance network showing the relationship between the four temperature nodes: T_{zone}, T_{si}, T_{se} and T_{im}

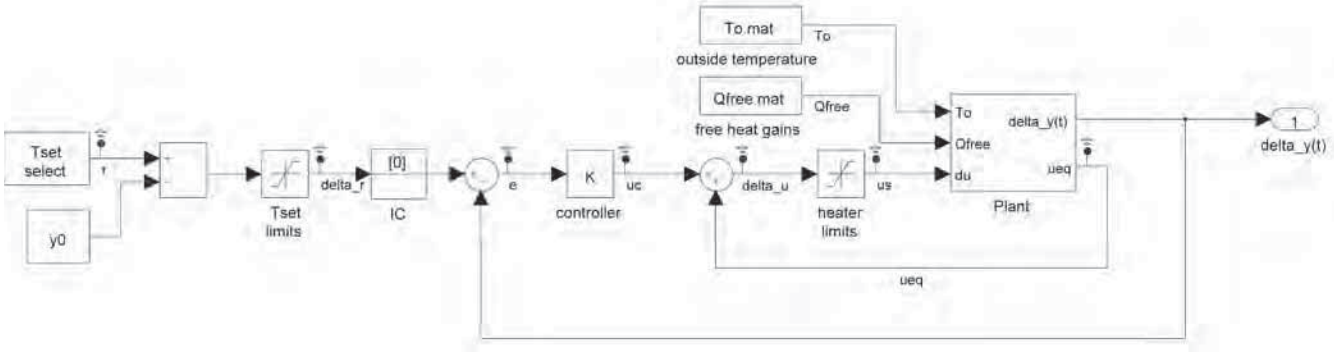

Figure 3: Example of Simulink model processing the mathematical model and numerical simulation

Figure 5: Air source heat pump located in dwelling built to PassivHaus standards. IDEAS tool could be used to highlight where novel control strategies could improve the performance of this heating system © www.flickr.com/murphygb

for use in the project with its dynamic dwelling and air source heat pump models supporting the testing of control strategies for various system configurations (Figure 5).

To provide an example of alignment with SAP, a dwelling with solid brick construction (U-value of 2.1 W/m^{2}K) was modelled in both IDEAS and SAP. Comparing the mean monthly temperature and energy requirement as predicted, both tools demonstrated good agreement with the results corresponding to R^2 values of 0.978 and 0.995, respectively. Additional calibration work and examples are detailed in the section, ***Publications/Research output***.

Project outcomes/Conclusions

The contribution to knowledge delivered by this project relates to the development of an explicit, dynamic calculation method that gives outputs that are aligned with SAP and is configured in a manner that supports the appraisal of control algorithms of arbitrary complexity (eg multi-input/multi-output and rules-based control).

Application of IDEAS to the design of novel heating systems led to insights which have been incorporated in the SAP framework. Other applications of IDEAS are reported in the research outputs listed below.

Publications/Research output

Murphy G, Allison J and Counsell J. Benchmarking the effect of weather data upon energy estimation of UK homes. Poster presentation at CIBSE Technical Symposium 2013, Liverpool John Moores University, 11–12 April 2013.

Murphy G, Counsell J, Baster E et al. Symbolic modelling and predictive assessment of air source heat pumps. Building Services Engineering Research and Technology 2013, 34 (1), 2013.

Murphy G, Baster E, Allison J and Counsell S. Simplified modelling of air source heat pumps producing detailed results. Poster presentation at CIBSE ASHRAE Technical Symposium 2012, Imperial College London, 18–19 April 2012.

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A component-based air source heat pump model for building simulation

Eric Baster

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While air source heat pumps (ASHP) offer the potential to reduce CO_2 emissions, they have often failed to meet performance expectations. Integrated simulation of buildings and ASHP heating systems can provide a basis for the optimisation of system design and control approaches. The output of this project will be a new ASHP modelling method, developed for initial testing and use within the ESP-r simulation framework. The intention is to enable a detailed representation of system dynamics while allowing easy calibration of the model.

Background

Air source heat pumps (ASHP) typically make use of the vapour compression cycle to absorb low-grade heat from the external air and deliver this at a higher temperature inside a building. They offer a potentially efficient method of providing space and water heating: it is often stated that they can supply three times more energy in the form of heat as they require in the form of electricity, though currently this level of performance is seldom achieved in practice. Nonetheless, they have the potential to reduce the costs, emissions and resource intensity of UK heating, particularly where electricity is generated from renewable sources.

ASHPs are widespread in Scandinavia and central European countries. In the UK, they have yet to become established, and field trials have revealed widely varying performance. Issues are thought to stem from poor system design and installation to problems with the specification and usability of the controls. Furthermore, at temperatures below approximately 5 °C, frost forms on ASHP evaporators. Some of the heat produced must then be diverted from the heating system to remove this, thereby reducing performance. It has been suggested that this problem is particularly prevalent in the UK's humid oceanic climate.

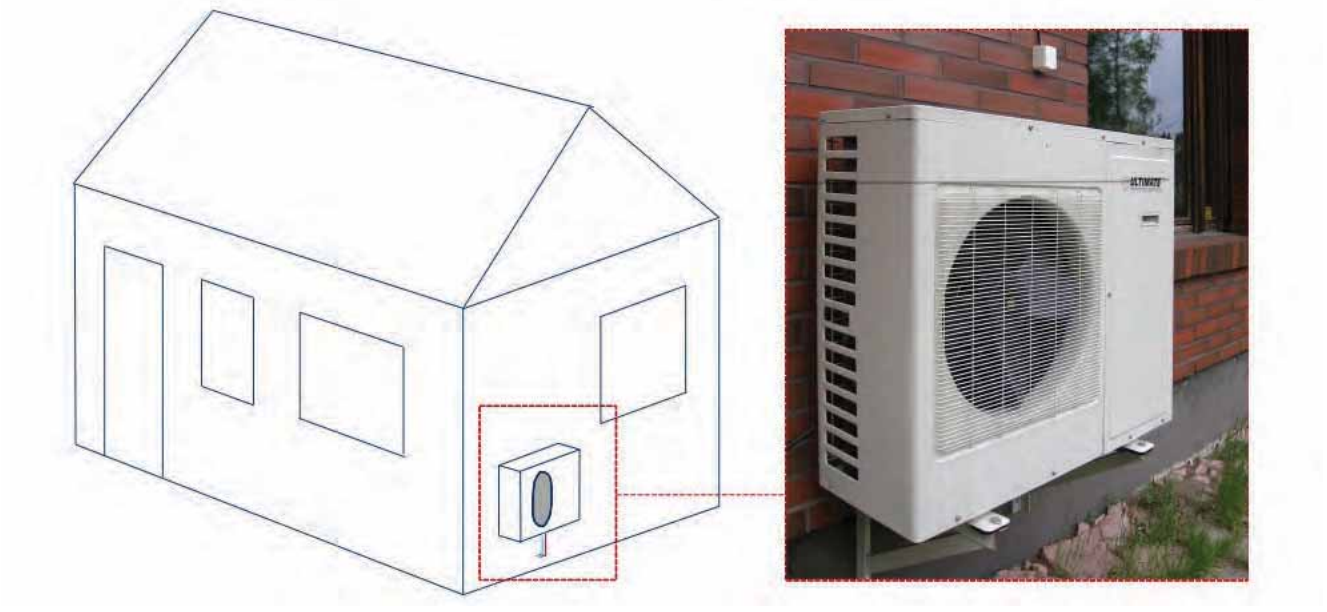

Figure 1: A domestic air source heat pump (Photo Wikimedia Commons)

Further developments in ASHP technology, controls and design methods are required to ensure performance levels are more robust across the anticipated operational range. Computer modelling is a valuable tool in this regard. Modelling of ASHP systems is challenging because they are sensitive to continually changing parameters, chiefly:

- ambient temperature
- humidity
- heating system return flow temperature.

Fully dynamic models are therefore required, integrated within an overall building simulation tool. The development of such a model is the aim of the present project.

Research programme

Previous work on the simulation of ASHP systems has typically involved fitting polynomial curves to standard performance test data. A model of this type has been developed as part of this project and has been implemented in a simplified building model intended as a basis for the development of controls; this rudimentary model is described in the publications listed in the section opposite, ***Publications/Research ouput***. The accuracy of such models is limited by the extent of the test data available. Detailed data are required to include transient behaviour (evaporator frosting and part load cycling) or to cater for varying heat transfer media flow rates – this is rarely available in practice.

A more sophisticated modelling method is therefore being developed, which involves explicitly representing the energy exchanges within the components of the refrigerant cycle rather than treating the system as a black box. This builds on techniques previously used for ground source heat pumps, for example those described by Jin and Spitler[1] and Lepore et al[2]. This sub-model will be combined with recently developed models of evaporator frost growth. Often component-based models require as parameters hard-to-obtain internal measurements of refrigerant cycle components. It is intended to use a version of Jin and Spitler's parameter-estimation technique to reduce these requirements, thus enabling a range of ASHP units to be readily modelled.

The ASHP model is being installed and tested within the ESP-r integrated building simulation program, which has been evolving for over three decades and provides a high resolution building modelling environment. The ASHP model follows ESP-r's underlying approach of dividing a system into a number of control volumes and applying mass and energy balance considerations to the connected systems.

Project outcomes/Conclusions

The main outcome of the project will be the ASHP modelling algorithm, fully integrated and tested within the ESP-r environment. The final system will:

- enable a dynamic analysis of whole-system behaviour,
- allow comparison of performance under different climates
- have the ability to simulate ASHP in multivalent systems or in conjunction with thermal storage.

Publications/Research output

Murphy G, Counsell J, Baster E et al. Symbolic modelling and predictive assessment of air source heat pumps. Building Services Engineering Research and Technology, 2013, 34 (February), 23–39.

Murphy G, Baster E, Allison J and Counsell S. Simplified modelling of air source heat pumps producing detailed results. Proceedings of CIBSE Technical Symposium, London, April 2012.

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Control of future autonomous offices with integrated advanced lighting networks

John Allison

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This project addresses the design of advanced control algorithms for commercial offices with the objective of reducing their energy consumption and carbon emissions, and thereby creating energy autonomous offices. The algorithm controls the renewable and co-generation energy sources within a building to provide the required heat and electricity demand while minimising electricity grid use. As lighting networks represent the single greatest energy use within commercial offices[1], the control algorithm seeks to reduce their electricity grid energy demand through the use of in-built electrical energy storage.

Background

Commercial buildings account for 40% of global energy consumption[2], making them a key target for energy reduction measures (Figure 1). In the UK, commercial offices account for 10% of the service sector's energy consumption[1], making them the third the largest consumers of energy behind retail outlets and hotels.

One method of reducing the energy consumption of commercial buildings so that they become as sustainable as possible is to make them more autonomous, for example by:

- creating more of their own energy
- disposing of their own waste
- collecting their own water.

A move towards these energy autonomous systems could be accomplished by the use of renewable and co-generation energy sources. However, there is a multitude of these energy sources available, such as combined heat and power (CHP), thermal energy storage and electrical energy storage plants, heat pumps, photovoltaics, etc. Making these systems work together presents a control challenge for their efficient use, especially since they can have a simultaneous effect on both the thermal and electrical energy networks.

Figure 1: Commercial offices are major consumers of energy so are a key target for energy reduction measures

The aim of this research is to design control strategies that can control any configuration of the renewable and co-generation energy sources to provide the required heat and electrical demand while minimising electricity grid use.

As lighting accounts for the majority (32%) of the electrical energy used within commercial offices[1], the control network also endeavours to reduce electrical energy demand through the use of integrated energy storage and light level control.

Additionally, it is intended that the office does not have to be part of a net-zero or nearly zero energy building as the controller should be a pragmatic solution that can be implemented within existing commercial offices.

Research programme

A non-linear multi-loop, multi-input, multi-output controller design has been developed as an evolution of a robust inverse dynamics estimation (RIDE) control algorithm.

The outer loop dynamically determines the control strategy employed for each energy source in order to meet the thermal and electrical demands of the office space. This RIDE control algorithm (Figure 2) operates as a dual regulating and tracking control system. An equivalent control term is implemented to aid in disturbance rejection and compensation for slow building dynamics. This equivalent control has resulted in the creation and validation of an energy performance mathematical model of an office zone's thermodynamics.

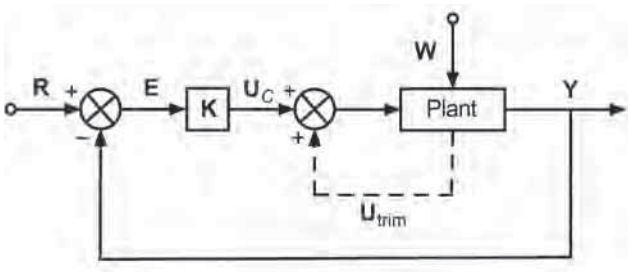

Figure 2: Schematic diagram of robust inverse dynamics estimation (RIDE) control algorithm

The inner loop controls the supply of power to the lighting network via its integrated battery storage. A secondary control algorithm, carbon optimised distributed energy storage (CODES), has been developed for this loop which aims to power the lighting network from the available electrical energy storage. The lighting network also incorporates a variety of sensors: battery state-of-charge (SOC), air temperature, humidity, lux level and power consumption. This integration of the building services and IT network effectively creates a pervasive sensor network throughout the office spaces which will enable far greater levels of sophistication to be deployed for lighting and power demand control.

Project outcomes/Conclusions

Thus far, the research confirms that it is possible to run an electrically led CHP system with a coupled thermally/electrically led thermal energy store, while maintaining a prescribed operative temperature profile within the office zone. Figure 3

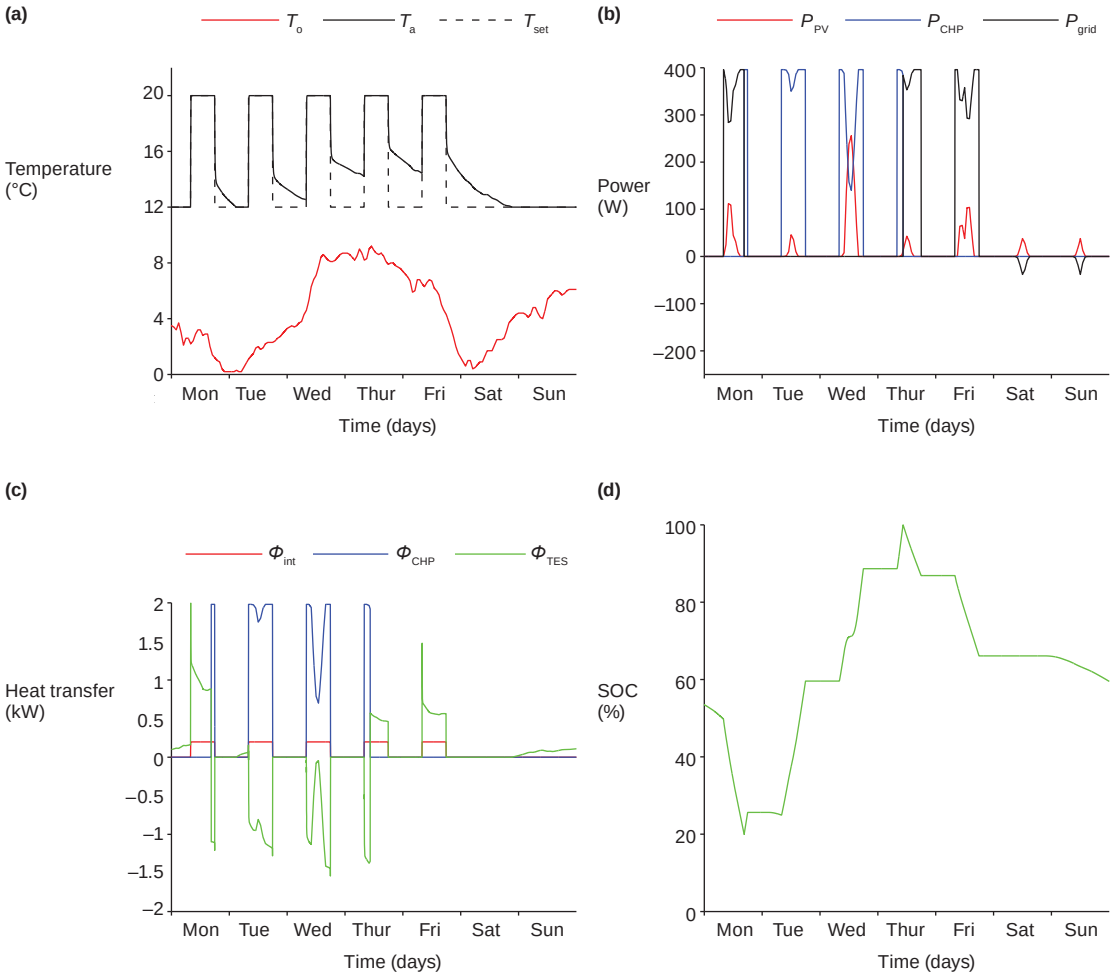

Figure 3: Dynamic results from outer loop control: (a) temperature, (b) electrical power, (c) heat transfer to air, (d) thermal energy store state-of-charge (SOC)

T_o = outside temperature; T_a = actual temperature; T_{set} = temperature at setpoint; P_{PV} = photovoltaics power; P_{CHP} = CHP power; P_{grid} = electricity grid power; Φ_{int} = internal heat transfer; Φ_{CHP} = CHP heat transfer; Φ_{TES} = heat flow rate to/from the thermal energy store.

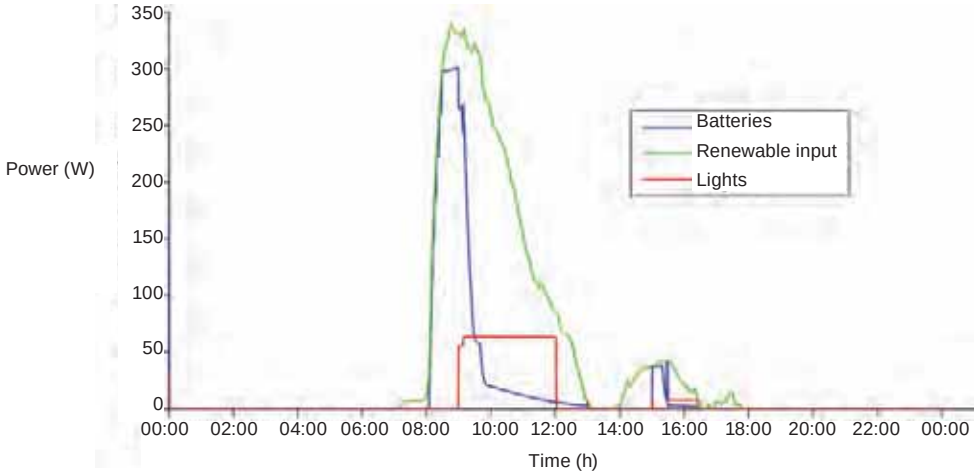

Figure 4: Inner loop control of lighting network with integrated electrical storage

shows the model results corresponding to the outer loop control algorithm, highlighting the operative temperature against a minimum use of the electricity grid. These results were generated using a control approach which aims to show if ideal control is feasible for a given design. Future development of the controller will incorporate high-frequency dynamic components such as sensors and heat delivery mechanisms.

Figure 4 shows the results from the inner loop control – a combined power use of 8 lights in a simulated office space with inputs from photovoltaics and micro-CHP. As depicted, the batteries do not charge until there is sufficient power available from the renewable and co-generation sources. This highlights the self-regulating nature of the lighting network, and would also allow for a defined minimum operating time, when there is no available renewable energy, by using the integrated energy storage.

Future work on the control algorithm will include detailed plant models for the renewable and co-generation sources with case studies to highlight platform use as a building control's virtual test bed.

Publications/Research output

Allison J and Murphy G. Control of micro-CHP and thermal energy storage for minimising electrical grid utilisation. Paper presented at the 3rd International Conference on Microgeneration and Associated Technologies (Microgen III), Naples, Italy, 15–17 April 2013.

Murphy G and Allison J. Determining the effect of weather data upon building simulation in regulatory processes. Paper to be presented at Building Simulation, Chambery, France, 26–28 August 2013.

Murphy G, Counsell J, Baster E, Allison J and Counsell S. Symbolic modelling and predictive assessment of air source heat pumps. Building Services Engineering Research and Technology, 2013, 34 (February) 23–39.

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A robust method for benchmarking energy performance in multi-tenant office buildings

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The aim of this project is to develop a tool for evaluating the occupant-related energy performance of office buildings. The tool will be of value to architects, engineers and building managers for benchmarking regulated and unregulated energy performance in multi-tenant offices.

The method is derived from pairing of building energy performance and occupancy load assessments pre- and post-design stage and will:

- **enable succinct portrayal of a building's operational limits under different tenancies**
- **convey the impact of low or high occupancy on energy use**
- **explain where opportunities in energy performance improvement may arise.**

The method supports proposed green tenancy agreements and energy performance contracts.

Background

The difference between predicted and actual building energy performance is well documented[1,2]. This gap has arisen because mandatory compliance calculations do not account for occupancy-related energy (ORE) use[3], although ORE accounts for up to 70% of a building's total energy consumption. Thus, to accurately represent building energy use ORE consumption should be considered as part of the design process. By 2030 building regulations will require new techniques to achieve net zero carbon performance. Accounting for ORE is seen as a significant contribution to achieving this goal.

The aim of this research project is primarily to test and evaluate a method for the benchmarking of predicted and actual ORE during both pre- and post-design phases, as a way to calibrate energy performance over a specified performance range. A supplementary aim is to establish how much the aforementioned performance gap can be attributed to building design and regulatory processes.

The research aspiration is to communicate useful guidelines to end users. Using buildings more efficiently in addition to optimising their design is widely regarded as the best way to enhance performance, reduce impact and negate expensive remedial costs.

Research programme

The elements of the research programme are as follows:

- investigate the impacts of occupant density in multi-tenant office buildings
- deduce the barriers to assessing energy performance
- evaluate compliance methods of building energy performance representation
- model the effects of occupant density on energy performance
- test the ORE benchmarking method by comparing energy usage patterns to establish design limitations.

ORE (kWh/m^2/occupant) is a method of measuring and benchmarking unregulated loads, including design changes, variations in design standards, plug loads, variations in operational hours, occupant density and building management in a multi-tenant office building. It does this by considering energy performance (kWh) criteria against net floor area (m^2), as considered within the current compliance method[4], together with the actual occupancy load factor for each sub-tenanted office, O_A. The ORE can be calculated for yearly, monthly or daily comparisons. A new method of calibrating energy performance is derived as follows.

(a) *Calculate ORE performance maximum and minimum values of the* **as-designed** *regulated and unregulated loads:*

$$ORE_{D\,Min} = [kWh/\,NFA_T] \times O_{Min}$$

where:

$$O_{LF\,Min} = NFA/O_{Min}$$

$$ORE_{D\,Max} = [kWh/NFA_T] \times O_{Max}$$

where:

O_{Max} = $NFA/O_{LF\,Max}$
$O_{LF\,Min}$ = designed minimum occupancy load factor
$O_{LF\,Max}$ = designed maximum occupancy load factor
O_{Min} = established from compliance standards and HVAC sizing
O_{Max} = established from compliance standards and HVAC sizing
NFA = net floor area (m^2)
NFA_T = net floor area of the subtenant (m^2).

(b) Define the **as-designed** *building sub-tenant ORE regulated or unregulated performance range:*

$$ORE_{Ra} = ORE_{D\,Min} - ORE_{D\,Max}$$

where:

$ORE_{D\,Min}$ = designed ORE performance minimum value
$ORE_{D\,Max}$ = designed ORE performance maximum value
ORE_{Ra} = designed ORE performance range.

(c) Calculate the ORE performance of the **in-use** *regulated and unregulated loads:*

$$ORE_A = [kWh/NFA_T] \times O_{LFA}$$

where:

O_{LFA} = NFA/O_A
O_{LFA} = actual occupancy load factor
ORE_A = actual ORE performance.

If the ***actual*** ORE regulated or unregulated load falls within the ***designed*** ORE parameters then the office energy performance is as expected. The closer the energy performance indicator is to the benchmark, the more efficient are the office utilities in use.

The technique enhances the existing compliance metric by explaining the building energy use in terms of the impact of occupants. Consequently, notional ORE performance limitation parameters can be established and the results calibrated with the design intent. This allows detailed analysis of specific multi-tenant buildings as opposed to an evaluation of the building type as a whole[5]. It also allows the evaluation of the impact of occupant density on energy efficiency, considered in the current National Calculation Method[4].

The benchmark can be tailored to compare all energy loads, including HVAC, lighting, IT equipment, small power and special functions, all against sub-metered data following the same principles. It provides an understanding of how a building will react under low and high occupancy while conveying efficient working hours and strategies (Figure 1). The method therefore supports a move to green tenancy agreements and energy performance contracts.

Project outcomes/Conclusions

Both theoretically and practically, the ORE performance method and metric has been shown to be capable of benchmarking and calibrating the energy performance of multi-tenant office buildings. The technique supports understanding of building operational limits, conveys the impact of occupant density on energy efficiency and promotes energy efficiency in use by tethering occupant energy demand to actual building performance.

The project outcome is a method of disseminating ORE performance information to facilities managers to a level of detail that goes beyond that presently required for compliance and certification (Figure 2). The expectation is that specific ORE benchmarks and a monitoring strategy will be documented and developed with the building as a means of calibrating energy performance. The method supports and enhances existing BRE[6], CIBSE[7, 8] and Soft Landings principles.

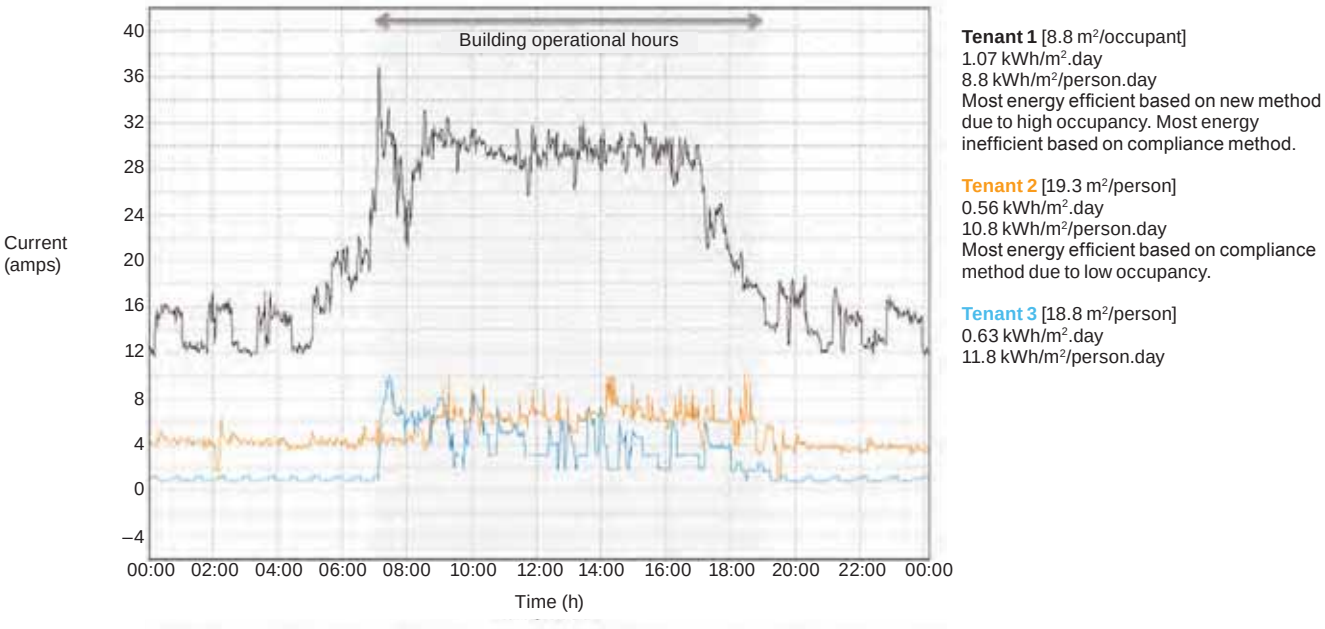

Figure 1: ORE performance method applied to a multi-tenant office building over a typical 24-hour period in January

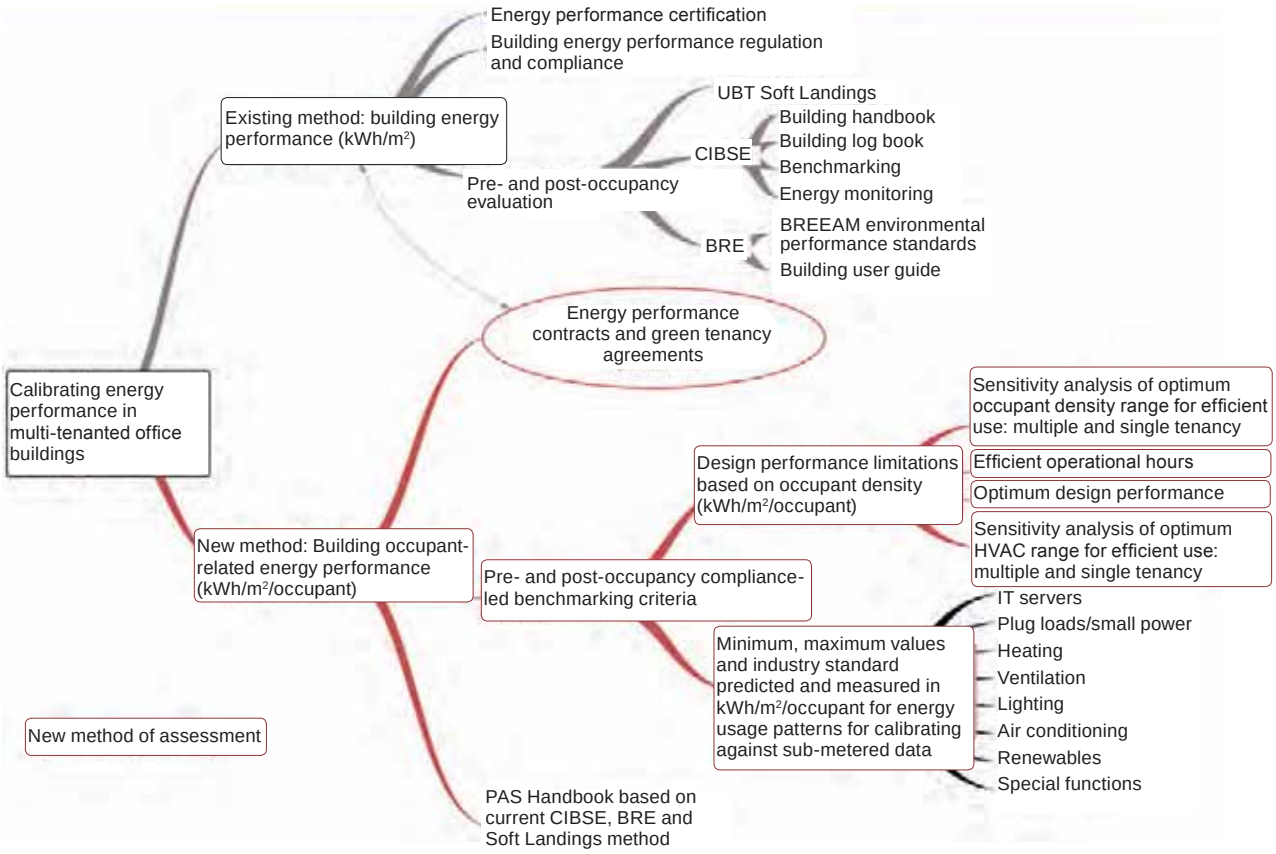

Figure 2: An occupant-related energy performance map

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Fire and security

Performance of cavity barriers in external wall constructions incorporating combustible materials

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Fire safety, BRE Gobal

A series of 21 fire experiments was undertaken to investigate the performance of generic types of cavity barrier when used as a fire barrier within an external wall cavity formed from a load-bearing timber frame and an external masonry rain screen wall. The results from the experimental programme, together with a review of previous research, were used to develop guidance for the industry.

Background

Fires in timber-frame buildings are the subject of significant interest to stakeholders. One particular area of concern is the unseen spread of fire within wall cavities and roof voids. Fire spread of this nature poses a real challenge for the fire and rescue service, a potential life safety risk and significant property damage risk. There is a growing body of anecdotal evidence that shows that the methods used for the protection of cavities incorporating combustible material are not performing properly in a number of cases.

The primary objective of this project was to investigate the performance of some of the fire protection measures currently in use to determine if they actually work and to identify common modes of failure.

Figure 1: Intumescent cavity barrier between timber frame and masonry external façade

Research programme

The research project incorporated the following specific tasks:

- Form a project stakeholder group which included representatives from manufacturer organisations, regulatory bodies, the insurance industry and the fire and rescue service.
- Collate existing information in relation to cavity fire incidents which included both previous research projects and investigations from real fires[1,2].
- Undertake an experimental programme to evaluate the performance of horizontal cavity barriers subject to a realistic fire scenario representative of a cavity fire incident within an external cavity wall formed from a load-bearing timber frame and an external masonry rain screen.
- Provide guidance on the important factors responsible for the risks of fire spread in cavities and best practice guidance in relation to the installation and inspection of cavity barriers on site.

Figure 2: Experimental set-up prior to ignition

Figure 3: Fire spread to upper panel above cavity barrier

Project outcomes/Conclusions

- All generic forms of cavity barrier tested were capable of inhibiting the spread of fire and smoke when installed in accordance with manufacturer's instructions.
- The relationship between the ignition source and the ventilation conditions within the cavity is complex and has a marked impact on fire development. This issue was not investigated as part of this project.
- There was no fire spread in any of the experiments incorporating non-combustible sheathing board (Magnesium Oxide board).
- The presence of discontinuities was shown to have a marked effect on all generic forms of cavity barrier other than intumescent barriers to inhibit the spread of fire for a reasonable period when present alongside a combustible sheathing board in the scenarios investigated. It must, however, be noted that the nature of the discontinuity in terms of size, shape and geometry may result in different types of behaviour and these particular variables were not systematically investigated as part of this work.
- The performance of solid timber battens used as cavity barriers is particularly sensitive to discontinuities. In particular, solid timber battens are unable to accommodate dimensional variations in cavity widths and any inconsistencies will lead to the creation of gaps around the timber batten which tend to lead to a rapid increase in failure times and fire spread above the level of the barrier in the event of a cavity fire.

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Development of improved testing methods for toxic hazards in fires

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Fire safety, BRE Global

This project was undertaken in collaboration with a number of European partners involved in the Transfeu project. It examined the feasibility of using Fourier Transform InfraRed (FTIR) spectroscopy for the continuous analysis of toxic species in smoke. This led to the development of a standard test method for analysing the toxic fire effluents produced by materials and products in the BS EN ISO 5659 smoke box. The test method was developed and validated using a number of Round Robin exercises (inter-laboratory tests) between the participating laboratories.

Background

Development of new innovative materials and composites in the construction and transport industries is increasing to meet sustainability targets and environmental concerns. These materials need to be assessed for their toxicity in fire to ensure members of the public are protected against the use of materials that can easily ignite and produce dangerous levels of toxic fire gases. Current fire toxicity test methods do not provide appropriate data to enable calculations to be made for tenability in enclosed spaces.

The development of a new test was intended to allow the design of a safer environment and for that environment to incorporate more innovative materials which were being developed in response to global demand for a more sustainable built environment.

This project has initially been established by and is therefore concerned with the rail industry. However, it was expected to have significant implications for testing in other industry sectors, hence the involvement of BRE Trust.

Research programme

The BRE Trust research was intended to contribute to the European project, Transfeu, in developing the standard test method for assessing the toxicity of fire effluents produced by burning materials. The main aim of the project was therefore to develop the technique through practical trials and to assess the reproducibility of the technique by working in conjunction with the European partners.

The specific objectives of the project were to:

- contribute to the development of a small-scale method to measure the species and toxic gases produced during the combustion of innovative materials and composites.
- contribute substantially to the development of a future European Standard (DD CEN/TS 45545[1]).

Project outcomes/Conclusions

The setup of the coupled ISO 5659-2 apparatus (the smoke box)[2] and the FTIR analyser was completed. Figure 1 shows the current arrangement of the apparatus.

The test setup was successfully included in Round Robin exercises (inter-laboratory tests) carried out in conjunction with the European project partners. The work carried out led to the development of a test method for continuous measurement of toxic species produced by burning materials. It has provided an indication of the reproducibility and robustness of the method which can be passed on to standards committees for consideration of inclusion into future standards such as DD CEN/TS45545[1].

Figure 1: Smoke box and FTIR apparatus

The amendments to the technical specification will initially result in manufacturers of products for the rail industry needing to commission testing involving the use of the amended method, incorporating FTIR spectroscopy.

It is widely expected that this change in the testing regime for the rail industry will then cascade outwards, first to road and marine applications, then to the construction industry, and that there will be significant markets to capitalise on in each of these sectors.

Publications/Research output

The UK national workshop for the EU Transfeu project was held on Wednesday 20th June 2012. The event brought together partners of the EU Transfeu project with the UK rail regulator, various industry representatives (including rolling stock manufacturers and contractors responsible for infrastructure), as well as representatives from the marine sector. The marine sector is expected to be the first sector outside the rail industry to adopt the knowledge that has been developed by this project, although further adoption by other sectors including construction is anticipated.

The final report of the Transfeu project is to be published at www.transfeu.eu.

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Integrated Fire Resistance Test Methodology for natural fibre-reinforced polymers

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This project confirmed the suitability of the BRE-developed integrated fire resistance test methodology tool (IFRTM) for determining the key performance aspects of composites in fire, specifically natural fibre-reinforced polymers (NFRPs). It developed a decision matrix as a guide to parameters for assessment.

A hemp fibre-reinforced polyester was investigated in detail. The data generated using the methodology has led to the development of a theoretical model to predict the combustion behaviour and residual mechanical properties of NFRPs exposed to high temperatures.

This research has attracted much interest from researchers and industry. Further work has been secured, including work for the automotive industry.

Background

Fibre-reinforced polymer composites (FRPs) form a multi-billion dollar market internationally, 95% of which are glass-reinforced plastics (GRPs)[1]. Natural fibre-reinforced polymers (NFRPs) have been identified as a potential low-impact alternative to GRPs.

Of the many unique technical issues associated with the development of NFRPs, fire resistance is perhaps one of the most important factors. Prescriptive methods for establishing the fire resistance of materials in the construction industry are a limiting factor for the future use of NFRPs as construction materials because of the costs and the lack of material information obtained from standard fire resistance tests.

This research has established cost-effective methods for developing the fire resistance of NFRP materials. The experimental methodology has provided data and analysis tools that are indicative of fire resistance for flat panel NFRPs exposed to a constant heat flux on one side simulating fire resistance furnace conditions.

Research programme

The integrated fire resistance test methodology (IFRTM) was used to measure the thermal response of flat panel hemp fibre-reinforced polyester composites (NFRPs) subjected to radiant heat on one side. A total of 130 samples with varying levels of fibre volume fraction (V_f) and varying thickness were tested at varying exposure times from 5 minutes to 17.5 minutes and at varying exposure levels of 25 kW/m² and 50 kW/m².

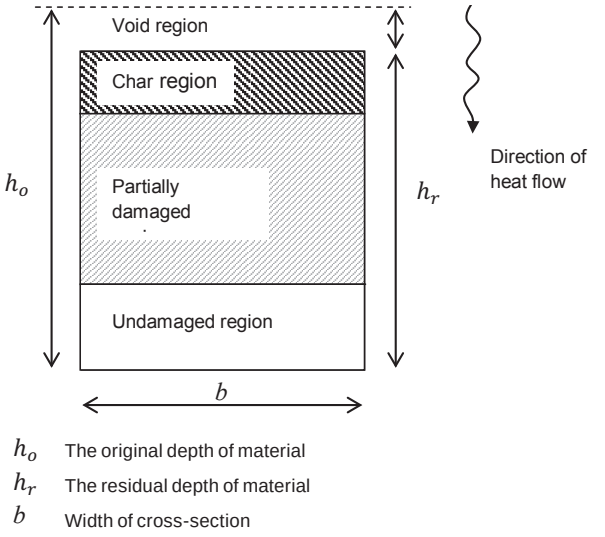
A structural testing programme was conducted in parallel with the fire testing. Tensile test coupons were taken from fire-damaged samples and tested for residual tensile strength. Undamaged samples for all thicknesses and fibre volume fractions were also tested for tensile strength.

Thermal damage criteria such as charring and discoloration were measured through the depth of the material by means of cross-sectional analysis under a reflected light microscope. A variety of damaged samples were also prepared for transmitted light microscopic analysis. The depth and degree of damage was correlated with the temperature response and the residual mechanical properties.

Project outcomes/Conclusions

The introduction of natural fibres alters the conceptual model for thermal degradation and decomposition of polymer composites. Natural fibres contribute to the production of char material. The moisture content associated with natural fibres affects the temperature response of the material due to desorption of moisture at 100 °C. Moisture also contributes to the degradation of the fibre matrix interface due to the differential thermal expansion of the fibre cell walls.

Four damage regions through the depth in the direction of heat flow have been identified (Figure 1):



h_o The original depth of material
h_r The residual depth of material
b Width of cross-section

Figure 1: Four damage regions through the depth of the NFRPs in the direction of heat flow

- ***Void region:*** A layer of exposed charred fibres that do not contribute to residual mechanical properties.
- ***Char region:*** A layer of conglomerate charred matrix and fibre material. This layer contributes a small proportion to the residual mechanical properties.
- ***Partially damaged region:*** A layer of material that may be discoloured but not charred. The mechanical properties of this region are significantly reduced.
- ***Undamaged region:*** This region has been protected from thermal degradation and retains its original properties.

The main results can be summarised as follows.

- With an increase in fibre volume fraction (V_f) there was an increase in thermal conductivity (k)[2] which results in a increase in time to ignition (t_{ign}). An increase in matrix volume fraction (V_m) resulted in an increase in the probability of ignition. Natural fibres helped to inhibit flaming ignition. Ignition led to more loss of material and an increase in the void region.
- With an increase in V_f there was an increase in the production of char material which increased with exposure time. An increase in char material resulted in a decrease in thermal conductivity.
- With an increase in V_f there was an increase in the tensile strength of char material.
- With an increase in V_f there was a decrease in the residual tensile strength of partially damaged material.
- With an increase in V_f there was an increase in residual material.

The results from the experimental program have been used to derive a model to describe the residual tensile strength of flat panel NFRPs exposed to fire conditions. The model has been adapted fro NFRPs from an existing model used for GRPs[3].

The model for residual tensile strength is given in Eqn 1 which describes the sum of the contributions from different damage regions through the depth of the material (Figure 2).

$$\sigma_r = \left(\frac{h_c}{h_o}\right)\sigma_c + \left(\frac{h_{r1}}{h_o}\right)\int_{h_p}^{h_m} \frac{\sigma_o a {T_1}^c h^{dc}}{h_{r1}} dh + \left(\frac{h_{r2}}{h_o}\right)\sigma_o \quad \text{[Eqn 1]}$$

where:

σ_r Residual tensile strength
σ_o Original tensile strength
σ_c Char tensile strength
h_o Original depth
h_c Char region
h_{r1} Partially damaged region
h_{r2} Undamaged region
h_p Pyrolysis depth
h_m Partial damage boundary depth
T_1 Reference temperature when h 1
a = Constant associated with fibre volume
c = Constant associated with fibre volume
d = Constant associated with fibre volume

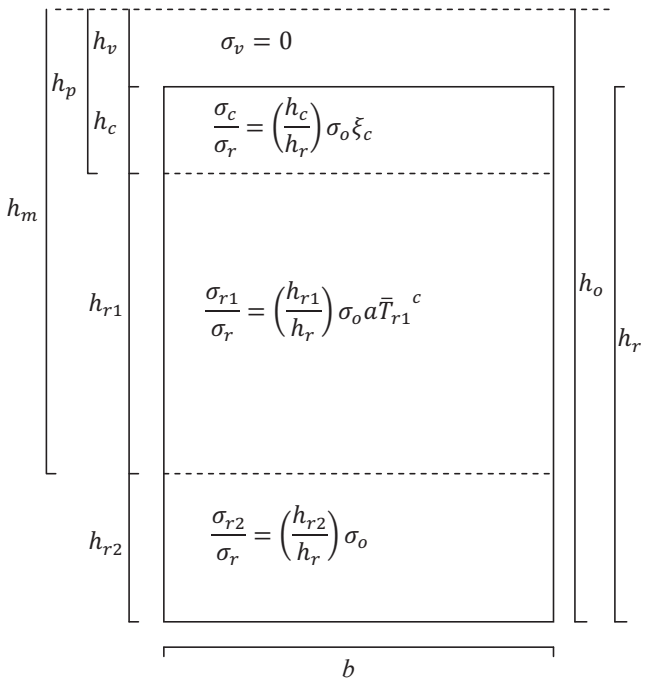


Figure 2: Cross-section with model contributions for residual tensile strength

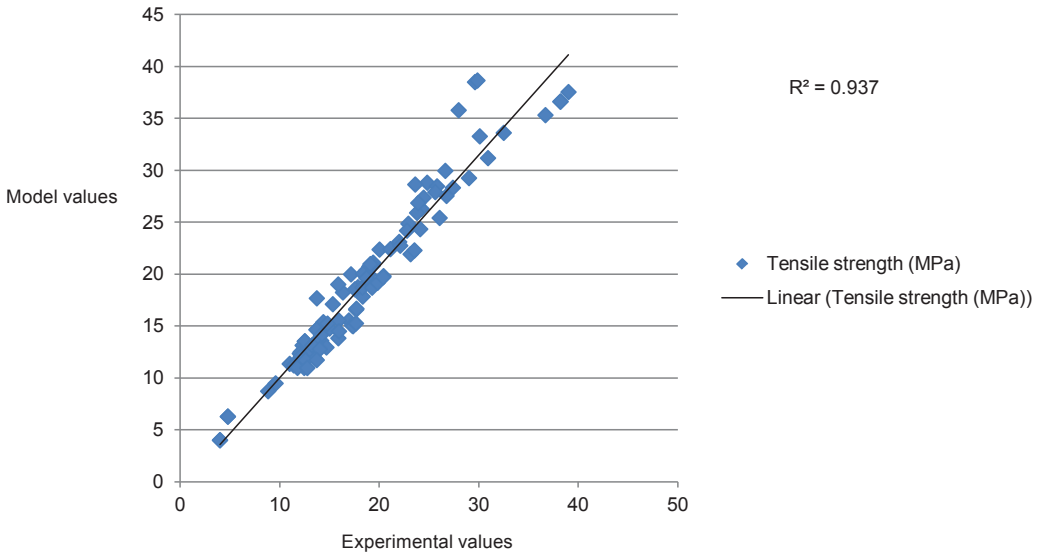


Figure 3: Correlation between model and experimental values

A good correlation was found between the model and experimental data (Figure 3). The results suggest that the test methodology can be used to derive similar models for a variety of fibre-reinforced composites.

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Non-intrusive examination of buildings for fire safety risk assessment

Martin Shipp, Corinne Williams and Phil Clark

BRE Global

This project investigated the use of selected non-intrusive or partially intrusive techniques for locating and identifying fire stopping and other hidden or inaccessible passive fire protection measures.

Overall, the project showed that none of the methods examined were found to satisfy the performance requirements that formed the practical objectives of this project. Many of the techniques examined required an expert user and/or expert interpretation, and there were also technical issues with some techniques which limited the ability to achieve the results expected or desired. The result was that the main project objectives were not achievable.

Background

Currently, cavities and voids (such as those that might contain a passive fire protection system) can only be examined intrusively and destructively, ie by cutting holes. In practice, most risk assessors are not able to do this because, for example, specialised cutting equipment might be needed. Also, clients would not agree to it, in part because such an intrusive examination risks damaging the fire protection. Consequently, these elements are left out of the risk assessment with potentially serious consequences for life safety and loss prevention. The main purpose of this project was to determine if one or more of the various techniques could be quickly and easily used in the identification of fire stopping by a fire safety risk assessor.

Research programme

A literature review examined a large number of techniques which appeared to exhibit some potential to be used in buildings to locate and identify passive fire protection. Of these, a number of potential methods were selected for further study, three

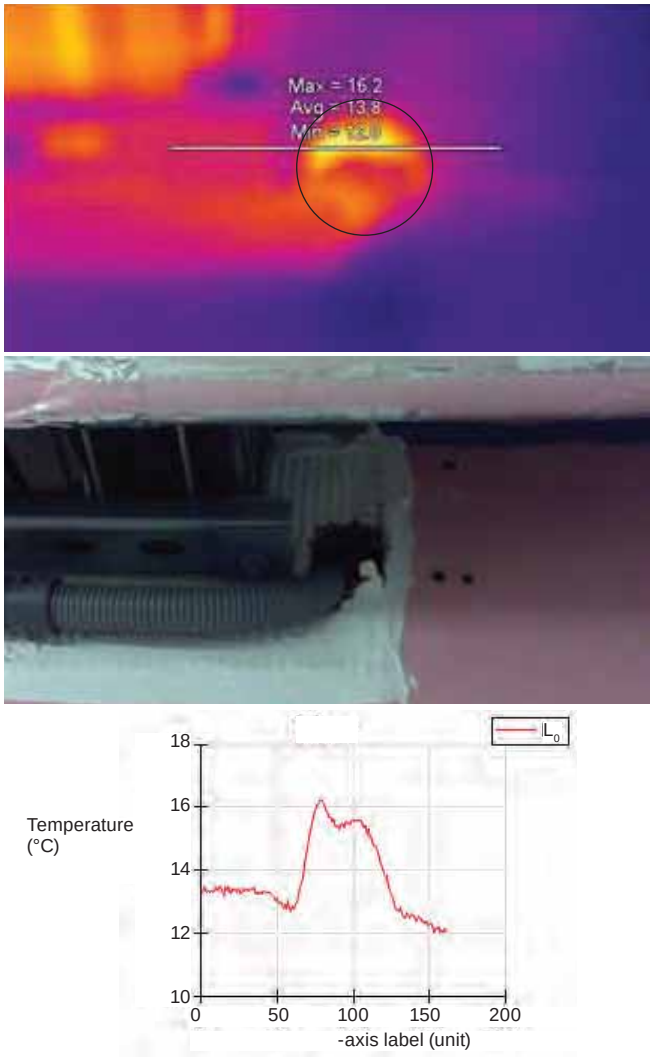

Figure 1: (a) Thermal infrared image showing a breach in fire stopping (circled), (b) gap in the fire stopping is visible to the eye, (c) graph shows a clear thermal differentiation of the breach in fire stopping

of which were wholly non-intrusive and the fourth classed as partially intrusive. The methods were:

- thermal infrared (passive and active)
- radar
- ultrasonic depth gauges
- videoscopes.

The techniques were assessed in the laboratory*, in one of the BRE Innovation Park buildings, and in an actual building under construction in London. Three of the methods are illustrated in Figures 1–3.

Project outcomes/Conclusions

A number of issues were identified as part of this project which have an impact on the ability of the tested techniques to be used in the required way. In the case of thermal imaging and ground-penetrating radar, these techniques were shown to be of limited use to a fire safety risk assessor. The partially intrusive videoscope method had some success in finding fire stopping but with some technical difficulties.

In all cases, the primary constraint was access to the areas where fire stopping was or would be present. Generally, fire stopping will be in an area with limited access or without a direct line of sight. Both thermal infrared and ground-penetrating radar rely on the ability to see, or have a line of sight of, the object under investigation. Ground-penetrating radar has to be used in contact with the surface (ie without an air gap).

None of the methods examined were found to satisfy the performance requirements that form the practical objectives of this project; of the three systems that showed early promise, none of the fully non-intrusive systems offer the flexibility, reliability or simplicity that is needed for 'routine' use. Videoscopes offer the most practical benefits, but are partially intrusive (in that they need only a small hole and may therefore exploit existing openings when the opportunity arises).

Many of the techniques examined require an expert user and expert interpretation. There are also technical issues with some techniques which means that unless initial conditioning or stabilisation of ambient conditions is undertaken then the technique does not achieve the results expected or desired.

It follows that the main project objective, namely to provide a description of a practical and robust methodology to exploit the identified technologies, was not achievable.

Figure 3: Videoscope view of the cavity behind the external façade. The fire stopping (green plastic membrane) is visible at the top of the photo

* Following technical discussions with the suppliers of the ultrasonic depth gauges, it was agreed that the gauges would not be included in the laboratory assessment.

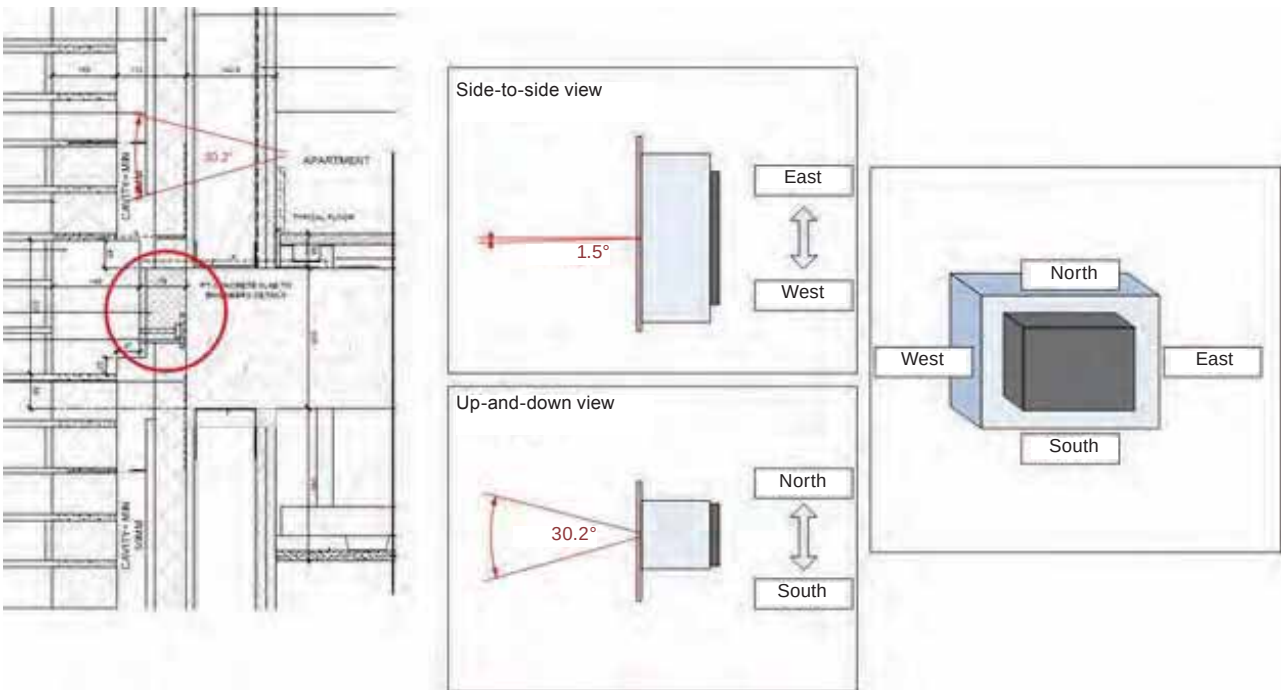

Figure 2: A typical light steel-frame construction showing the fire stopping (circled) and the typical field of view for ground-penetrating radar

However, there may be specific circumstances where the use of some of this equipment may be of benefit to the fire safety risk assessor, although most likely by calling on specialist assistance. The project has identified some key selection factors and Appendix A of the final report provides some guidelines to assist in identifying where and how these techniques might be of value.

These techniques may be of particular value where the location of fire stopping or cavity barriers and similar might be anticipated from design drawings or other sources of information. In this regard, having the plans or other detailed information about the fire protection measures in the building (that are a requirement of Building Regulation 38[1]) are of particular importance. Unfortunately, there is an increasing body of opinion within the fire safety community that Regulation 38 is quite frequently ignored.

Acknowledgements

The authors would like to thank the following people and organisations for their help with this project:

- Peter Clarke, Radir Ltd, Milton Keynes
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- Steve Brunswick, Carillion Group Technical Services, Wolverhampton.

The authors also wish to thank BRE colleagues who assisted with the project.

Publications/Research output

Shipp M, Williams C and Clark P. The non-intrusive examination of buildings for fire safety risk assessment: Literature review – identification and selection of candidate technologies. BRE Trust client report 128968 v2, 30 March 2011.

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BRE Centre of Excellence in Fire Safety Engineering, University of Edinburgh

José Torero* and Luke Bisby†

BRE Trust/RAEng Professor of Fire Safety Engineering*

Arup Professor of Fire and Structures and Acting Director of BRE Centre of Excellence in Fire Safety Engineering†

The BRE Centre for Excellence in Fire Safety Engineering at the University of Edinburgh had another successful year in 2012. The Centre has continued its initiatives to provide fire safety engineering solutions for today's challenging environments.

The 'Real fires for the safe design of tall buildings' project is firmly underway with a team of PhD students and post-doctorate researchers constructing and instrumenting a large-scale test rig within the Burn Hall facility at BRE's Watford site (Figure 1). With more than 3000 sensors, these tests will be the most comprehensive fire tests ever conducted. The tests are designed to provide a vast data set for the development of modelling tools. This Engineering and Physical Sciences Research Council (EPSRC)-sponsored project, running from January 2012 through to December 2014, involves some 20 partners from all aspects of the construction industry. To find more information about this project and to stay updated with its progress, visit www.eng.ed.ac.uk/tall-buildings.

The Centre hosted the 2012 Lloyd's Register Educational Trust (LRET)/University of Edinburgh Global Technical Leadership Seminar in Fire Safety Engineering. This was the second in a series of three annual week-long intensive seminars ('think tanks') focused on areas related to fire safety engineering. The seminar the theme of 'The future of structural fire engineering' was held near Gullane in Scotland in June. Participants represented leading international architects, engineers and construction managers together with staff and students from the University of Edinburgh.

The next event is scheduled for May 2013 and will focus on sociological issues surrounding fire safety engineering, in conjunction with the Integrating Technical and Social Aspects of Fire Safety Engineering and Expertise (IT-SAFE) project currently running at the University of Edinburgh. The IT-SAFE project is an interdisciplinary research project between the BRE Centre for Excellence in Fire Safety Engineering and the School of Social and Political Science, under the leadership of Professor Robin Williams (Sociology) and Dr Luke Bisby (Fire Safety Engineering).

Figure 1: Burner testing is carried out in the purpose-built, heavily sensored test compartment, constructed within the Burn Hall facility at BRE's Watford site

In collaboration with the University of Toronto and the University of Western Ontario in Canada, the University of Edinburgh submitted an entry to the Bill & Melinda Gates Foundation's 'Reinvent the toilet challenge'. The team's design which uses smouldering combustion as a means to dispose of solid waste claimed 3rd place in the competition (Figure 2).

The Centre was well represented at many of the major conferences in the field this year. Notably, some of the team helped to organise a successful mini-symposium on Performance-based fire safety engineering of structures as part of the 1st International Conference on Performance-based and life-cycle structural engineering, held in Hong Kong in December.

Figure 2: Professor José Torero talks Bill Gates through the smouldering process experiment which was central to the Centre's entry to the 'Reinventing the toilet challenge'.

Figure 3: Dr Stephen Welch (University of Edinburgh) sporting the Centre's own tartan scarf with fellow graduates and Professor Bart Merci (University of Ghent) at the first IMFSE graduation ceremony in Ghent, July 2012.

Members of the Centre have also enjoyed numerous individual achievements. Notable among these is Dr Luke Bisby's appointment as the first ARUP Professor of Structures and Fire. This follows from his previous appointment as the Ove Arup Foundation/Royal Academy of Engineering Senior Research Fellow in Structures in Fire.

This past year has seen the graduation of five PhD students from the BRE Centre for Fire Safety Engineering, including Dr Nicolas Bal and Dr Freddy Jervis who were sponsored by BRE Trust. Summaries of their projects can be found on the following pages. All theses produced by the Centre can be found in electronic form at: http://www.era.lib.ed.ac.uk/handle/1842/1154.

This year also saw the graduation of the first class from the International Masters in Fire Safety Engineering (IMFSE) (Figure 3). The IMFSE, one of the numerous Masters programmes run at the Centre, is a two-year EU Erasmus Mundus degree course for which students spend time studying at the Universities of Edinburgh, Ghent (Belgium) and Lund (Sweden).

For further information on any of the projects that follow, contact Professor Luke Bisby
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Uncertainty and complexity in pyrolysis modelling

Nicolas Bal, Guillermo Rein and José Torero

BRE Centre of Excellence in Fire Safety Engineering

This project focused on the calibration of complex pyrolysis models. For the first time in fire safety, it has been demonstrated that the most complex model is not necessarily the most appropriate and that the model complexity should be related to the resources available for calibration. The parameter uncertainty can have more influence on the predictions than the error resulting from the absence of mechanisms required to explain the physical and chemical phenomena.

Background

Despite the constant development of fire modelling tools, the current state-of-the-art is still not capable of accurately predicting solid ignition, flame spread or fire growth rate from first principles. The condensed phase, which plays an important role in these phenomena, has been widely studied, allowing the development of numerical pyrolysis models with an increase in the physical and chemical mechanisms.

This growth in complexity of the models has been justified by the implicit assumption that models with more parameters should be more accurate (the prediction error is shown by the continuous blue curve in Figure 1). However, as a direct consequence, the number of parameters required to perform a simulation has increased significantly. A problem arises when the uncertainty in the input parameters builds up beyond a certain level in the model output (prediction uncertainty is shown by the dashed red curve in Figure 1). The overall error induced by the parameters' uncertainty balances out the improvements obtained by adding new parameters, leading to an optimum (or at least more appropriate) level of complexity (see the green point in Figure 1). The calibration of the parameters tends to reduce the parameters' uncertainty and therefore change the optimum level of complexity.

While one of the first modelling tasks is to select the appropriate model to represent a physical phenomenon, this step is often subjective, and detailed justification of the inclusion or exclusion of the different mechanisms is often absent. The issue of how to determine the optimum level of model complexity is becoming a major concern and this work presents a methodology for estimating the appropriate level of complexity for polymer pyrolysis modelling prior to ignition. The study used polymethylmethacrylate (PMMA) which is a reference material in fire dynamics as a result of the large number of studies of its pyrolysis behaviour. The methodology employed was based on a combination of sensitivity and uncertainty analyses.

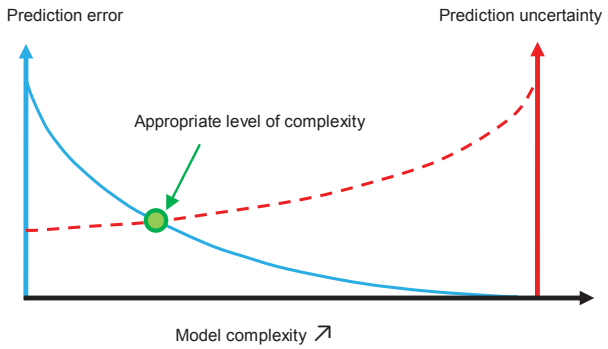

Figure 1: Schematic of the relationship between prediction error (lack of mechanisms to explain a phenomenon), prediction uncertainty (related to the parameter uncertainty) and model complexity

Research programme

The project was divided into three parts:

- evaluation of the prediction error due to the lack of mechanisms
- assessment of the prediction uncertainty resulting from two different parameter calibration processes which are increasingly used, especially in the context of performance-based design and forensic analyses:

  - inverse modelling
  - literature database
- identification and improvement of a critical mechanism.

Evaluation of the prediction error
The approach used corresponds to a mechanism sensitivity. It diverges from usual sensitivity analyses which are parametric. The problem has been investigated in two studies: the first using a simple model and the second a complex model.

Using the simple model, different mechanisms were tested to find the minimum set of mechanisms that can explain the experimental results (Figure 2). The mechanism of indepth radiation absorption was shown to be essential to predict the ignition of PMMA samples at extreme heat fluxes (up to 200 kW/m²).

The complex model used was one of the most complex found in the literature and simplifications were introduced one by one, thereby gradually reducing its complexity. For the prediction of the pyrolysis process prior to ignition, the mechanisms of heat transfer (including the indepth absorption mechanism) were demonstrated to have a large influence on pyrolysis behaviour.

Assessment of prediction uncertainty
The variability of the main parameters encountered in pyrolysis modelling was investigated through an extensive survey of the literature. The controlling parameters and the overall level of confidence associated with a solid ignition model were assessed using sensitivity and uncertainty analyses. The results showed that the uncertainty of only a few parameters had significant influence. The parameter controlling the mechanism of indepth radiation absorption (ie the attenuation coefficient) was found to be one of them. When the prediction uncertainty was compared with more than 250 test results, the range of predictions was shown to be significantly wider than the experimental uncertainty.

The influence of the model complexity was investigated using genetic algorithms. Identical matches to experimental results were achieved for various levels of complexity (Figure 3), demonstrating the presence of compensation effects between the mechanisms and optimised parameters.

Identification and improvement of a critical mechanism
The mechanism of indepth radiation absorption appeared to be critical in the two previous studies. The results were sensitive to the mechanism and the variability of its main parameter (ie the attenuation coefficient) was large. Experimental investigations were therefore carried out to improve understanding of the variability of the attenuation coefficient (scalar). The use of different heat sources revealed its dependency on wavelength. Fundamental investigation enabled the quantification of its spectral heterogeneity (Figure 4) which explained the variability found in the literature when it was considered only as a scalar (no spectral dependency).

Project outcomes/Conclusions

The calibration of a model (pyrolysis model in this project) is extremely important since the parameter uncertainty can be the controlling phenomenon that avoids the increase of prediction accuracy (see Figure 1). This process is a function of the available resources. Advanced techniques such as inverse modelling present some problems due to the coupling between the model equations and the optimised parameters. The database from the literature provided ranges for the input parameters which may already be too wide for simple pyrolysis models.

Due to the parameter uncertainty, the most complex model is therefore not always the most appropriate and the choice of model equations cannot be purely arbitrary. A combination of numerical (sensitivity and uncertainty) analyses and experimental studies is required to avoid an unnecessary increase in the level of complexity of a pyrolysis model.

The two main questions that should drive the specification of a model are:

- what is the minimum level of complexity required to explain the experimental results?
- what level of complexity can be afforded given the resources available to calibrate the model?

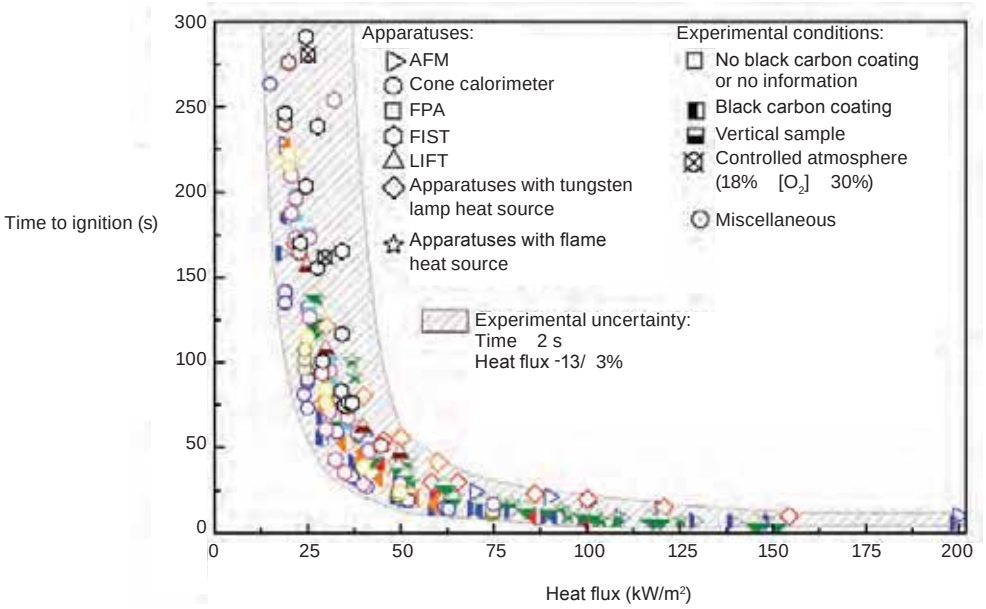

Figure 2: Time to piloted ignition of black PMMA samples for a wide range of experimental conditions in the literature[1]

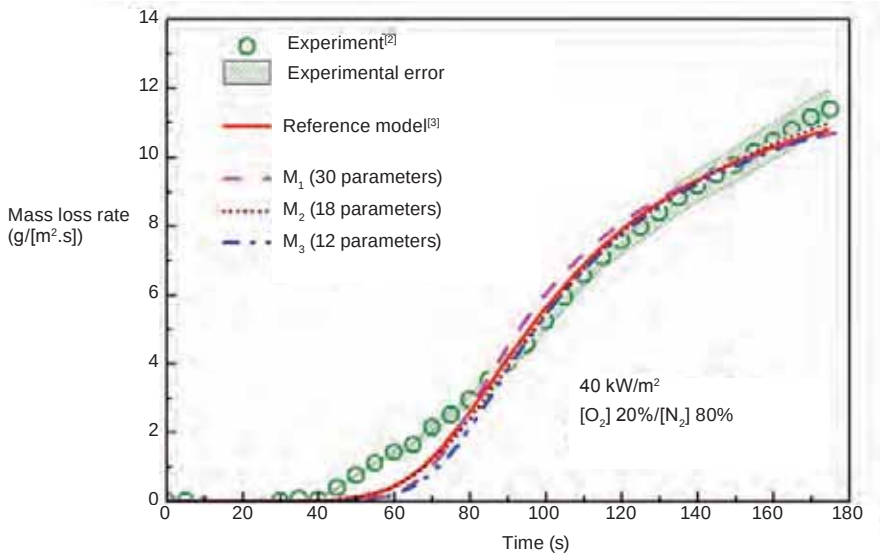

Figure 3: Comparison of the mass loss rate measurement with the predictions from four pyrolysis models of different complexity (number of parameters)

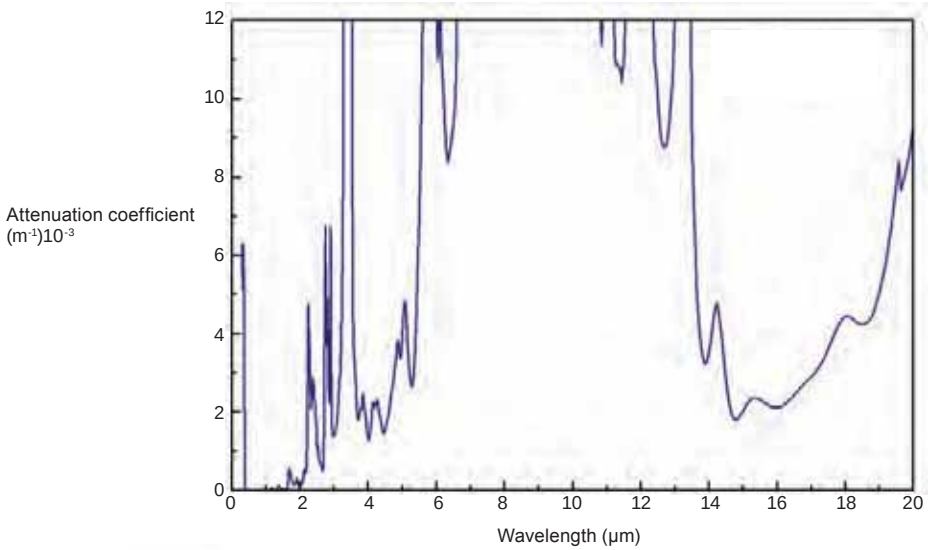

Figure 4: Spectral distribution of the attenuation coefficient for Plexiglass

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Application of fire calorimetry to understand factors affecting flammability of cellulosic material: pine needles, tree leaves and chipboard

Freddy Jervis

BRE Centre of Excellence in Fire Safety Engineering

Calorimetry, the science of measuring heat from chemical reactions and physical changes, is one of the most valuable tools that fire safety engineering has at its disposal. This project reported a range of calorimetric studies performed on cellulosic material from the natural and built environment. All experimental tests described here were undertaken using the fire propagation apparatus (FPA), the state-of-the-art calorimeter for fire safety studies. The experimental techniques presented here show how invaluable calorimetry is in giving insight into the combustion dynamics of fire-related processes.

Background

Calorimetric devices such as the cone calorimeter and the fire propagation apparatus (FPA) give us the means to evaluate and understand how different materials burn at a small scale. Due to fire being affected by many different environmental factors, these devices help us to isolate and examine how each factor affects fire as a whole and to apply this knowledge to tools that can be used at larger scales.

Research programme

Burning of live and dead pine needles
Pine forests present a relatively high flammability risk, largely comprising pine needles. Different moisture content, flow conditions and their inter-relationship were studied on the different parameters affecting the combustion processes. Overall, the results showed that fire physics and chemistry vary with fuel and flow conditions and that moisture content is not the only difference between live and dead fuels but that the needle bed physiochemical mechanisms matter as well. Figure 1 presents results for peak heat release rate (HRR) for the different needle groups studied and the effect of flow and drying.This is the first time calorimetry data on the burning of live and dead pine needles have been presented.

The effect of different pine needle species, fuel load and imposed heat insult and the inter-relationship between these variables was shown to have a strong effect on the overall combustion process. Fuel load was shown to be an essential condition as it gives a direct indication of the intensity of the fire. Figure 2 shows these results for peak HRR with varying fuel load for each species. Flow was shown to have a varied effect depending on the fuel load; it can either aid or be detrimental to the overall combustion process, especially relating to ignition times.

Effect of leaf morphology on flammability
The Triassic/Jurassic boundary was a time period of major environmental changes and therefore of great importance. Representative natural fuel samples from this time period were used to evaluate fire activity as a whole during the period. The study showed that smaller leaf area and larger surface area to volume ratio have a strong correlation with an increase in flammability of these fuels. Figure 3 shows some of these results, illustrating the effect of time to ignition with varying surface area to volume ratio.The research presents new insight into how leaf morphology can be used as a tool to assess the effect of fire activity around the world and how closely vegetation is linked to this.

Flammability of chipboard
The burning behaviour of wood, an inhomogeneous, non-isotropic material, presents researchers with a complex problem. It has for centuries been a preferred construction material and is still widely used in construction today.

Different oxygen levels, heat insults, material thicknesses and densities, and the inter-relationship between these variables, were assessed to observe the effect on the flammability of chipboard. Density and thickness was shown to have little effect on the overall burning dynamics for thermally thick samples

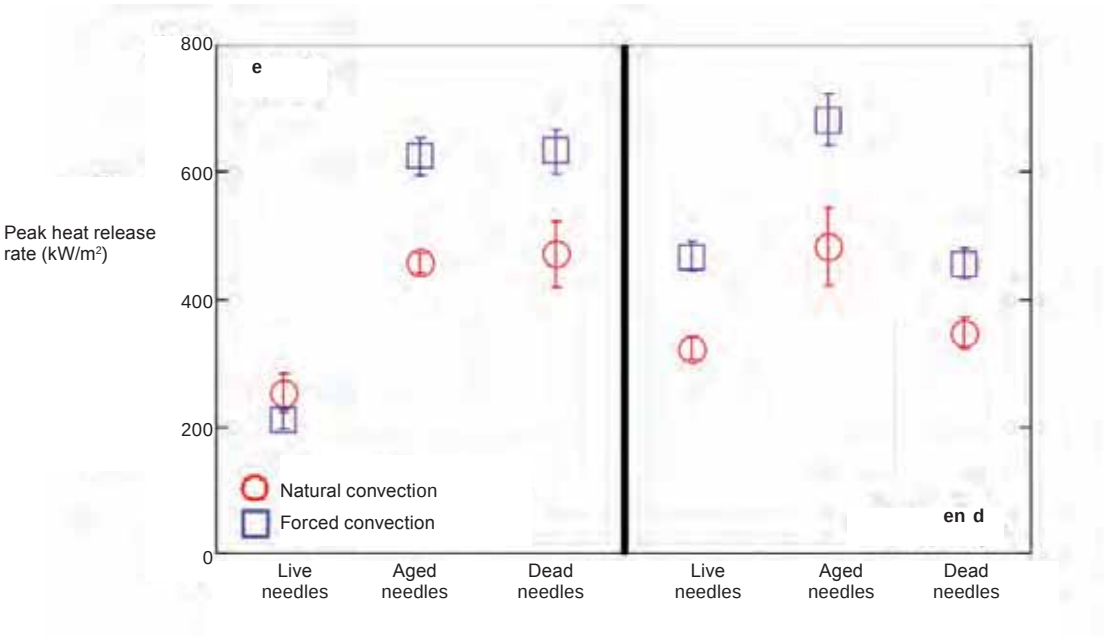

Figure 1: Peak heat release rate on different needle groups

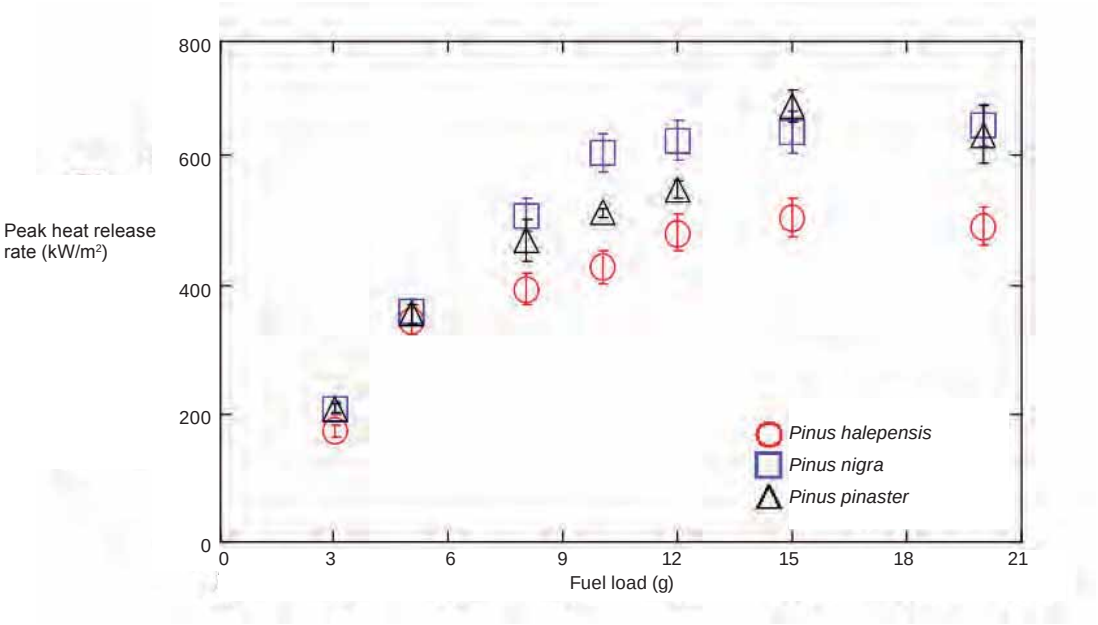

Figure 2: Effect of fuel load on peak heat release rate for different needle species

apart from the increased fuel content. Oxygen levels and imposed heat insults, however, showed a wide range of effects and the inter-relationship proved to be quite important during the combustion process. Figures 4 and 5 show the results of the effect on HRR of oxygen concentration and thickness and density, respectively. The research outlined how char formation is affected by the different variables and how important this process becomes in the overall combustion process.

Project outcomes/Conclusions

Calorimetric studies were presented that illustrate the use of FPA devices to study the effect of varying environmental conditions and the importance of their inter-relationships on both natural and built environment fuels. The project highlights the importance of first establishing the dynamics of the combustion process in order to be able to extract the combustion parameters that are needed for improving fire modelling in both natural and built environments.

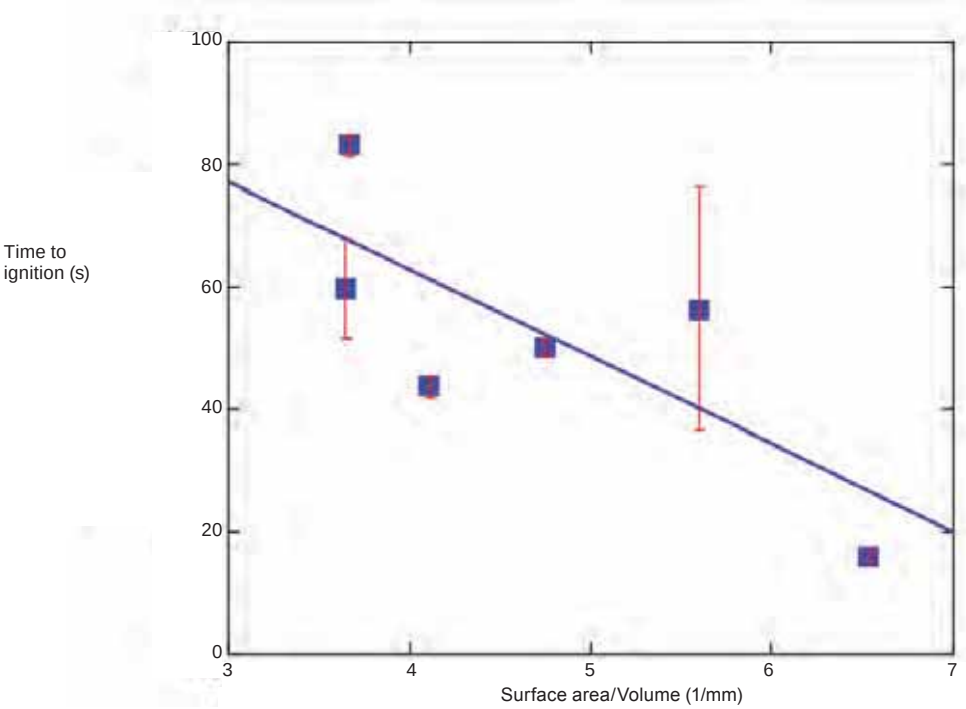

Figure 3: Effect of surface area per volume on time to ignition

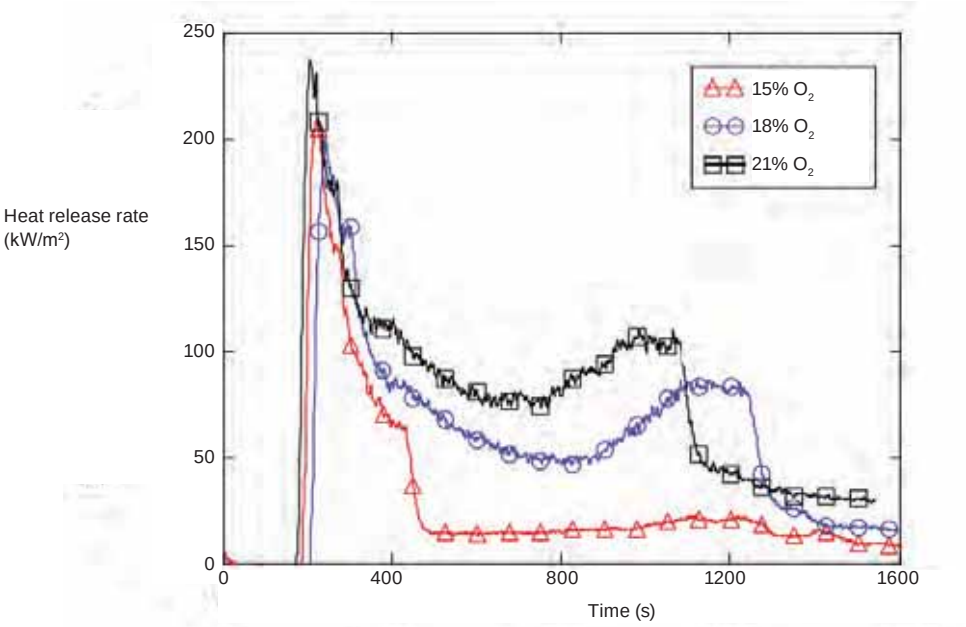

Figure 4: Effect of oxygen concentration on heat release rate for low-density chipboard

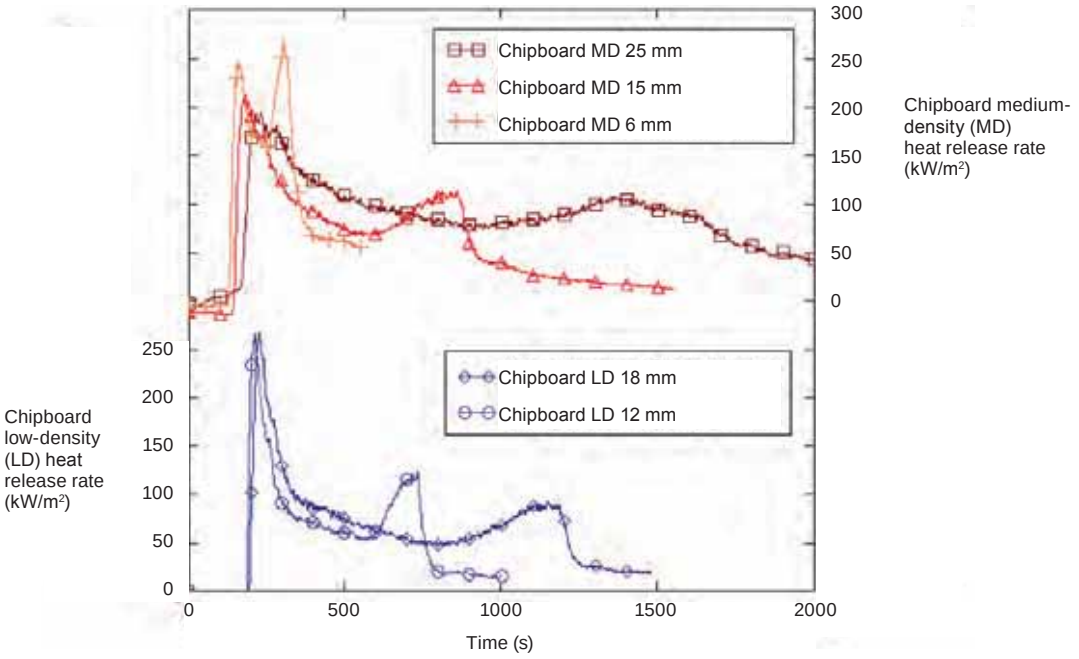

Figure 5: Effect of density and thickness on heat release rate of chipboard

Publications/Research output

Belcher C M, Mander L, Rein G, Jervis F X et al. Increased fire activity at the Triassic/Jurassic boundary in Greenland due to climate-driven floral change. Nature Geoscience 2010, 3 (6) 426–429.

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Sustainability

Sustainable substructures

Ken Watts

Building Technology Group, BRE

A key aim of this project was to maintain and extend BRE's lead in the development of sustainability tools and best practice guidance. This was achieved through collaboration with the BRE Global IMPACT project[1], which has produced an embryo carbon calculator for foundations based on 'decision' flow charts designed as part of this project. Feedback from industry sources and via a BRE-sponsored seminar has ensured that the decision charts are informed and logical, and incorporate all the mainstream innovations in low-carbon foundation techniques. This project has described in detail approaches to attaining sustainable substructures and has set out the potential for developing the work.

Background

Foundations are not currently included in the Code for Sustainable Homes[2], or dealt with specifically within BREEAM[3]. It has also been recognised that substantial CO_2 emissions are associated with the constituents of most traditional foundation types. The construction industry is increasingly aware of the need to reduce the carbon 'cost' associated with foundation design, which can be a major proportion of the embodied energy for the whole project, particularly for low-rise commercial and residential developments. It is recognised that sustainability in foundation systems must now be embraced in much the same way as the supported structures themselves. The rationale for this project was to develop best practice guidance, together with robust methodologies, for assessing the environmental impact of foundations with the aim of reducing the impact of construction and maintaining BRE's lead in the development of sustainability tools.

BRE Information Paper 11/10[4] on sustainability in foundations provided a useful preview and summary of the issues concerning existing foundation practice and the influence of ground conditions on foundation choice. This project took as its starting point the almost infinite variability of the ground and the resulting complexity of decision and choice in foundation design. The project objectives are stated as '…to carry out a state-of-the-art study into more sustainable foundations… and to investigate and develop a BRE-owned prototype engineering-based methodology for assessing the sustainability of foundations'.

To these ends 'decision' flow charts or a 'matrix' were considered to be essential to setting out the logic behind both geotechnical necessities in the process of foundation choice but also to provide a framework for introducing all innovative techniques aimed specifically at reducing the carbon footprint of substructures. In particular, it was recognised that many stakeholders concerned with sustainability issues, but without a geotechnical background, would benefit from a more visual explanation of the technical complexities.

Research programme

The research programme focused on three main aims.

1. To develop a means of setting out the main issues requiring consideration and quantification before a foundation solution can be arrived at
2. To engage a broad range of industry expertise to ensure that advice and recommendations are based on state-of-the-art knowledge and that industry thinking and innovation in this area is captured
3. To explore the way forward, including possibilities and means by which these achievements can be used ultimately to develop a BRE-owned prototype engineering-based methodology for assessing the sustainability of foundations

1 Developing decision flow charts/matrix

Structures above ground may take many forms but the materials used are limited in number and can be defined with great precision. Technically adequate foundations for structures are dependent on a great many variations in ground conditions, which are difficult to categorise other than in relatively simple terms and a combination of factors can have a marked influence on a suitable foundation type.

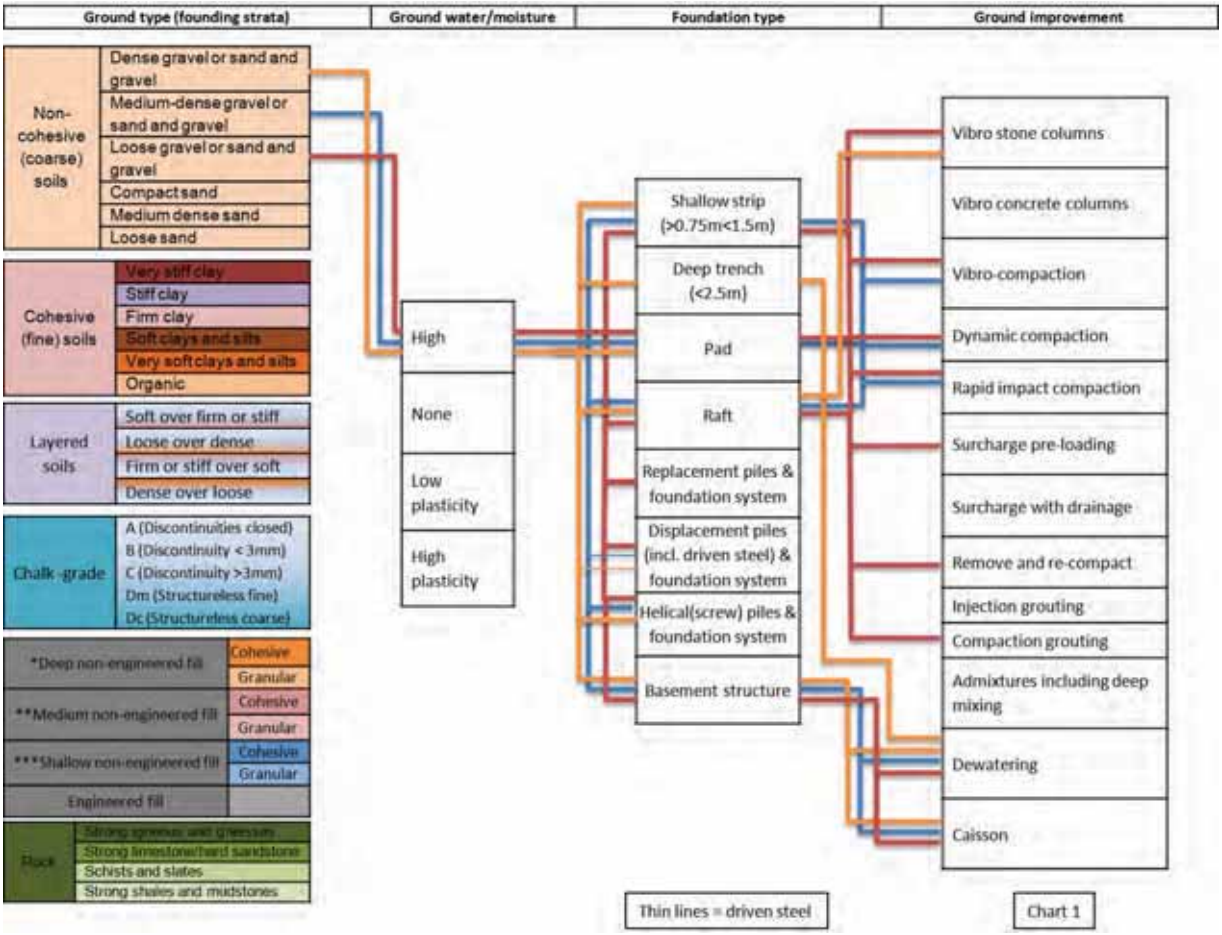

Figure 1: Suitable foundations and ground improvement options for medium depth non-engineered fill

The first step in this process was to develop flow charts based on the logical decision sequence that would start with information about the ground at a development site (first matrix factor). Ground type, along with other ground-related factors such as level of ground water and volumetric stability (second matrix factor) will largely determine the range of commonly adopted foundation types (third matrix factor) that can be safely constructed in that ground. Where existing ground conditions do not readily permit the type of foundation required (other than deep piled foundations), options to improve those conditions are available in the form of ground improvement techniques (fourth matrix factor). Figure 1 shows a typical chart.

2 Engaging with industry

Credibility is a key element to anything that BRE is involved in and seeking wider industry input was considered essential. Original project partner, Roger Bullivant Ltd, set up a team comprising senior engineering managers to carry out a peer review of the draft charts. This provided the opportunity to discuss in detail the views of experienced foundation professionals committed to the project ethos in general and direction it had been taking specifically. The engineers concluded that the flow charts would be extremely useful to both engineering professionals and non-geotechnical users as a basis for demonstrating the complexity associated with foundation engineering.

A *Sustainability in foundations* seminar, jointly organised by the Deep Foundations Institute and BRE, was held in November 2011 at BRE and was well attended by a wide range of industry stakeholders. The project aims and objectives were well received and a number of delegates offered assistance. This led to further detailed and informed input, particularly with regard to innovative foundation solutions aimed at reducing material and installation resources.

A significant finding was that the type of building should feature at an early stage in the decision diagrams, possibly being the first of the fundamental criteria, ie the prime variable that would drive the decision process. This is odd from a geotechnical viewpoint given that on any particular site, the ground and groundwater conditions are an established fact and all foundation considerations must follow from that. However, from a developer's viewpoint the availability of land and the type and potential occupancy of buildings are the prime consideration.

The general approach in the commercially orientated construction industry world is to make the foundation solution fit the development. The factors likely to preclude a particular development would be:

(a) a suitable foundation solution being technically impossible
(b) a suitable foundation solution being uneconomic.

Assuming neither (a) nor (b) apply then efforts can be made to minimise the carbon weighting of the available viable solution(s). With this consideration in mind, it would seem reasonable to factor in the building type either as the first consideration preceding the 'Ground type/founding strata' column in the flow charts or immediately preceding the 'Foundation type' column (see Figure 1).

Figure 2: Helical steel (screw) piles being installed on the BRE Innovation Park, Watford

The project has highlighted several recent innovations in foundation construction, some of which have been specifically developed to reduce the embodied energy in substructures. Helical steel (screw) piles, in particular for housing, are being actively marketed by several contractors. They potentially offer significant carbon savings in materials and construction and also benefit from their ability to be removed and reused. Figure 2 shows a typical installation at the BRE Innovation Park.

3 Exploring the way forward

The potential of the charts and the embryo calculator developed for IMPACT[1] is to apply life-cycle analysis (LCA) to all the foundation techniques and technologies using the BRE Environmental Profiles Methodology[5]. The main stumbling blocks to the inclusion of foundations/substructures in ***The Green Guide to Specification***[6] and the Code for Sustainable Homes[1] are stated in ***The Green Guide*** as:

> ***'the provision of representative functional units for these elements',***
> ***'comparable specifications'.***

It is also clear that the information currently available on substructures and ground improvement processes falls well short of that required for a robust LCA.

The European Federation of Foundation Contractors (EFFC) and the Deep Foundations Institute (DFI) have let a contract to develop a standardised carbon calculator for deep foundations and ground improvement works. The IMPACT calculator will be used by member companies to compare different foundation techniques on specific projects and offer clients competitive comparisons between providers on a strict like-for-like basis. BRE expressed its interest in this work and has remained engaged through the process. The first full version of the calculator will be available in summer 2013. This will provide data for BRE to substantially enhance the IMPACT calculator and also will offer significant robust input for developing LCAs for a substructure element in future editions of the ***The Green Guide***.

It is recommended that further research is undertaken to complete the flow charts/decision matrix and build on the achievements to date. This can now be undertaken based on the EFFC/DFI project outcomes and it is hoped that the two research and industry approaches can be combined with minimum effort to give a full range of foundation specifications which are fully quantified in terms of LCA and to which summary ratings can be applied for a full new element in ***The Green Guide***.

Project outcomes/Conclusions

- The application of environmental ratings through LCA of building substructures (foundations) has been studied and a method of assessing the complex relationship between inherent ground conditions, building type and foundation options has been devised using BRE professional resources and liaison with industry.
- Decision flow charts have been created to provide a means of visualising:
  - the range of ground conditions generally encountered in the UK
  - the 'traditional' and innovative foundation options that can be employed
  - importantly, the geotechnical engineering logic that connects the various options with the prevailing ground conditions on any particular site.
- A 'first iteration' carbon calculator has been created using these flow charts through collaboration with the BRE Global IMPACT project[1]. However, it has become evident that there is a substantial shortfall in the environmental data needed to achieve robust LCAs for the many specifications available.
- Liaison with the ground-engineering industry through profiling the project at an important industry seminar on sustainable foundations provided valuable feedback on project direction and detail. The cross-fertilisation of ideas at this vital forum led to engagement of BRE with the EFFC/DFI project to create a standardised Carbon Calculator for Foundations.
- Further detailed development of the flow charts will provide a definitive decision matrix. Output from the EFFC/DFI Carbon Calculator can now be attached to the matrix, resulting in a robust set of fully quantified foundation specifications suitable for inclusion in ***The Green Guide***.

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Updating the BRE standard house types used for SAP and BREDEM modelling

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The 'standard' dwellings have been devised to be typical of different categories of dwelling. These standard dwellings are valuable when used with modelling software, BREDEM[1] and SAP[2, 3], for calculating energy consumption, energy costs, carbon dioxide emissions, and savings from energy-efficiency measures.

This project reviewed the 'standard' dwellings and provided an updated set of drawings for 22 standard dwellings, together with their dimensions for entering into BREDEM and SAP. The report provides a comprehensive specification of the standard dwellings which will enhance the quality of results from BREDEM and SAP.

Background

The BRE standard house types provide data for national government and other organisations to use in devising effective measures for reducing CO_2 emissions and energy use, which can be reliably projected across the entire housing stock. Using these data, government can set national targets and issue guidance on how to achieve these targets through organisations such as the Energy Saving Trust who have published guides such as ***Energy efficiency and the Code for Sustainable Homes: Level 3***[4] and ***Sustainable refurbishment***[5].

The current standard house types are not the first to have been developed and used by BRE. The first set of standard house types was developed in 1990 for the Building Environmental Performance Analysis Club (BEPAC) for use in energy modelling benchmarking for which the forecasts of different thermal prediction models could be tested. The standard house types at that time consisted of six main types which were based on 'averages' of many types that were indicative of the broad cross-section of existing dwellings. The document also included a comprehensive set of modelling assumptions to ensure that all subsequent modelling was done on a like-for-like basis.

The 1990 set of house types was updated and expanded in 1999 for the Department of the Environment, Transport and Regions. This revised set of 13 dwellings, again based on 'average' types, was intended to provide information on running costs, CO_2 emissions and energy use for the government's Energy Efficiency Best Practice programme (and other programmes). Standard dimensions were provided for all the dwellings together with a series of suggested specification inputs, although some degree of flexibility was accommodated for modelling in the BRE domestic energy model (BREDEM)[1] and the Standard Assessment Procedure (SAP)[2, 3].

This project recognised the need to revise the 1999 standard house types by:

- reviewing the information provided for the existing set of dwellings and providing house types that are more typical of current housebuilding practice
- reviewing the typical specifications of both existing and new-build dwellings to ensure that the output data generated using the standard house types will provide the most accurate and up-to-date information for policymakers, designers, etc.

Since the current set of standard house types was compiled 12–13 years ago, the revision also needed to take account of the requirement to project CO_2 emissions from both existing (and also pre- and post-refurbishment) and new dwellings in the short, medium and long term.

Research programme

The project comprised the following stages.

- Determine which common ***existing*** dwelling designs should be included in the report.
  - Analyse English Housing Survey data[6] to determine which major typical dwelling types are not present in the current report.

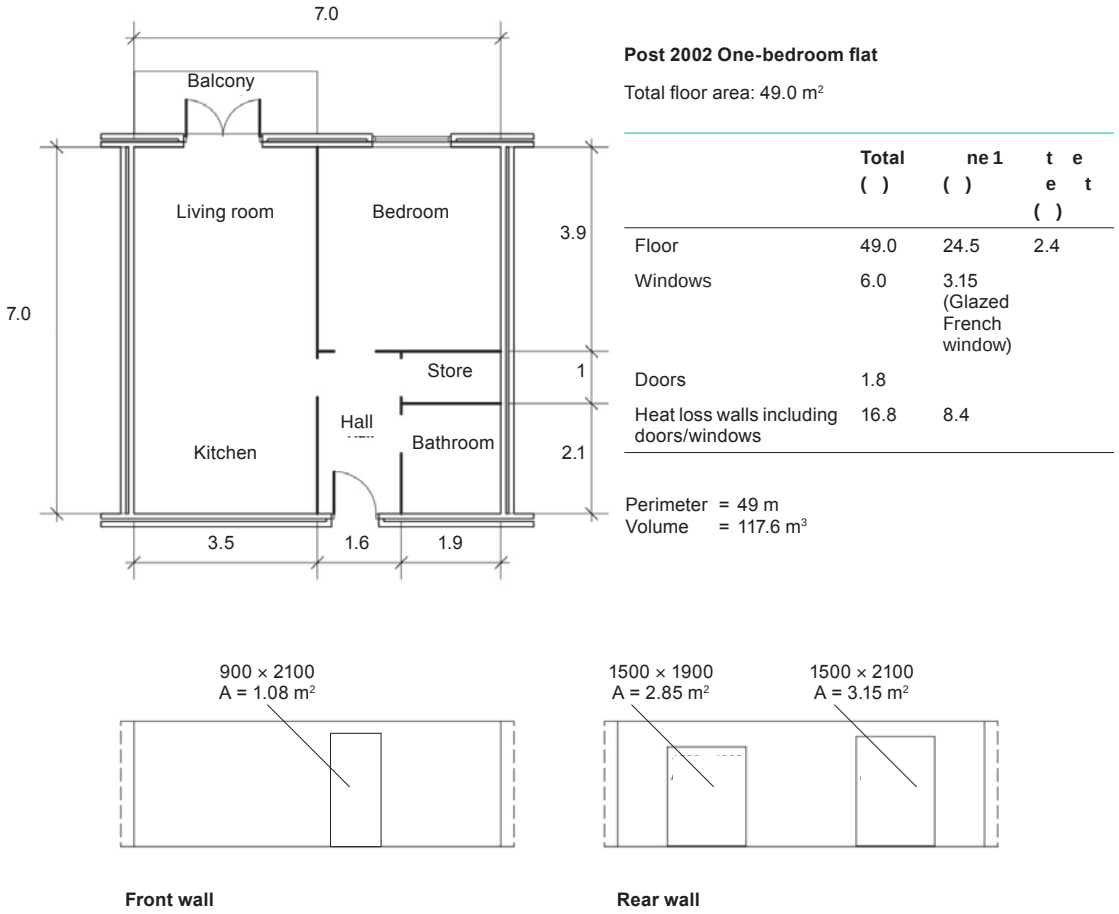

Figure 1: Drawing for the post-2002 one-bedroom flat (49 m²), one of the new house types included in the new set of 22 standard house types

- Determine the range of contemporary ***new*** dwelling designs which should be included in the report.
  - Analyse NHBC completions figures for the past three years to inform the selection of house types.
- Determine typical specifications for both existing and new dwelling designs.
  - Determine the prevalence of clear cavity party wall construction for the existing standard house types.
  - Produce a Specification Data Sheet for each additional dwelling type.
- Model all dwelling specifications using SAP software.

Project outcomes/Conclusions

Government policy can only be as useful as the data that are used to frame it. It is therefore essential for appropriate standard dwellings to be used for modelling which generate these data in the area of energy, carbon and cost savings from the housing stock.

This project has updated the 'standard' dwellings from 13 to 22, and provided an updated set of drawings with their dimensions for entering into BREDEM and SAP. The comprehensive specification of the standard dwellings will enhance the quality of the results from BREDEM and SAP modelling.

In addition, previous SAP/BREDEM modelling of existing dwellings did not include the energy used for heating that is lost through the party wall thermal bypass mechanism. This becomes even more relevant when determining the heating energy requirement for a dwelling following an energy-efficiency refurbishment since currently there are no approved methods of filling a clear cavity party wall.

Similarly, in terms of SAP modelling the predicted energy use of newer homes moving towards low-energy homes and net zero-carbon homes that will be required from 2013 and 2016, respectively, will be invaluable to policymakers in these areas.

Publications/Research output

An update of the report, ***BRE standard dwellings for energy modelling***, originally written by P J Iles, January 1992, has been produced for use in BRE consultancy.

Post-2002 one-bedroom flat (49 m^2)		Building Regulations 2006	Building Regulations 2010
Fabric U-values W/m^2.K	Roof	0.16	0.16
	Walls	0.28	0.28
	Ground floor	0.25	0.25
	Windows	1.80 BFRC g-value = 0.45	1.80 BFRC g-value = 0.45
	Doors	2.45 (half D/G)	2.45 (half D/G)
	y-value	0.08 (Accredited construction details)	0.08 (Accredited construction details)
	Thermal mass	Medium	Medium
Ventilation	Airtightness m^3/(m^{2}h)	5.0	5.0
	Type	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans
	Number of flues	0.0	0.0
	Number of chimneys	0.0	0.0
	Number of extract fans	2.0	2.0
	Number of sheltered sides	2.0	2.0
Heating	Type	Boiler system with radiators	Boiler system with radiators
	Boiler	Gas combi boiler SEDBUK B-rated (Efficiency = 90%)	Gas combi boiler SEDBUK B-rated (Efficiency = 90%)
	Controls	Programmer, room thermostat, and TRVs room-sealed, fanned, weather compensator	Programmer, room thermostat, and TRVs room-sealed, fanned, weather compensator
	Water heating	From combi boiler	From combi boiler
Lighting	Low-energy lighting	100%	100%
CO_2	TER	23.65	18.75
	DER	22.45	24.1
	Improvement	**1.20%**	**-28.50%**
Energy-efficiency rating (SAP rating)		**80 - C**	**80 - C**
Environmental impact rating		**85 - B**	**85 - B**
Running costs (£/yr)		**£287**	**£287**

Figure 2: Specification data sheet for the post-2002 one-bedroom flat (49 m^2), one of the new house types included in the new set of 22 standard house types

BFRC = UK's national system for rating energy-efficient windows; D/G = double-glazed; SEDBUK = Seasonal efficiency of domestic boilers in the UK; TER = target emissions rate; DER = dwelling emissions rate.

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BRE Centre of Excellence for Sustainable Design of the Built Environment, Cardiff University

Christopher Tweed

Professor, Sustainable Design of the Built Environment

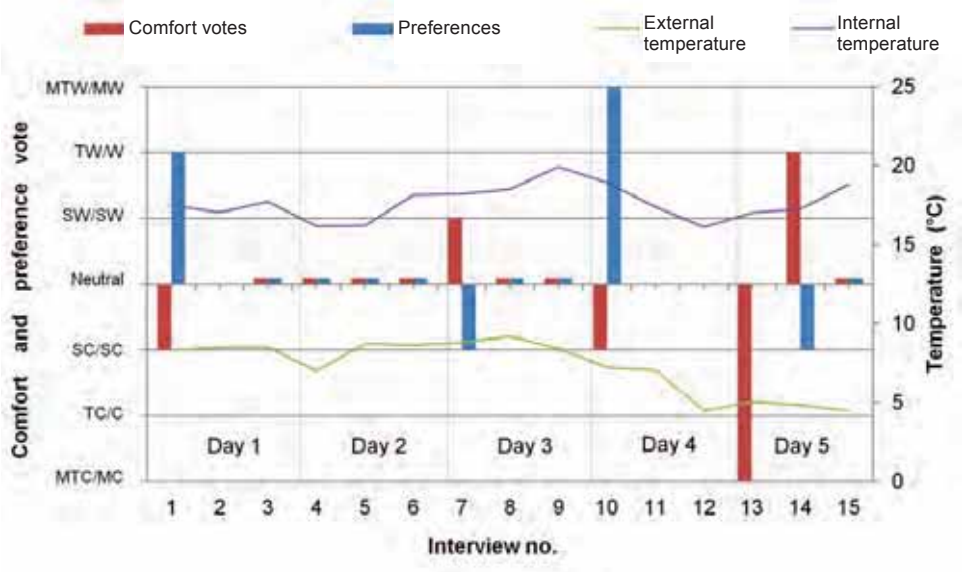
The BRE Centre for Sustainable Design of the Built Environment (SuDoBE) is based in the Welsh School of Architecture (WSA) at Cardiff University. The Centre was established in 2007 with the appointment of its Director, Professor Chris Tweed.

The main focus of the Centre's research is on improving interactions between people and the built environment and recognising the need for a holistic approach to sustainable design which embraces social and economic aspects of sustainability as well as environmental concerns. If carbon dioxide emissions and reliance on energy consumption are to be reduced, ingenuity is required to develop solutions to persuade people to change their ingrained habits.

In the past year, the Centre has continued to develop its research portfolio on the evaluation of building performance. Although this entails the physical measurement of the thermal and visual environments created in buildings, the Centre's interest is primarily focused on what these conditions mean for the occupants and their experiences in buildings. Three projects have significant elements of post-occupancy evaluation.

Carbon, control and comfort: user-centred control systems for comfort, carbon saving and energy management

The results from this collaborative Engineering and Physical Sciences Research Council (EPSRC)-funded project have shown significant variations in the internal environmental conditions across similar properties and across different spaces within these. The Centre has been working with King's College London on developing a detailed understanding of how people create and maintain thermal comfort conditions in their own homes. This has involved comfort surveys, physical monitoring and interviews with occupants. The comfort surveys established



	Comfort scale	
3	Much too warm	MTW
2	Too warm	TW
1	Slightly warm	SW
0	Neutral	N
-1	Slightly cold	SC
-2	Too cold	TC
-3	Much too cold	MTC

	Preference scale	
3	Much warmer	MW
2	Warmer	W
1	Slightly warmer	SW
0	No preference	N
-1	Slightly colder	SC
-2	Colder	C
-3	Much colder	MC

Figure 1: Results from a winter comfort survey suggesting that this occupant may overcompensate mild discomfort (slightly warm or cool) with preferences for more extreme conditions. Courtesy of Dylan Dixon

occupants' votes on perceived thermal comfort and their immediate preferences for changes to the environment, such as to make it warmer or cooler. Although dealing with a small sample of homes, there are indications of wide variation across different dwellings and occupants. An example of the results gained from a winter thermal comfort survey is shown in Figure 1.

Sustainable refurbishment of building façades and external walls (SUSREF)
The SUSREF project was a collaborative project funded by the European Commission under FP7. The main role of the team at SuDoBE was to monitor the hygrothermal behaviour of five external solid stone walls in the harsh climate of North Wales before and after different insulation treatments were applied. Although the official end of the project was in April 2012, the team has worked with Sustainable Gwynedd Gynaladwy (SGG) and Voelcker Architects to continue to collect data on the hygrothermal performance of these walls (Figure 2). The monitoring installations are about to be dismantled and the research outputs on the data collected will be analysed to inform the debate surrounding how best to insulate traditional buildings to improve their energy efficiency.

Low-carbon built environment (LCBE): monitoring the performance of low-carbon technologies
The Centre leads Work Package 6 of the LCBE project and through this consolidates and extends the findings emerging from the other projects described here and developing these into a coherent set of guidelines for evaluating the performance of low-carbon buildings.

Since last year, the team in Cardiff has embarked on detailed studies of two non-domestic buildings:

- Preston Manor Junior School in London (Figure 3)
- the Passivhaus-certified Brackley Care Home, near Northampton.

Figure 3: Preston Manor Junior School, London, designed by HLM Architects. BRE SuDoBE is monitoring physical environment and conducting post-occupancy evaluations. Courtesy of Olivia Guerra Santin

The main focus is on occupants' responses to the thermal environment in these buildings, but informed by measurements of environmental conditions and energy consumption.

Conditioning demand: older people, diversity and thermal experience
The project is funded by EPSRC and EDF and is a collaboration between Manchester, Lancaster, Exeter and Cardiff Universities. The research investigates themes addressed by the carbon, control and comfort project described earlier but focuses on older people and on private sector housing. The research is revealing interesting trends in how older people respond to energy upgrades in their homes. For example, while the

Figure 2: Monitoring the hygrothermal performance of upgraded thick, stone walls in the harsh climate of North Wales. Courtesy of Shiyu Jiang

Figure 4: Comfort 'practices' in the home. Heating and cooling the conservatory. Courtesy of Nicholas Humes

'rebound' phenomenon of energy saving is less than predicted, our results suggest there can be a 'spatial rebound' in which occupants may now use spaces that were previously considered uninhabitable during winter because their overall heating bills have been reduced (Figure 4).

Co-heating project
The SuDoBE team, in collaboration with the other members of the consortium, have completed the NHBC/BRE-funded project on co-heating including a comprehensive report on co-heating as a technique for assessing building fabric performance. A journal article is currently being prepared for publication on the issues surrounding the use of co-heating in low-energy buildings.

Health impact of structural energy performance investments in Wales
This new project has been awarded to Dr Wouter Poortinga, who works closely with the BRE Centre, and Professor Tweed. The research is linked to the work currently being carried out by Christine Suffolk as part of her PhD (see below). The project will start in May 2013 and will include physical monitoring and assessment of thermal comfort in dwellings before and after energy upgrades. The retrofitting is being carried out as part of Stage 2 of the Welsh Government's strategic energy performance investment programme (Arbed scheme), partly funded by the European Regional Development Fund. The research study is being funded by the National Institute for Health Research (NIHR).

PhD students
The following PhD students in SuDoBE are supported by BRE Trust:

- Christine Suffolk
  Rebound and spillover effects: occupant behaviour after energy efficiency improvements are carried out

- Kate Knowles
  Developing effective strategies for design interventions to improve sustainability in existing urban communities

- Gabriela Zapata
  Situated learning in the context of low-carbon design (ie learning from low-carbon design).

In addition, two more PhD students are working closely with BRE as their industrial partner:

- Timothy Forman
  Maintenance and lifespan of low carbon and energy efficiency retrofits in UK domestic construction (BRE-supported EPSRC CASE Award)

- Mark Waghorn
  Developing low carbon buildings with Welsh timber (BRE-supported Knowledge Economy Skills Scholarship [KESS]).

For further information on these projects or the one that follows, contact Professor Chris Tweed
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Situated learning in the context of low-carbon design

Gabriela Zapata Poveda

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This research investigated the design process for six non-domestic buildings designed by four sustainable architecture firms. The study sought to unveil how low-carbon non-domestic buildings were designed in the 2010 energy regulation transition. The investigation focused on the knowledge and tools used by architects and design team members to embed energy performance in real-time project design. The research documented and compared the design process for six buildings procured by the 'design and build' route.

Background

The UK is committed to reducing its carbon emissions by 80% by 2050 compared with 1990 levels. The aim of the decarbonisation plan for the building sector is that new buildings will be zero carbon by 2020 with transitional reduction targets set in three-year increments:

- 25% by 2010
- 44% by 2013
- zero carbon between 2016 and 2020.

Wales is intending to lead this decarbonisation by aspiring to higher transitional targets. In 2007, the Welsh Government announced the aspiration of new zero-carbon homes by 2011[1]. As the Welsh construction industry adopts more demanding energy regulations, barriers to achieving policy intentions have been identified, highlighting the need to engage with and support the industry in delivering low-carbon buildings.

The process of developing skills, knowledge and supply for technologies and products to achieve the mandated carbon level is estimated by the European Council for an Energy Efficient Economy (ECEEE) to take 10–15 years[2]. Research suggests that the construction industry will have to develop skills, learn the relevant technologies and understand the practical implications of carbon reductions during the transition to zero carbon[3–8]. In this context, the design processes for six non-domestic projects were analysed to investigate how designers incorporate energy considerations in real-time project design, with a focus on the knowledge and tools used for low-carbon building design.

Research programme

The investigation involved the indepth study of four architectural practices to observe how the designers adopted the standards, guidance and the tools for low-carbon design. The study comprised an average of 75 hours in each architecture firm spread over 18–25 visits per firm.

The research used ethnographic methods, such as document analysis, shadowing of work, non-participant observation and interviews. The study focused on the work of the architect but included other design team members such as mechanical engineers, energy consultants and BREEAM assessors. The design process was documented, focussing on knowledge flows and tools used to embed energy performance in new non-domestic buildings.

Special attention was paid to practitioners' deployment of policy mechanisms such as the Approved Document Part L2A, Conservation of Fuel and Power[9], BREEAM[10] and the Simplified Building Energy Model (SBEM)[11]. The data were collated in accordance with the Royal Institute of British Architects' Plan of Work. The analysis was informed by social constructivist theories (eg Communities of Practice) in relation to knowledge creation[12, 13] and Philosophy of technology and human–computer interaction in relation to tools for low-carbon design[14–16]. The social theories examine how a phenomenon develops as a result of the experience, perceptions and social interactions of the members of a group.

The research objectives were to:

- identify the barriers experienced by designers working in low-carbon non-domestic building
- identify the models and routines that facilitate the understanding and inclusion of low-carbon performance in buildings during conceptual and detailed design

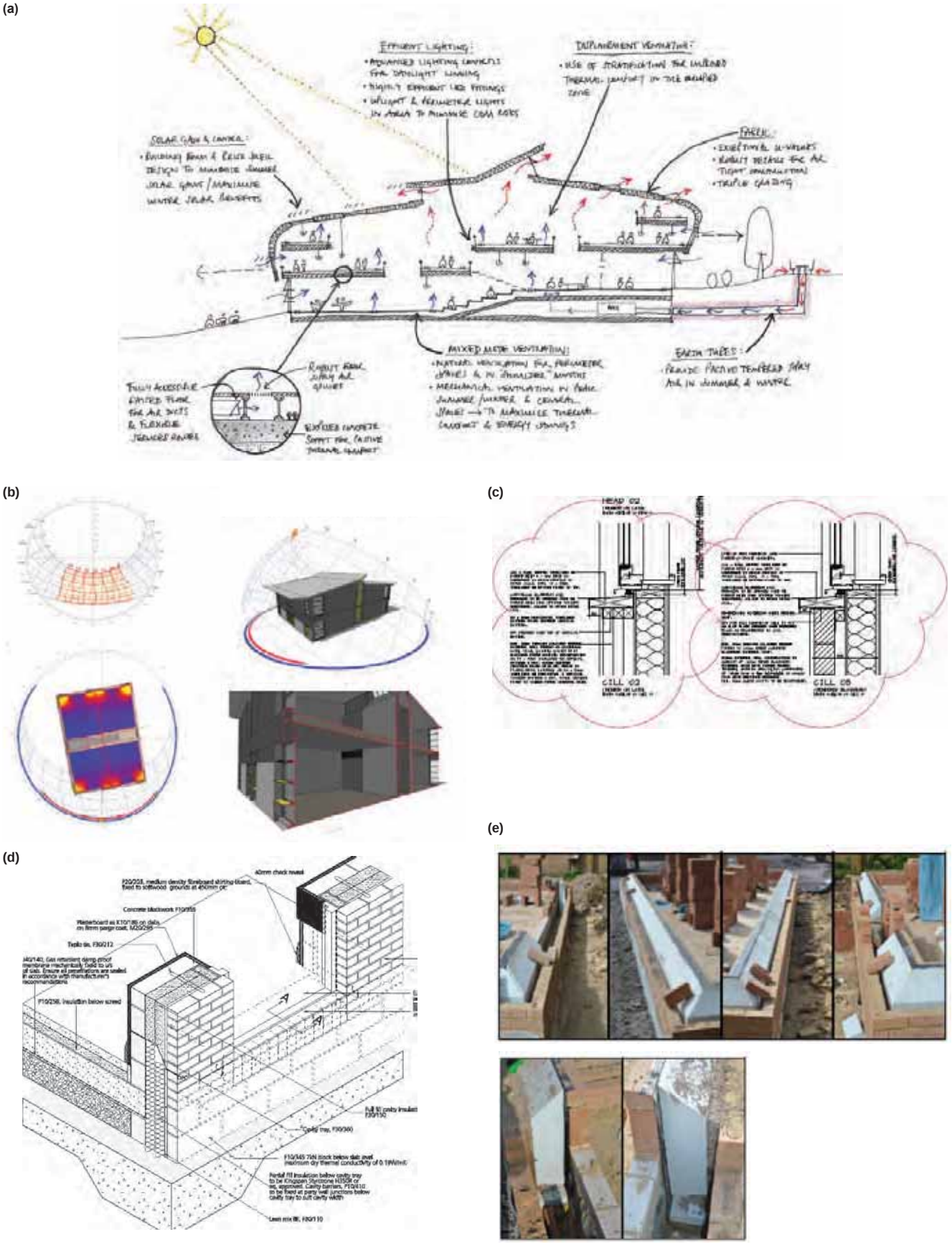

Figure 1: Designers used a variety of methods to embed energy targets in their designs: (a) rules of thumb and experience-based advice benchmarked the project targets and were used to provide a qualitative estimate of performance, (b) simulation tools were used to predict performance, (c) annotations on drawings indicated low-carbon aspirations, (d) fabrication studies were used to improve understanding of how the design would be delivered on site and to develop energy metrics for the construction phase, (e) site visits were used to identify modifications or discrepancies between the design and construction details

- reveal the use of tools in routine project design
- explore the social mechanisms that encourage the inclusion of low-carbon consideration, their dissemination and learning across projects (social factors that enhance knowledge and learning).

In summary, the investigation sought to reveal what designers were doing to embed energy performance compared with what they should be doing.

Project outcomes/Conclusions

The practitioners' perspectives were found to be at variance with the policy dimension, for example:

- differences in project drivers versus policy agenda
- fragmentation between the design and delivery phases
- knowledge gaps
- design process breakdowns
- difficulties in incorporating the tools for low-carbon design in the process.

Mandatory requirements are perceived to be key to achieving the low-carbon policy agenda. Due to higher targets, practitioners are adapting their ways of working and new forms of practice are emerging. They use a variety of informal tools and routines to understand, assess and embed the energy targets in the design. There is a preference by practitioners to use heuristics, experience and collective knowledge in the design process. The official tools such as SBEM and simulation software have to be legitimised and incorporated in the process by the designers.

Overall, the research has given an improved understanding of designers' preferences and support needs in the process: how knowledge is disseminated and how tools and design aids are used.

The field studies suggest that the designers are:

- developing performance investigations to relate the energy performance targets to indicators of design, construction and operational phases
- using informal low-carbon aspirations that exceed the mandatory targets by regulations
- using a variety of informal tools to mediate the performance dialogue and to calculate performance.

It was inferred that the simulation tools and the official compliance tools are not necessarily located in the centre of the performance dialogue. The designers in the case studies relied on their experiential knowledge and social networks to improve their collective knowledge about performance.

The investigation has identified the following features.

- The problem-solving tasks used in the design process:
  - during conceptual design (outlining, understanding, calculating)
  - during detailed design (transposing, following and learning)
- The processes involved in understanding performance: from qualitative estimation to quantitative analysis
- The informal tools that assist the performance dialogue and facilitate the use of official tools in the process
- The stages in the process which are prone to fragmentation and where knowledge gaps are likely to emerge (This reflects the need to develop improved knowledge about performance)
- The need to close the learning cycle in the design process in the light of construction and operational phases (as-built and in-use performance)

Publications/Research output

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Design

Comparison of UK and China sustainable building assessment methodologies

Adam Tilford, Simon Cross and Christopher Gaze

Building Futures Group, BRE

The aim of this project was to compare BREEAM with the Chinese Standard for the Evaluation of Green Buildings (popularly known as Three Star) in order to understand the differences between the schemes. The results could be used to consider the relative sustainability of a building rated under each assessment method.

Background

Since the launch of BREEAM in 1990, a number of building assessment methodologies have been developed around the world. The latest of these is the Chinese Evaluation Standard for Green Buildings, popularly known as Three Star. The aim of this project was to compare the BREEAM and Three Star methodologies:

- to ensure that BREEAM is maintained as the leading environmental assessment method
- to improve understanding of the needs of international developers who may be certifying buildings under both schemes.

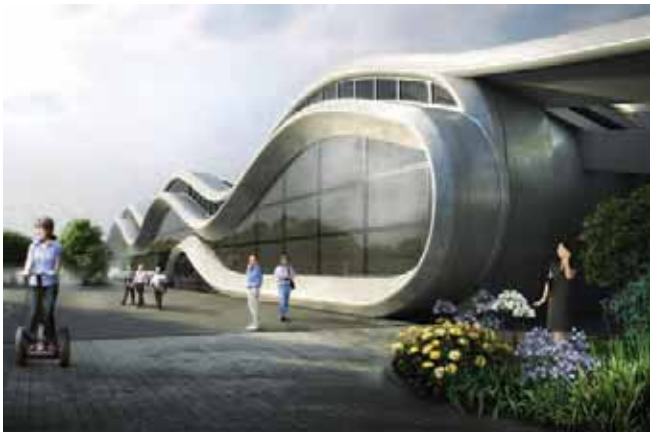

Figure 1: A computer-generated image of the proposed Visitor Centre at Beijing Green Buildings Park which has been designed to achieve both a three star rating under the Chinese Evaluation Standard for Green Buildings and an Outstanding rating under BREEAM

Research programme

The initial stage of desk-based research undertaken for this project involved gathering information from contacts in China on the Three Star method and the regulations which it overlays.

Having established acceptable English translations of key documents, the content of the Three Star scheme was analysed in the context of the basic Chinese regulations. A comparison with BREEAM was made by drawing up a table which mapped the similarities and differences of the two schemes. Both are appropriate to the regulatory framework in their respective countries of origin, and advantages can be seen in some of the approaches taken by each scheme. On balance, BREEAM has greater flexibility to be applied in different countries, while Three Star is, to a greater extent, tied to local building regulations.

Project outcomes/Conclusions

A comprehensive table mapping equivalent Three Star and BREEAM credits was drawn up for commercial buildings. Credits within the schemes are of course not always directly comparable so in many cases this had to be done on the basis of the desired aims of each credit. This gave rise to the conclusion that compliance with BREEAM credits was often on the basis of a performance outcome while for compliance with Three Star, a more elemental approach is taken to improving building sustainability.

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Green Deal and Refurbishment Performance Gap

Robbie Thompson and Robin Brylewski

Building Futures Group, BRE

The purpose of this project was to answer the following questions.

- **What methodology and evidence have been used to define the thermal performance (U-value) of some of the most common construction types used in houses in the UK?**
- **Are there any known 'standard errors' within these U-values? ie are there any accepted variations to be found between the defined (theoretical) and actual U-values?**
- **Are there variations in the U-values of construction types modelled in 'reduced data standard assessment procedure' (RdSAP) software[1]? How significant are the variations? What impact do they have in relation to the total space heating cost of a house? What impact do they have on Green Deal packages?**

Background

There has been a concern from some potential Green Deal providers that there will be a significant difference between the modelled space heating requirement and the actual space heating requirement. If these concerns prove to be well founded, Green Deal measures may, in reality, not meet the 'Golden Rule' which require that the financial savings achieved by the homeowner are more than the cost of the measure. This could bring about a negative perception of the Green Deal by consumers which could reduce future uptake of the Green Deal and therefore reduce scope for economies of scale by providers.

Thus, it is important to fully understand the modelling of space heating requirements used in the Green Deal.

Research programme

The research programme followed two phases of work.

Phase 1
The aim of this phase was to investigate the methodology, evidence and accepted variations which have resulted in defining the U-values used in the 'reduced data standard assessment procedure' (RdSAP)[1]. This included modelling the effect on a building element's U-value by varying the assumptions that RdSAP makes about the building materials used, including varying factors such as brick density or cavity ventilation rate.

Phase 2
This phase involved a RdSAP sensitivity analysis to determine what impact, if any, the results of phase 1 had on the modelled space heating demand of some of the most common construction types in UK houses and their effect on the Green Deal's 'Golden Rule'.

Project Outcomes/Conclusions

The report concludes that:

- RdSAP's U-value assumptions are based on the age of the property and generalised type of construction. For older properties, RdSAP assumes a common form of construction that is assumed to be representative and then calculates the U-values for that form of construction. For newer properties, RdSAP assumes that the U-values of the building elements are equal to the maximum U-values specified by building regulation requirements at the time of construction.
- The construction details chosen for use in RdSAP were those understood by RdSAP's developers to be the most common in the housing stock, based on their expert knowledge, precedent and consultation with industry. The construction details chosen are consistent with other publications such as CIBSE Guide A[2].

- The space heating cost calculated by RdSAP is highly sensitive to the assumptions that RdSAP makes on U-values of different building elements (assumptions such as the density or moisture content of bricks used in walls; Figures 1–3), so much so that the potential difference in cost savings for the two house types (a standard uninsulated mid-terraced house and a semi-detached house built to 1976 building regulations), due to the assumption made in RdSAP, is greater than the factors that the Green Deal in-use would account for (Figure 4).
- The variation is theoretical and this may or may not be consistent with the actual housing stock. To determine whether it is, it is recommended that a further research project is undertaken to determine the likelihood of any component occurring in the housing stock and in particular the likelihood of the occurrence of certain combinations of building components.

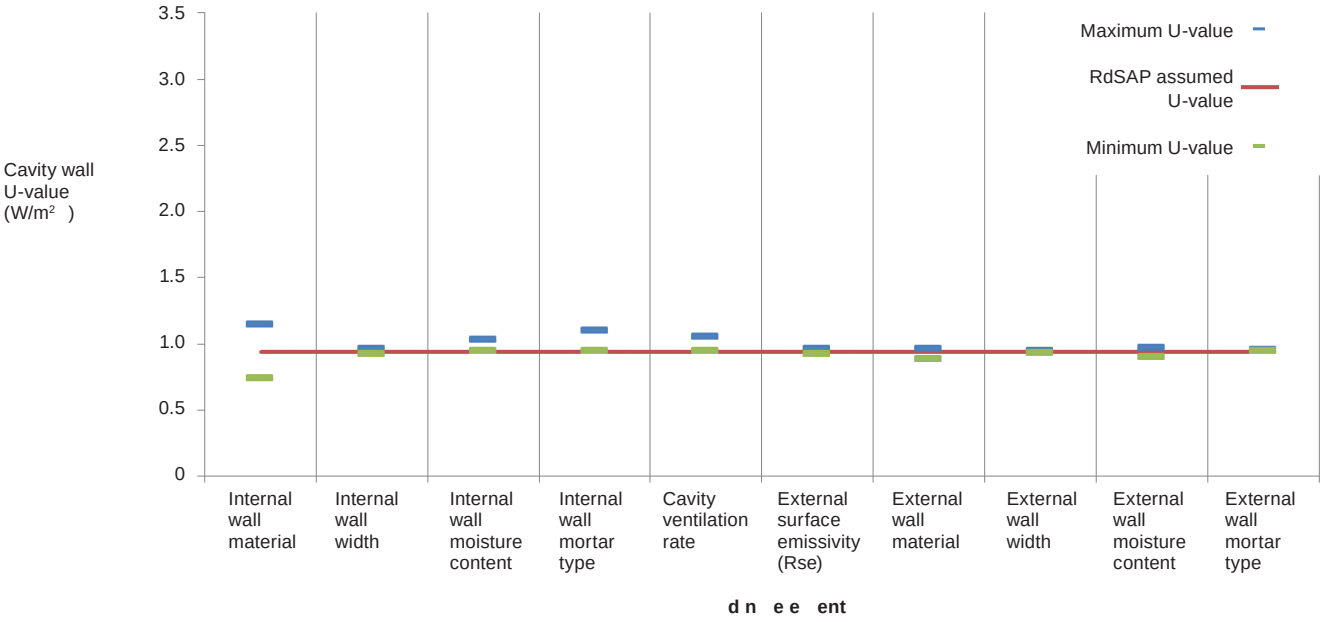

Figure 1: Potential variation in calculated U-value due to building element assumptions for a cavity wall built to 1976 building regulations

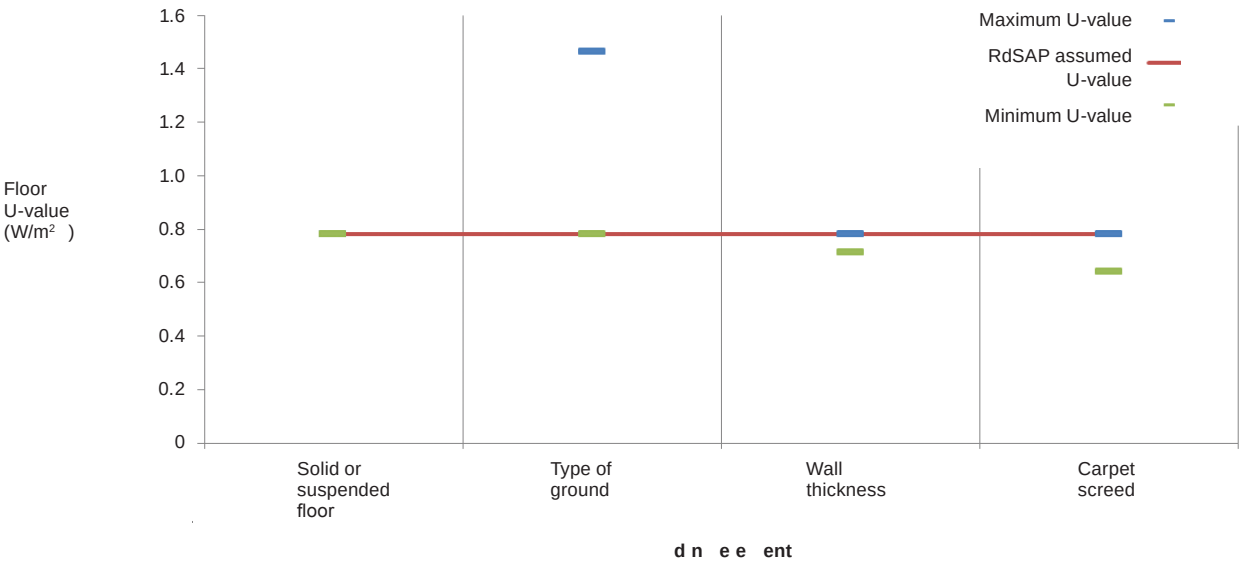

Figure 2: Potential variation in calculated U-value due to building element assumptions for a solid floor built to 1976 building regulations

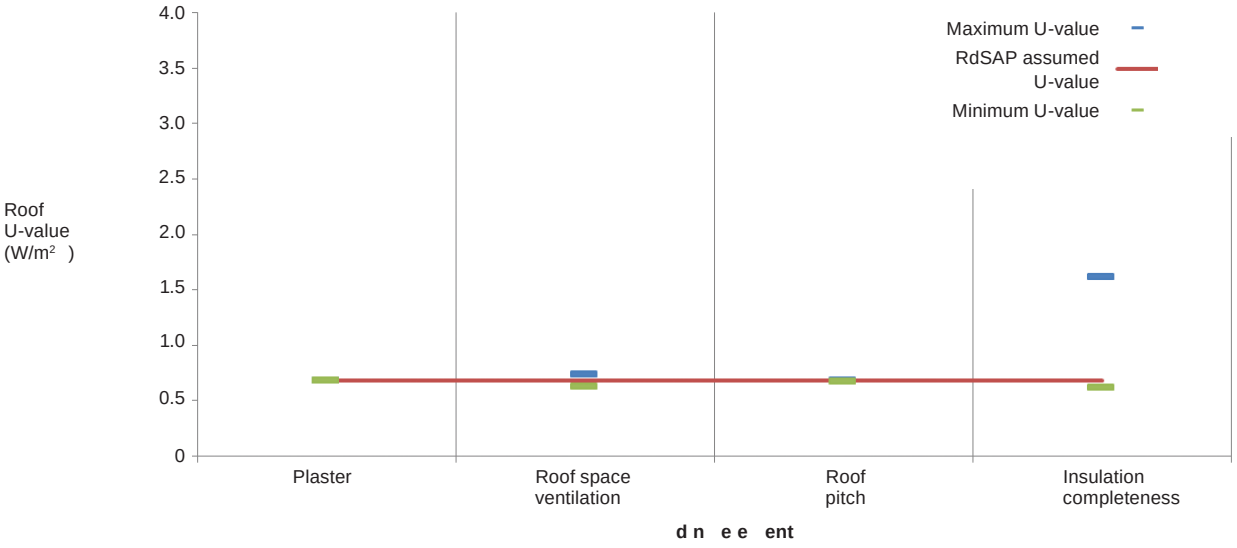

Figure 3: Potential variation in calculated U-value due to building element assumptions for a pitched roof built to 1976 building regulations

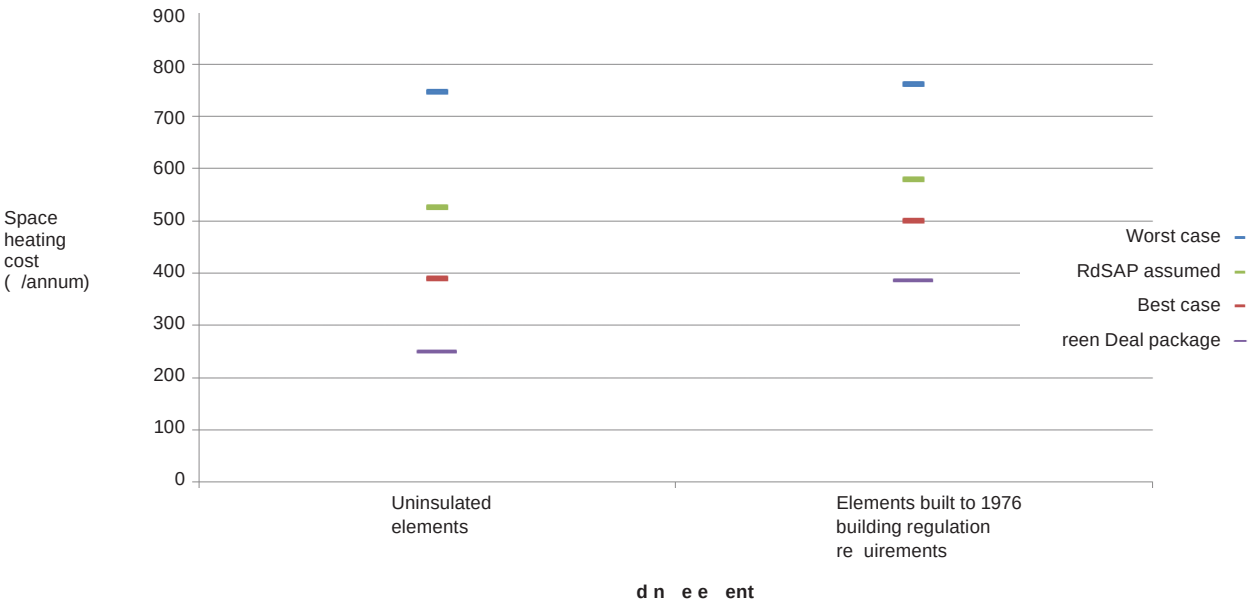

Figure 4: Comparison of a building's space heating cost with one to which a Green Deal package has been applied

References

1. Department of Energy and Climate Change (DECC). Standard Assessment Procedure. Guidance on how buildings will be SAP energy assessed under the Green Deal and on recent changes to incentivise low carbon developments. London, DECC, 2013. www.gov.uk/standard-assessment-procedure
2. CIBSE. Environmental design. CIBSE Guide A. London, CIBSE, 2006.

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Alpha Factor sustainable performance-improvement benchmarking tool for the corporate sector

Laura Birrell

BRE Scotland

The Alpha Factor tool can be used by organisations to measure and improve their sustainability performance. Three areas of focus were identified to create question sets that:

- **qualify why the criteria are important**
- **quantify the impact on the business**
- **educate the user.**

The completed question set produces an output that determines how the organisation has performed against target and can be used to report to stakeholders. Feedback has been positive for the criteria considered and for the ability of the tool to be a performance improvement tool that helps to set actions rather than targets for an organisation.

Background

Sustainability has different interpretations depending on the industry sector in which an organisation operates (eg industrial versus financial sectors). This makes sustainable benchmarking challenging as it would be difficult to compare M&S with Barclays Bank as one is supply chain driven whereas the other relies on technology to support its operations. However, both require built estate from which to operate.

With the growing requirement for integrated reporting (the merger of financial statements with the sustainability report), research was undertaken on what benchmarking tools were available. It was concluded that sustainability reporting was based on indicators of past performance that provided little in respect of a mechanism to promote progress towards more sustainable practice.

The objective was to provide a single benchmarking tool for the market that would focus on delivering transparency to stakeholders on an organisation's approach to managing a sustainable business model going forward.

Research programme

The research programme involved:

- a review of existing sustainability indices to interpret the approach and the technical depth of questions and responses
- market research to identify the common opportunities and/or challenges for companies addressing sustainability issues
- population of an Excel tool using the research data to provide an output rating
- obtaining feedback from stakeholders on tool criteria and market acceptance of the tool
- refining the tool based on stakeholder feedback.

Figure 1: Key business drivers for adopting a sustainability strategy

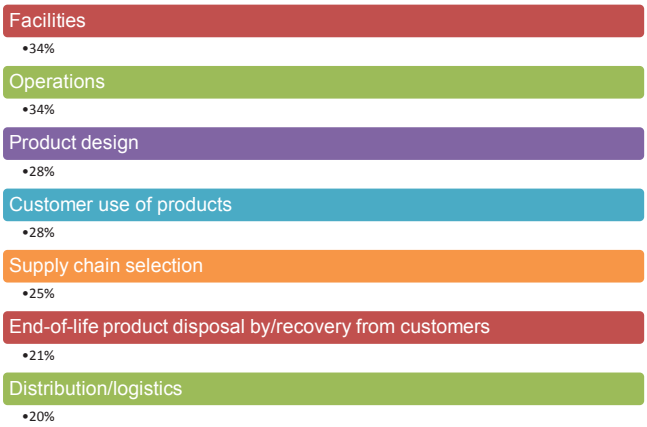

Figure 2: Top seven areas of focus for companies adopting a sustainability strategy as reported by the desk-based study

Figure 3: Three core areas used to create question sets

Project outcomes/Conclusions

The research outcomes from this project concluded that there is a need in the market for a tool that creates a level playing field from which to build sustainable benchmarking across sectors. As resource scarcity due to population growth and other climate-related issues start to affect product pricing and our knowledge increases about pollutant effects on the environment and health of employees, these issues are being mapped within the risk registers of large organisations. This means that to operate sustainably is not only 'doing the right thing' but also responsible business management. However, it is not all about risk as sustainability will not only benefit the environment, but it can also increase turnover and provide a mechanism for giving something back to the communities in which an organisation operates.

The desk-based market intelligence study sourced information from the Chartered Institute of Management Accountants as the Chief Financial Officer within a company was seen to be key to driving a company's sustainability strategy. The information received highlighted how topical sustainability is within the Boards and financial functions of large organisations. Ninety-three per cent of CEOs reported that a sustainability strategy can influence the key drivers to a successful business (Figure 1).

The top seven areas identified as being the focus for companies' sustainability efforts are given in Figure 2.

During the market intelligence, recurring topics were listed and sorted into three core areas of focus with five sub-categories (Figure 3). The sub-categories were debated by the project team to determine applicability across all industry sectors with the result that it was agreed that one core area (eg Shared value) may be more important to one industry sector than another. For example, the oil industry might find issues in the 'Operating environment' most relevant, whereas a retail organisation

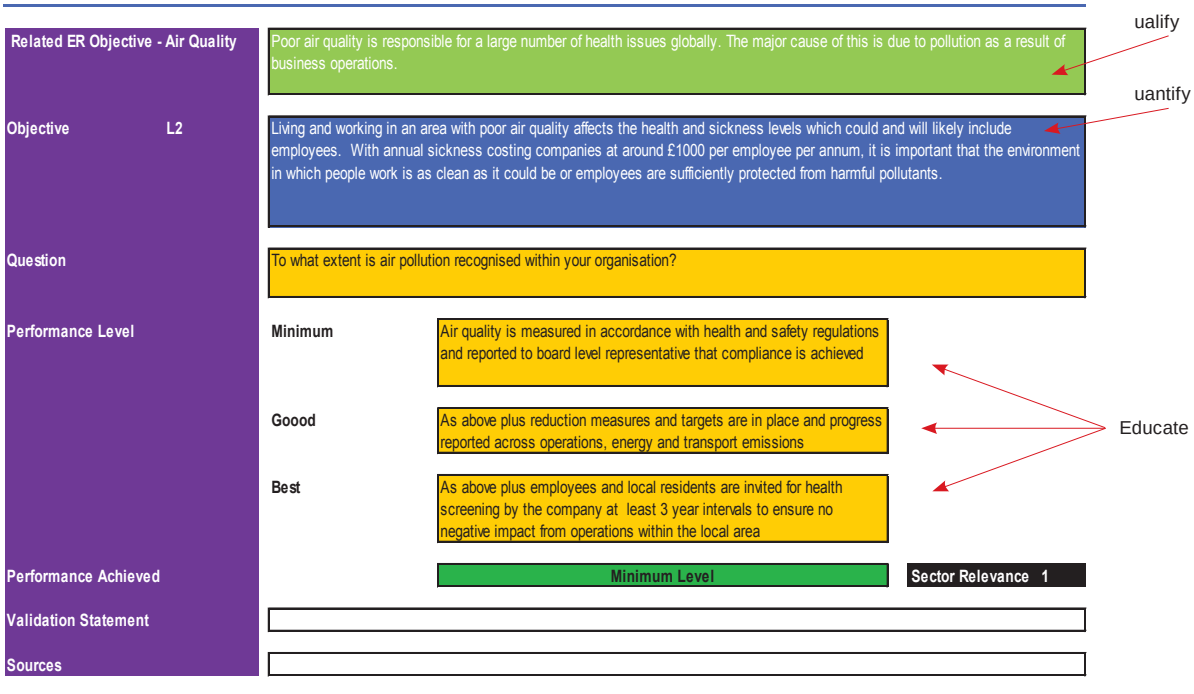

Figure 4: Set of questions for air pollution

might find issues in the 'Shared value' most relevant. However, regardless of industry sector all three core areas will have issues applicable to the sustainable operations of a business. The core areas provided the framework from which to develop the methodology.

The core areas were used to create question sets that:

- qualified why the core areas were important
- quantified what the impact was to the business of addressing the issue (positive or negative)
- educated the user on how to achieve higher levels of best practice.

Figure 4 shows an example of the question set for air pollution.

On completion of the question set by the organisation, the tool will produce an output that determines how the organisation has performed against target as demonstrated in Figure 5.

Feedback from stakeholders was positive both in terms of the criteria considered and the ability of the tool to be a performance improvement tool that helps to set actions rather than targets for an organisation. Figure 6 gives a summary of stakeholder feedback.

In summary, the tool creates a framework for consideration of a range of sustainability criteria relevant to large organisations and enables focus on areas most relevant to the sector without dismissing other key areas of sustainability. The output from this tool can be used to report to internal and external stakeholders how sustainably the business is being managed.

Figure 6: Summary of stakeholder feedback on the tool

Publications/Research output

An online tool will go into production in June 2013.

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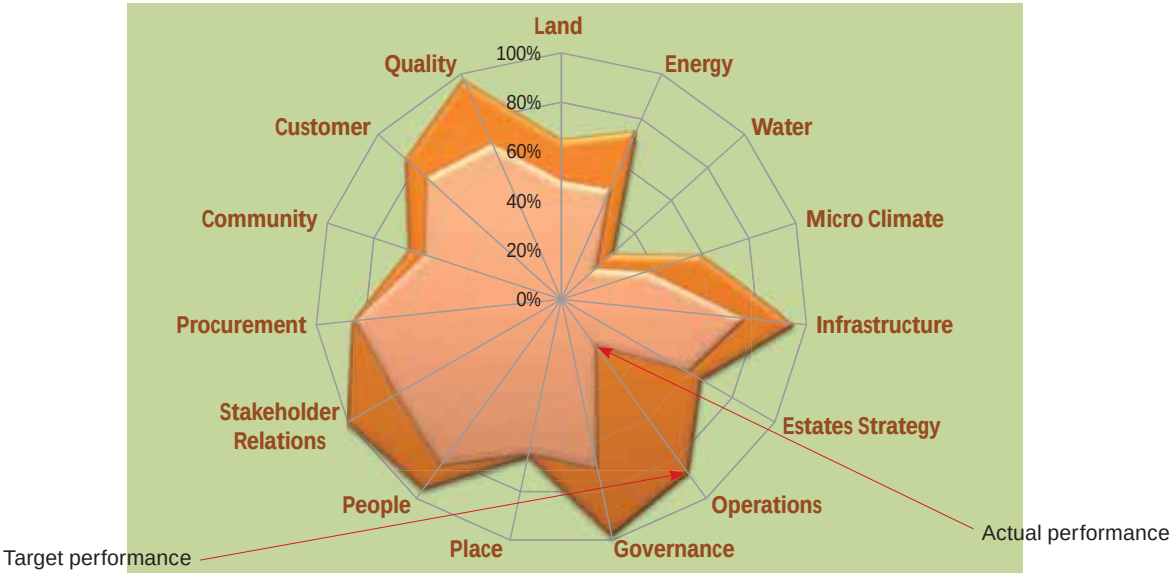

Figure 5: Output from the tool comparing an organisation's performance score with target performance

Energy Zone programme:
Future cities and smart energy management

Mike Perry

Building Technology Group, BRE

The Energy Zone Project investigated the role of smart energy management as part of the 'future of cities' agenda: the marketplace for digital infrastructure and systems, or future city systems.

The project's initial focus was on smart meters, only one component of the wider context of effective physical and social resource management and control (eg energy, healthcare and traffic management, particularly in cities). An important driver for good resource management in cities is effective and efficient operation, supporting cities' role as primary centres of economic activity and driving their economic recovery and growth.

The project's outputs contributed substantially to informing development of smart energy concepts, that is the flexible, responsive and cost-effective supply of energy from central and distributed sources, for the BRE Trust Future Cities Programme.

Figure 1: Energy use in the city

Background

The use of physical and social resources by cities is placing significant strain on traditional delivery systems (eg energy, healthcare, transport, etc.). In the coming decades, the proportion of the global population living in future cities is set to grow from 51% currently to a forecast 80% by 2050, greatly adding to the strain on the use of resources in cities. There is an urgent need for alternative delivery systems to monitor, manage and control physical and social resources. Smart grids and smart energy systems are fundamentally important components of these new delivery systems.

Research programme

The initial focus of the Energy Zone Project was to develop and validate the Service Aggregation Smart Homes (SASH) platform and Interoperability Framework Requirements Specification (IFRS), the outputs of two smart energy projects funded by Technology Strategy Board and supported by the BRE Trust Energy Zone Project. The projects technically validated two key issues in the application of digital technologies to the integrated monitoring and management of energy in buildings, particularly in the domestic setting.

Beyond the technical content, development of these smart energy projects made it clear that a marketing strategy would be needed to secure acceptance of the output in the marketplace. This would also apply to the wider context of so-called 'future city systems'.

Developing a process for implementing project outputs: SASH and IFRS

The next stage in the Energy Zone Project mapped a process to develop the smart energy concepts, SASH and IFRS. The principles of analysis employed by these concepts can be applied

to BRE's research and innovation programme, particularly its developing capability in future city systems.

An important finding from the analysis was that the development and technical validation of a concept is one component of a larger sequence of events. In most cases, the initial technical validation will not result directly in a full business operation. To bring the initial concept to commercialisation, it is necessary to develop supporting business concepts. The analysis identified nine fundamental building blocks that should be addressed to attain a full business model.

Major challenges for future cities energy issues
Future city systems will deliver societal services, including, but not restricted to:

- facilitating economic recovery and growth in urban conurbations (cities)
- providing the infrastructure to support implementation of at least:
  - smart grids and community energy systems
  - assistive living systems
  - transport monitoring and management
  - city logistics
  - eGovernment.

Successful implementation of societal digital services faces a number of challenges. However, resolving these challenges will not depend on the development and deployment of further technologies, but on understanding and addressing a range of 'soft' barriers including:

- economic and financial models for implementing future cities systems
- coordinated and consistent policies and directives
- a supporting framework of Standards and Codes of Practice
- a certification and accreditation scheme to support the Standards Framework
- training and education aligned with Standards and certification
- market acceptance and the practice of interoperability
- methods to achieve cost-effective installation of digital infrastructure and delivery of digital services in all classes of existing building stock, particularly in dwellings
- understanding how societal 'digital services' can be made commercially self-sustaining, including the need for new business models.

Completed, current and future projects
The Energy Zone Project framework ranges from research and development project concepts through to near-market applications and has been developed in collaboration with two of BRE's University Centres of Excellence at Cardiff and Strathclyde. The involvement of these Centres of Excellence will add substantially to the developing body of knowledge on future city and smart energy systems, while also potentially providing access to supporting resources through, for example, PhD projects that could be developed as part of the wider future cities programme.

Project outcomes/Conclusions

The concept of future city systems, and within that the concept of smart energy, is at an early stage of development. Many of the stakeholders do not have a clear understanding of the concept (eg Local Authorities and other public service commissioners) as future city clients and specifiers. This is a concern as these stakeholders will provide the early market specifications for the UK's first tranche of future city projects. If these groups do not have the ability to prepare informed tender specifications for the first round of major future city projects, development of the UK's future cities market, nationally and internationally, is at risk of underperforming.

The Energy Zone Project has enabled BRE to develop substantial understanding of the future city systems concept, laying a strong foundation to support development of a future cities capability for BRE. The Energy Zone Project has raised BRE's profile and engagement in the future cities sector, leading to a number of significant appointments and follow-on activities, including but not restricted to the following activities.

- Discussions with the UK Government's Department for Business, Innovation & Skills (BIS) and Department for Culture, Media & Sport (DCMS), where BRE has jointly led discussions to secure acceptance of interoperability as a fundamental requirement in the development of the UK's future cities market, a principle that will feed into international activity
- Development of a process specification for an Interoperability Accreditation Scheme funded by BRE Trust
- Development of interoperability in collaboration with industry (eg through SH&BA [formerly TAHI], an industrial and market group whose members are working together to promote interoperability for smart homes and communities) and the market (eg Local Authorities)
- Appointment as:
  - Technical joint author of a Future Cities Standards Strategy
  - Technical author of a Specification for a digital infrastructure for SME premises
  - Technical author of a future cities terminology.
- Appointment to:
  - Technology Strategy Board Future Cities Special Interest Group;
  - Technology Strategy Board Smart Energy Special Interest Group;
  - Technology Strategy Board Smart DC Network Special Interest Group;
  - BSI Committee: Metrics for smart urban infrastructure (UK Lead)
  - BSI Interoperability Advisory Group
  - BSI Steering Group: PAS 181 – Decision-making framework for the establishment of a smart city.
- In recognition of its future cities capability, BRE has joined the two cities' consortia bid for Technology Strategy Board future cities funding competition

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BRE Centre of Excellence in Sustainable Engineering, Cardiff University

Yacine Rezgui

Professor, Building Systems and Informatics

The BRE Centre of Excellence (Institute) in Sustainable Engineering has enjoyed another successful year reflected in major new contract awards at national level (Engineering and Physical Sciences Research Council [EPSRC] and Technology Strategy Board [TSB]) and European level (EU FP7).

The Institute has sustained its vibrant PhD base and currently hosts 35 registered PhDs researching in areas ranging from sustainable self-healing concrete to BIM-based computational simulation of buildings. It hosts three PhDs sponsored by BRE Trust:

- Alexandra Cemesova
  Future adaptability of buildings
- Apeksha Gupta
  Renewable energy solutions in the domestic sector
- Tobias Hazelwood
  Intelligent cementitious composites.

A new BRE Trust-sponsored Case Studentship PhD (Shaun Howell) will join the Institute on 1 July 2013 to develop analytical models for city systems reasoning and optimization.

In 2012, the Institute was awarded 11 new contracts, the details of which are given in Table 1. These new contracts are in addition to a wide range of research contracts which are progressing successfully, including the following which also have BRE research involvement:

- *Knowledge-based energy management for public buildings through holistic information modeling and 3D visualisation KNOWHOIEM*
  Researchers: Rezgui Y and Hopfe C
  Sponsor: European Commission (FP7)
  Duration: 01/09/2011–31/08/2014

Figure 1: The BRE Centre of Excellence in Sustainable Engineering Virtual Reality Laboratory

- *BIM-based regulatory compliance design environment*
  Researchers: Rezgui Y and Li H
  Sponsor: Technology Strategy Board
  Duration: 01/02/2012–31/01/2014.

The Institute members are also maintaining their high profile by disseminating research through high-impact refereed journals and international conferences.

Table 1: New contracts awarded to the BRE Centre of Excellence in Sustainable Engineering, Cardiff University

Researchers	Title of project	Sponsor	Duration
Gardner D	Capillary flow of autogenic healing agents in discrete cracks in cementitous materials	EPSRC	01/09/2012–30/11/2013
Kwan A and Rezgui Y	ProAir advanced indoor climate control system	Department of Energy & Climate Change	01/05/2013–30/05/2015
Lark R, Gardner D, Jefferson A and Harbottle M	Materials for life (M4L): Biomimetic multi-scale damage immunity for construction materials	EPSRC	01/04/2013–31/03/2016
Li H and Rezgui Y	SPORTE2 – Intelligent management system to integrate and control energy generation, consumption and exchange for European sport recreation buildings	European Commission (FP7)	06/07/2012–28/02/2014
Li H, Rezgui Y and Kwan A	Virtual environment for BIM and Future Cities research	Cardiff University	01/01/2013–31/12/2014
Mourshed M	The development of a 2050 Bangladesh energy and emissions calculator	Department of Energy & Climate Change	01/02/2013–30/03/2014
Rana O and Rezgui Y	Clouds4Coordination (C4C): Cloud-based project coordination in the AEC sector	Technology Strategy Board	01/05/2013–30/04/2015
Rezgui Y and Li H	RESILIENT – Coupling renewable, storage and ICTs, for low carbon intelligent energy management at district level	European Commission (FP7)	01/09/2012–31/08/2016
Rezgui Y, Kwan A and Li H	Developing a real time abstraction & discharge permitting process for catchment regulation and optimised water management	Technology Strategy Board	01/05/2013–30/05/2016
Rezgui Y, Li H and Mourshed M	Estate energy optimization	BRE Trust	01/04/2013–30/03/2015
Rezgui Y, Li H and Mourshed M	Portable, exhaustive, reliable, flexible and optimized approach to monitoring and evaluation of building energy performance	EU FP7	01/09/2013–30/08/2017

For further information on any of these projects, contact Professor Yacine Rezgui
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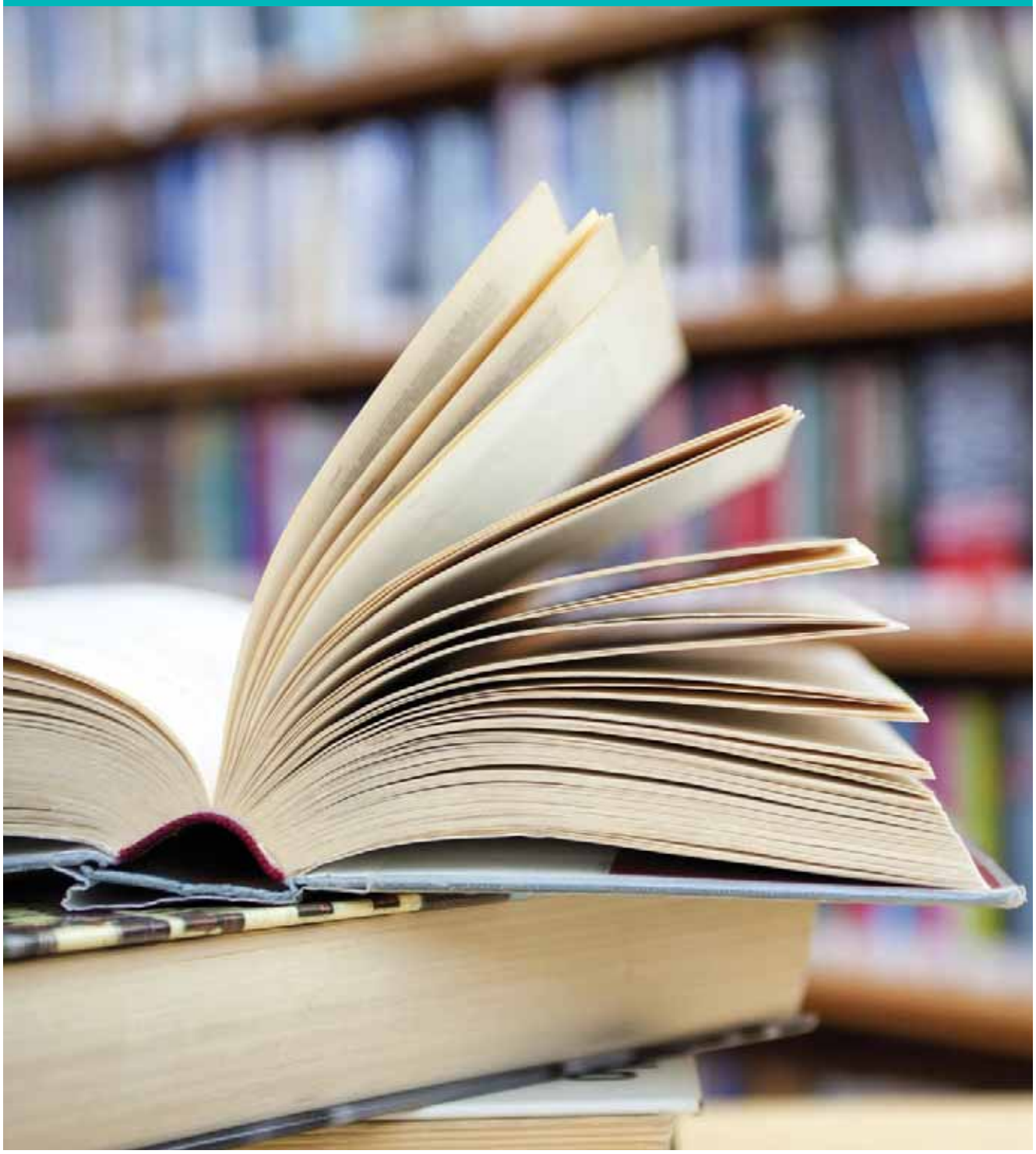
Publications



Foreword to the BRE Trust Publications Programme

The BRE Trust Publications Programme is now in its fourth year and during this time more than 150 new publications have been released, the writing of which has attracted more than £650k of additional funding from external sources. Forty-seven new titles were released in 2012 and a summary of each is included in the following pages, highlighting a diverse portfolio of topics covered in various formats appropriate to the subject matter and intended audience. These range from detailed technical guides which help practitioners in the field to deliver services to their clients and independent overviews of emerging technologies and products to shorter information papers providing a summary of outputs from research programmes.

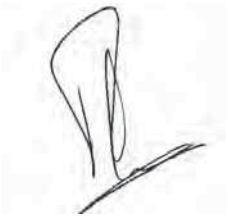
Subjects which have proved to be particularly popular include various aspects of the selection and effective use of renewable energy sources, including photovoltaics, and updates of effective site layout planning for daylight, sunlight and solar gain. Both are examples of where BRE's historic reputation for state-of-the-art technical advice and data are still valued and demanded.

Another topical series included three publications detailing different aspects of the design and build of particular buildings on the London 2012 Olympic Park and the Olympic and Paralympic Village, produced in collaboration with the Olympic Delivery Authority (ODA). These formed part of a larger learning legacy created by the ODA, which included contributions from many organisations involved in the delivery and post-project review of the construction of the Park.

The launch of Building4change in 2009 is an example of a web-based monthly publication and is part-funded by BRE Trust. It now has a circulation of more than 45 000 readers and provides informative researched articles which promote the outputs of BRE Trust in the context of the wider industry agenda in the UK and globally. Quarterly supplements, focused on retrofit and new technologies, were launched in 2012 to enable more detailed content to be provided on popular and topical themes where challenges and the need for up-to-date information are most pressing. Other supplements will follow in 2013.

Over the last 3 years, a number of projects have been supported where the outputs have taken the form of web-based information sources rather than traditional published documents. It is already evident that electronic formats are becoming popular, with more than 65% of sales of publications coming from electronic pdf downloads rather than printed formats. Ease of access, speed to market and wide outreach are all strong drivers for the BRE Trust Publications Programme and BRE Trust is keen to embrace technologies that can enable these drivers effectively and affordably, especially in a global marketplace.

It is important, however, that publications which are supported by BRE Trust, whatever the format, continue to include independent validated data and opinion for the benefit of all in the built environment. The development and launch of the BRE Digital Platform in 2013 will provide a new route to market and the BRE Trust Publications Committee will be supporting more publications in new formats in 2013.



Hugh Ferguson
Chairman
BRE Trust Publications Committee

BRE Trust publications in 2012

The funding that BRE Trust provides for publications drafted by BRE consultants has made a significant contribution to the literature available for use by construction professionals and others involved with the built environment. The Trust recognises that these publications are often definitive sources of data, information and knowledge relied on by the construction industry, and that many are referred to in legislation so it is imperative that they are kept up-to-date and relevant.

The titles of the publications approved for funding by the BRE Trust Publications Committee in 2012 are listed in Box 1. All publications are produced by IHS BRE Press and sold through the BRE Bookshop in hard copy or pdf format at www.brebookshop.com.

The following sections provide summaries of the 47 publications that were published during 2012 and whose preparation was funded by BRE Trust under the BRE Publications Programme funding initiative introduced in 2009. Many other Reports, Digests, Good Building and Repair Guides, and Information Papers are currently being prepared for publication. The range of topics reflects the main areas of work within BRE and deals with key topics of concern throughout the community of clients and professionals across the built environment.

Box 1: Publications approved for funding in 2012 by the BRE Trust Publications Committee

Advanced thermal insulation technologies in the built environment

A guide to Part L1 A and B in Wales

Benefits of green buildings annual update

BREEAM 2011 updates

Building on fill: geotechnical aspects, 3rd edition

Control of building environments using fast- and slow-acting heating systems

Cost-effective Code Level 4 homes without renewable energy systems

Energy surveys and audits: a guide to best practice

Delivering a user-centred demonstrator to assess the future needs of elderly people

Facilities Managers Guides
– delivering resilience to fire
– delivering energy efficiency

Green Deal guides

How to assess the age of houses

Impact of noise on building occupiers

Implementing the Physical Agents Directive

Improving the strength class attribution of UK-grown Douglas fir

Interpretation and use of construction product standards
– wall linings
– doors

Learning from resource efficiency plans

Minimising cold bridging when installing solid wall insulation – best practice guidance

Recognition of responsibly sourced materials within BREEAM 2011

Radon reduction measures for listed buildings

Radon solutions for homes

Reducing the health risk of overheating in the home

Resource-efficient refurbishment

Retail lighting: an essential guide

Specifying structural timber

Supporting sustainable development through planning

The cost of poor housing in London

The Digest of Annual BREEAM Statistics

The Green Guide for interior fitout

Thermal insulation – avoiding risks, 4th edition

Timber frame design for low-energy housing – best practice guidance

Through-life care and management of concrete structures

Understanding the environmental impacts of construction

Understanding factors affecting the time to flashover of a fire in a modern building

Visual alarm devices for fire: an introduction to BS EN 54-23:2010

Walls, windows and doors: Performance, diagnosis, maintenance, repair and the avoidance of defects, 2nd edition (BRE Building Elements series)

Materials

Bio-resins in construction: A review of current and future developments
IP 4/12, January 2102
Bio-resins have the potential to form the basis of resins and adhesives for bonding construction products. Adhesives from crop residues and by-products can bond wood-based panel products or laminated timber sections in place of adhesives derived from petroleum. Bio-resins can also be used in paints and coatings. Improved recycling options at end of life and a potential lowering of the environmental impact of construction products are attractive targets, but there are challenges in delivering robust bio-resin systems.

This Information Paper introduces bio-resins in the context of current synthetic adhesives and resins in construction. It analyses the opportunities, challenges and current status of their use.

Service life prediction of timber cladding
IP 16/12, July 2012
Timber cladding is a growing commercial opportunity for wood, becoming more frequently specified on public and private buildings. It also has a high-value end use, which can take advantage of all the factors that influence the service life of the product.

The pan-European WoodExter project is developing a model for predicting the service life of exterior timber cladding to enable better selection of material for the required service life. This Information Paper reviews service life prediction for timber, and the work within the WoodExter project, to provide information for building professionals wanting to use timber cladding.

Innovation in timber supply at the London 2012 Olympic and Paralympic Games
IP 17/12, July 2012
This Information Paper sets out the challenges involved in realising the Olympic Delivery Authority's (ODA) pledge to set new standards for sustainable development, and the processes and procedures that the ODA set in place in order to deliver that pledge. It highlights key feedback and learning from the project. The content is based on interviews with key personnel and research using relevant project documentation.

This Information Paper will be of interest to those involved in procuring timber, construction companies and contractors.

Concrete usage in the London 2012 Olympic Park and the Olympic and Paralympic Village and its embodied carbon content
FB 49, September 2012
Concrete was widely used in the Olympic Park and Olympic and Paralympic Village. Its specification and use provided an opportunity to reduce embodied carbon emissions involved in the construction of facilities and infrastructure, and to influence the overall carbon footprint of the London 2012 Games.

This report sets out the evidence on concrete supply to the Olympic Park and the Olympic and Paralympic Village and the lessons learned from using sustainable concretes, and examines the estimated carbon footprints. Case studies of the Aquatics Centre and the Olympic and Paralympic Village are included.

A guide to the use of urban timber
FB 50, September 2012
This illustrated guide provides information on improving the use of timber culled from the UK's urban timber resource (streets, parks, gardens and urban woodlands), giving advice on:

- selection and identification of high-value stems
- wood processing
- drying
- transport
- storage.

It aims to promote the use of common and exotic urban tree species for solid wood products rather than being processed for firewood or chipped to produce mulch.

The guidance will help local authorities, park owners and individuals interested in unusual tree species to maximise the value of the timber produced in towns and cities and to develop the best practicable options for using the solid wood produced during normal maintenance procedures.

Effects of chemical, physical and mechanical processes on concrete
DG 527, November 2012
This Digest provides an overview of the physical and chemical degradation processes that can affect concrete buildings and infrastructure. It outlines the main considerations in designing, specifying and executing durable concrete in order to ensure that it continues to perform in aggressive environments without premature deterioration or unplanned maintenance.

The Digest will interest developers, asset owners, engineers and specifiers who wish to gain a broad understanding of the factors controlling the performance of concrete structures in aggressive environments.

Asset management and service life of concrete structures and components: Potential benefits of emerging data capture and management technology
IP 26/12, December 2012
This Information Paper explores approaches to the asset management of concrete components and structures using data from sensor and wireless communication technology (ICT). As well as providing a short description of the emerging technology and its potential uses, the Paper also examines the potential business cases for use of data capture and management technology and specific areas (including supply chain and through-life management), where its potential value may spur early adoption.

Energy

Energy management in the built environment
FB 44, January 2012
Energy management is explained in a step-by-step approach, together with the use of a matrix tool for implementing energy management initiatives within an organisation. The tool can help identify areas for improvement, prioritise energy management activities and maximise benefits. Most of the examples are from the built environment but the principles can be employed in any organisation or industry sector. The guidance is applicable to anyone responsible for energy management in an organisation, from board level to operational staff. In addition, the publication:

- examines how data from sources such as BREEAM assessments, energy audits, energy performance certificates, display energy certificates and monitoring and targeting can underpin energy management
- addresses asset and operational performance and discusses how information from both is needed to adequately assess the energy performance of a building
- illustrates how undertaking an energy management programme can improve energy ratings
- introduces the new energy management standard ISO 50001 and explains its contribution to an auditable energy management programme.

Smart meters and smart energy networks for dwellings
IP 2/12, January 2012
This Information Paper outlines the options available for automatic meter reading, monitoring and management and the challenges to implementing these technologies.

Great Britain is making a strong commitment to smart meters and the role of smart meters as a focal point for smart energy management in homes. Several national initiatives are running in parallel with the smart meter programme. Coordinating these programmes will maximise the return on the substantial investment for each programme.

The Paper informs building and energy professionals and building owners about the exciting opportunities available through implementing smart meter technology.

Potential for reducing carbon emissions from commercial and public-sector buildings
IP3/12, January 2012
This Information Paper summarises the contribution to UK carbon emissions of energy use in non-domestic buildings and outlines possible savings in the commercial and public-sector stock, based on the potential that existed in 2007 and looking ahead to 2012, 2017 and 2022. It will be of interest to policymakers and researchers in the field of climate change and carbon emission reductions.

The importance of energy quality in matching supply and demand
IP5/12, January 2012
Energy used in buildings accounts for around half of the UK's total carbon emissions. Most of this energy is used for space heating, so minimising heat losses is a high priority. The heating requirement of buildings is primarily dependent on the building fabric, so less energy is needed to heat better-insulated buildings. However, the quality or grade of energy needed for space heating is very low.

This Information Paper examines the importance of energy quality in matching energy supply and demand and will be of interest to those working in the field of energy in buildings, including building services engineers, building contractors and specifiers.

Building-integrated photovoltaic systems: Challenges and opportunities for manufacturers and specifiers
IP 11/12, April 2012
The aim of this Information Paper is to help to close the gap between building designers and manufacturers of building-integrated photovoltaic products. Specifiers will find useful information on products currently available and some typical applications, while manufacturers may benefit from the feedback obtained directly from potential users of the technology.

Information was gathered from three main sources:

- a survey of products currently on the market
- a survey of architects
- two stakeholder workshops held at BRE in 2010 and 2011.

Static and dynamic wind loads on building-mounted microwind turbines
IP 14/12, June 2012
This Information Paper focuses on microwind turbines attached to residential buildings. It is intended for use by manufacturers and installers of microwind turbines and by structural engineers responsible for designing the mounting arrangements for turbines. The benefit of this Paper to the manufacturers and installers is that in many circumstances reductions in the wind loads can be achieved without compromising the safety of the installation.

Funding renewable energy projects: An introduction to the Feed-In Tariff and Renewable Heat Incentive schemes and associated funding options
IP 18/12, August 2012
This Information Paper introduces the Feed-In Tariff and Renewable Heat Incentive schemes as new stimuli to investment in renewable energy, replacing renewable energy grants. It outlines the capital financing options and their pros and cons, considers community investment options and features case studies of renewable energy projects. It is aimed in particular at developers, energy companies, registered providers of housing and local authorities.

Making use of carbon emissions in the built environment
IP 25/12, November 2012
The aim of this Information Paper is to provide a brief overview of some carbon capture and use (CCU) technologies and to highlight their potential applications and uses within the built environment. The Paper is intended for any reader with a general interest in the built environment, but will be of particular significance to policymakers, construction material manufacturers, energy companies and those specifying products and materials for the built environment.

Fire and security

Selecting electronic security systems: An introduction
IP 1/12, January 2012
This Information Paper provides an introduction to selecting and procuring electronic security systems and is designed to aid security and facility managers of all types of buildings and premises. Areas covered are intruder alarms, automatic access control systems, closed circuit television (CCTV), integrated systems, remote monitoring, maintenance and false alarms, and product and service verification.

Passive and reactive fire protection to structural steel
IP 6/12, January 2012
This Information Paper collates and updates available information on passive and reactive fire protection to structural steelwork. It is intended for use by those responsible for specifying fire protection, main contractors, building control authorities and installers. It provides information on the options available to the designer, ranging from the use of unprotected steelwork to the selection of products for extreme events such as hydrocarbon fire exposure.

Fire doors
DG 524, April 2012
This Digest explains the role played by fire doors and smoke control doors, methods of assessing their performance and the requirements made under regulations and codes of practice. In recent years, fire door assemblies have been developed using widely different forms of design, so it is no longer appropriate to give simplified guidance on their construction. The importance of third-party certification for manufacture, installation and maintenance of fire doors is highlighted.

The Digest will be of interest to specifiers, manufacturers, installers and approval authorities such as building control and insurers.

Assessing the fire performance of existing reinforced concrete flooring systems
IP 9/12, April 2012
This Information Paper provides information on assessing the fire performance of existing reinforced concrete flooring systems using tabulated values from national standards and the fire part of the Eurocode for the design of concrete structures, as well as experience from assessment of existing buildings and historical research from the Fire Research Station (now part of BRE Group). It will assist clients, contractors and building control authorities to estimate levels of performance provided by specific forms of construction, many of which are incorporated within existing buildings but are no longer in widespread use as a current construction system.

Domestic smoke alarms
DG 525, June 2012
Smoke alarms in homes can save lives, are easy to use and are inexpensive. If correctly specified, installed and maintained, they will give an early warning of fire that can allow occupants to safely escape, while nuisance alarms are minimised.

This Information Paper provides guidance on the different types of smoke alarm available, and on correctly specifying, locating, installing and maintaining fire detection and alarm systems. It reviews a number of the recommendations given in relevant regulatory guidance, as well as the use of third-party-approved fire detection and alarm products and installers.

It will be of particular interest to UK house builders, building control officers, specifiers, manufacturers, building owners and the fire and rescue services, and may also be of use to similar professionals in other countries – subject to local code or national legislative requirements.

Smoke detection in high ceiling spaces
IP 15/12 (2 Parts), July 2012
Specifying suitable smoke detection in high ceiling spaces such as atria, warehouses and entertainment venues is very complicated, and the criteria for assessing the performance of aspirating and optical smoke detectors are not fully understood. Research by BRE Trust and the Fire Industry Association (FIA), using computer modelling and full-scale tests, has provided valuable data that have enabled guidance to be revised. This Information Paper outlines the programme of research and summarises the conclusions.

Part 1 of this Information Paper covers the literature review and CFD modelling. *Part 2* covers the fire tests and conclusions. It is aimed at manufacturers and installers of smoke detectors, building designers and regulators, who should find it valuable in gaining a full understanding of the main factors influencing smoke detection in such applications.

Residential sprinklers for fire protection
DG 519 (2 Parts), December 2012
This 2-part Digest provides information on installing residential sprinklers used for fire protection for non-specialist and specialists. Sprinkler systems in domestic and residential buildings are becoming more popular in the UK, and have recently become compulsory in Wales.

Part 1 explains how to design, install and maintain domestic and residential sprinkler systems, and the additional requirements of BS 9251. *Part 2* clarifies and amplifies BS 9251 and suggests additional recommendations to those provided in the standard.

Sustainability

LCA and REACH: The relationship between life-cycle assessment and the regulation on the registration, evaluation, authorisation and restriction of chemicals
IP 7/12, March 2012
This Information Paper provides information to product manufacturers and product specifiers on the relationship between LCA and REACH, using the BRE Global Environmental Profiles Methodology as an example of LCA. Both approaches are intended to evaluate the impacts of chemicals on people and the environment, but they perform different roles; REACH and LCA are not interchangeable but should be seen as complementary processes.

After reading this Information Paper, readers will have a better understanding of the requirements of REACH and LCA and how these approaches relate to each other.

Sustainability at BRE: Delivering the S Plan
IP 8/12, March 2012
In 2008, BRE adopted an innovative approach to addressing sustainability within the organisation. The company's sustainability strategy – known as the 'S Plan' – set out a four-year programme of continuous improvement across eight key areas of sustainability: carbon dioxide (CO_2) emissions, community engagement, ecology, information systems, resource efficiency, supply chain engagement, transport and water.

This Information Paper provides an overview of the S Plan and identifies the key success factors and lessons learned in its implementation. It is hoped that insight into the implementation of BRE's sustainability strategy will assist other organisations wishing to develop their own internal sustainability programmes to understand the key factors necessary to making such programmes successful.

Biodiversity offsetting for developments
IP 10/12, April 2012
This Information Paper provides an introduction to biodiversity offsetting, setting out the main issues and policy context and giving an overview of emerging mechanisms in the UK. As well as looking at the benefits, barriers and risks, it also explores the ways in which biodiversity offsetting can be implemented.

The Paper will help developers and their design teams to gain a better understanding of the process of biodiversity offsetting, enabling them to promote developments that enhance, rather than spoil, the natural environment. It will also increase Local Authority awareness so that procedures and policies are implemented in the right way for biodiversity offsetting to be carried out successfully.

Smart growth: a sustainable strategy for urban development and regeneration
IP 12/12, May 2012
This Information Paper presents the argument for a 'smarter' approach to policymaking and development. It recognises the need for sustainable physical, social and economic growth and introduces the 'smart growth' framework through which this can be achieved.

The publication is aimed at planners, developers, architects and urban designers, and other third-sector parties interested in the creation of our urban development. It offers readers a better understanding of the full suite of smart growth issues and proposes examples of how the principles can be implemented across varying political scales and design phases.

BREEAM and the Code for Sustainable Homes on the London 2012 Olympic Park: Lessons from the Velodrome, Aquatics Centre and the Olympic and Paralympic Village
FB 47, July 2012
This report contributes to the 'learning legacy' for the London 2012 Olympic and Paralympic Games and shares the lessons learned about sustainable design and construction on this exceptional project with the construction industry. It examines the achievement of high levels of sustainability on two of the key venues at the Olympic Park: the use of the BRE Environmental Assessment Method (BREEAM) in the design and construction of the Velodrome and Aquatics Centre; and the use of the Code for Sustainable Homes on the Olympic and Paralympic Village. The findings of these projects will be especially valuable to clients, designers and contractors.

Sustainable information technology: A review of current opportunities and challenges
IP 19/12, August 2012
Our growing reliance on information technology (IT) and its allied systems is adversely contributing to climate change. Closely linked to this is the built environment that houses these technologies. The purpose of this publication is to introduce overall concepts that can make IT more sustainable, otherwise more commonly referred to as 'green IT'.

This Information Paper is broadly aimed at anyone wishing to learn more about sustainable IT, and serves as a basic introduction to the layman while providing a baseline for further investigation. It reviews the literature and some current initiatives, and lists key issues that may influence an organisation's green IT policy when being formulated by sustainability officers and management.

Low flow water fittings: will people accept them?
FB 51, October 2012
Prompted by increasing concern in the UK that the demand for wholesome water will soon begin to exceed supply, particularly in South East England, BRE conducted a study of the likely public response to the introduction of low flow water fittings in domestic buildings. This included:

- an experiment using a specially designed test rig to measure reactions to low flow water fittings
- a focus group
- a survey of manufacturers and installers
- a literature review of public attitudes and behaviour regarding water use.

The results of the study increase our understanding of the barriers to and enablers of water-efficient behaviour and are of interest to policy makers, architects, planners, engineers, manufacturers and installers of water fittings and appliances, building developers, Local Authority housing managers and registered social landlords.

Sustainability strategies for healthcare estates: Lessons from University College London Hospitals
IP 24/12, October 2012
This Information Paper describes the sustainability strategies of the University College London Hospitals (UCLH) NHS Foundation Trust and aims to share the knowledge and successes of UCLH in implementing sustainability strategies in its healthcare premises. It is structured around the five key themes of waste, procurement, energy, travel and water, with community engagement as an overarching principle to operating sustainably that underpins each of these themes.

The aim of the Paper is to share best practice and push forward the sustainability agenda by providing examples of lessons learned in implementing sustainability strategies. It will be of particular interest to estates professionals and senior management within the health sector, along with their specialist advisers.

Design and management

Flood-resilient building
DG 523 (2 Parts), January 2012
This BRE Digest sets out an overall approach to building in flood-risk areas and the design of flood-resilient buildings, using a range of measures, including elements of resistance, resilience and avoidance. ***Part 1*** gives the background to building in flood-risk areas, and covers legislation, the principles of flood-risk assessment and the issues that define flood performance of buildings. ***Part 2*** covers designing flood-resilient buildings, and sustainable development and flood risk, and describes features and measures that can be used to protect buildings.

It will be of relevance to developers, designers, planners, regulators and others who need to take into account managing flood risk to new development.

The cost of poor housing in Northern Ireland
FB 45, May 2012
This report summarises the results of a research project commissioned by the Northern Ireland Housing Executive and BRE Trust to apply a methodology developed to calculate the cost of poor housing in England and Wales to the housing of Northern Ireland.

This research shows that there is proportionately less poor housing in Northern Ireland than in England or Wales, largely due to the fact that Northern Ireland has the most modern housing stock of the UK nations. However, there is still an unacceptably high (and previously unreported) proportion of health and safety hazards in the housing of Northern Ireland. Although great strides have been made in improving the energy efficiency of the housing stock, the excessively high fuel prices in Northern Ireland meant that a very large number of households are still in fuel poverty.

The report will be of interest to housing managers in the public and private sectors, landlords, property owners, housing policymakers, and health professionals and managers.

The Construction Products Regulation and CE marking
IP 13/12, May 2012
This Information Paper gives guidance on the Construction Products regulation (CPR) and on CE marking. These issues are important for manufacturers, specifiers, importers and distributors of construction products based in the UK owing to the previously voluntary nature of these requirements in this country. After reading this Information Paper, those UK professionals not previously familiar with the CPR and CE marking should be able to adapt their procedures to comply with the latest regulations.

Ninety years of housing, 1921–2011: Trends relating to living standards, energy use and carbon emissions
FB 46, June 2012
The housing stock in the UK has changed significantly since 1921. Many homes have been constructed since then, leading to the wide diversity that we see today. This report looks back over the past 90 years, presenting statistics that illustrate key changes and the progress that has been made in improving the nation's homes. The focus is on changes to the housing stock that have had an effect on standards of living, energy use and carbon dioxide (CO_2) emissions. Impacts on health are also discussed.

The report finishes by considering what the housing stock will need to look like in 2050 in order to meet the UK government's target to cut CO_2 emissions by 80% on 1990 levels, and the scale of the challenge that this presents. What has been achieved in the past is substantial, however the report provides an important reality check on the feasibility of achieving such large-scale changes over the next 40 years.

This report gives a fascinating insight into the development of the UK's housing stock for housing managers, landlords, property owners, housing policymakers and energy professionals.

Measuring the wellbeing benefits of interior materials: Research programme WISER (Wellbeing: Improving Satisfaction of End users in Refurbishment)
IP 20/12, August 2012
This Information Paper provides some background on the subject of wellbeing in buildings and presents the findings of a BRE Trust project, 'Measuring the wellbeing benefits of interior material selection'. The project's innovative approach was to focus on end users' wellbeing beyond the scope of indoor air quality: wellbeing that occupants perceive to be influenced primarily by the materials used in built environments. The objective of the project was to put occupants at the heart of the sustainable refurbishment and refit of buildings.

A data-collection tool was developed together with a 'Five golden rules' guide to enable decision makers to choose materials for refurbishment and refit projects that will support the wellbeing of occupants.

An introduction to structural dynamic comfort criteria
IP 21/12, September 2012
Modern buildings are becoming lighter and have less structural damping than older, heavier structures. Vibrations in such buildings can become annoying and even alarming, and different serviceability criteria have been developed over the years to ensure that buildings are suitable for their intended purpose.

This Information Paper gives an overview of current UK dynamic comfort criteria used to assess the acceptability of buildings, structures and components. It introduces a subject that is widely regarded as being confusing and difficult, and the subject is explained so that it is accessible to the non-expert reader. This Information Paper also presents four case studies that show the practical application of the techniques and methods described.

Saving money, resources and carbon through SMARTWaste
FB 48, October 2012
SMARTWaste Plan is an online tool that was developed by BRE to help users to prepare, implement and review their site waste management plans. This report provides an overview of SMARTWaste Plan and how the data it collects can be used. Since SMARTWaste Plan was introduced in 2008, data on over 8000 completed construction projects have been collected and this information has been used to produce a range of benchmarks and performance indicators.

This report provides detailed performance indicators of waste arising (related to project value or floor area) for both newbuild and refurbishment projects. These performance indicators will be of interest to clients, contractors and planners, and information is provided on how the data can be used. The report also provides case studies showing how the tool can provide an overall view of all company projects and how it has helped users to reduce the time spent on recording data and producing reports, thereby saving money.

Site layout planning for sunlight and solar gain
IP 22/12, October 2012
This Information Paper outlines revised BRE guidance on site layout planning to achieve good sunlighting, both within buildings and in the open spaces between them. It deals with sunlight within new developments and in existing buildings and gardens nearby. It addresses the provision of sunlight and access to solar energy in dense urban areas.

This Information Paper will be of interest to developers, architects and surveyors and their clients, and planning officials.

Site layout planning for daylight
IP 23/12, October 2012
This Information Paper outlines revised BRE guidance on site layout planning to achieve good daylighting, both within buildings and in the open spaces between them. It deals with daylight within new developments and in existing buildings nearby. It addresses the provision of daylight in dense urban areas and summarises some of the guidance on diffuse daylighting (ie light from the sky).

This Information Paper will be of interest to developers, architects and surveyors and their clients, and planning officials.

Radon solutions in homes: Improving underfloor ventilation
GR 37, Part 1, November 2012
This Good Repair Guide offers guidance to builders and homeowners carrying out installation works to increase ventilation under suspended ground floors. It covers the installation of both natural and mechanical (fan-assisted) ventilation to underfloor spaces. Advice is also given on system maintenance and what to do if a system fails to adequately reduce radon levels.

This Good Repair Guide is ***Part 1*** in a 3-Part set and replaces the guidance given in BRE Report BR 270. ***Parts 2*** and ***3*** cover positive house ventilation and sump systems.

Structural appraisal of existing buildings, including for a material change of use
DG 366 (4 Parts), December 2012
This Digest gives guidance to professional engineers and building owners on the structural appraisal of existing buildings, including making a structural appraisal for a material change of use.

Part 1 considers the overall regulatory requirements, and in particular the disproportionate collapse issues associated with Requirement A3 of the Building Regulations Approved Document A: Structure. ***Part 2*** introduces structural appraisal, and discusses the factors that might influence the outcome of an appraisal, and what might be involved in preparing for it. ***Part 3*** describes structural appraisal procedures and looks in detail at the process of structural appraisal: at the steps involved and at the levels of activity. ***Part 4*** provides additional coverage on sources of information, characteristics of materials, defects, deterioration and damage mechanisms, and through-life management in a low-carbon future.

About BRE Trust

Background

BRE Trust is a charitable company whose objectives are, through research and education, to advance knowledge, innovation and communication in all matters concerning the built environment for public benefit.

Building Research Establishment Limited, along with BRE Global Limited and FBE Management Limited, are wholly owned subsidiary companies of the Trust. This ownership structure enables BRE to be held as a national asset on behalf of the construction industry and its clients, independent of specific commercial interests and protects BRE's impartiality and objectivity in research and advice.

Profits made by the subsidiary companies are gift-aided to the Trust and used by it to promote its charitable objectives.

The Trustees meet in Council four times a year to provide strategic direction and to oversee and guide developments of the charity and of its subsidiary companies. The Trustees ensure that the charity pursues its objectives of 'for public benefit' research and education and that the assets owned by the Trust, namely its subsidiary companies, are used in a way that will contribute to the Trust achieving its objectives.

The Trust is the largest UK charity dedicated specifically to research and education in the built environment.

Constitution

BRE Trust is a company limited by guarantee Company number 3282856 and is registered as a charity in England and Wales (no 1092193) and in Scotland (no SCO39320). It is governed by its memorandum and articles of association.

Its registered office is Bucknalls Lane, Garston, Watford, Herts WD25 9XX.

Trustees and officers of the charity

The Trustees serving during 2012 are as given in Box 1. Since 31 December 2012, Michael Dickson CBE and Quentin Leiper CBE, FREng have been appointed as Trustees, both with effect from 20 February 2013).

During 2012 the Trustees delegated the day-to-day management of the Charity and management of its subsidiary activities to the CEO of BRE Group, Peter Bonfield, and the Finance Director, Russell Heusch.

Box 1: Trustees serving in 2012

Chairman

Sir Neville Simms FREng

Michael Ankers (appointed 25 July 2012)

Professor John Burland CBE, FREng, FRS (retired 20 February 2013)

Mark Clare

Professor Les Clark OBE, FREng (retired 20 February 2013)

John Carter

Mark Farrar

Hugh Ferguson

Richard Gillies (retired 25 July 2012)

Dr Liz Goodwin

Richard Haryott FREng

Sir Ken Knight CBE, QFSM

Peter Lobban OBE

Ian Tyler (appointed 7 November 2012)

James Wates CBE, FCIOB, FRSA

Secretary

Russell Heusch

Governance

Trustees are invited to become a Trustee because of the merit of their skills, and because their general expertise would be of benefit to the Trust and represent the wider interests of the built environment.

During 2012, the Council had three committees reporting to it:

- BRE Group Trust Audit Committee
- Research Committee
- Publications Committee.

Management

The role of the Trustees is to manage the activities of the Trust, its assets and investments. These are explicitly defined as:

- to manage and administer the activities of the BRE Trust, its assets and investments in accordance with the relevant Acts and guidance issued by the Charities Commission
- to give strategic direction to the work of the BRE Trust and group companies
- to make input into the strategic business plans of the group companies
- to extend the scope of BRE Trust's charitable activities for the public good and seek funding
- to develop research and education objectives for the charity and to prioritise expenditure against such objectives
- to act as ambassadors for the work and objectives of the Trust and its group companies
- to periodically benchmark the activities and achievements of the BRE Trust and its group companies
- to ensure the excellence of scientific standards within the BRE group of companies.

All other day-to-day decisions have been delegated to the boards of directors of the subsidiary companies.

Subsidiary companies

The Council of Trustees meets quarterly. The directors of subsidiary companies and senior staff are invited to the meetings to report on operational and business performance.

The activities of the trading subsidiaries are:

- Building Research Establishment Limited provides independent advice and information on building performance, construction and sustainability in the United Kingdom
- BRE Global Limited carries out research, testing and certification of materials and products, and certification of personnel, buildings, processes, systems and supply chains
- FBE Management Limited manages research work and carries out consultancy and research for the European Commission and provides technical support for the Construction Products Directive.

This book has been funded by BRE Trust

BRE Trust Review 2012

The BRE Trust Review 2012 presents a summary of the year's activities and achievements. The main focus is on short papers from BRE and the five Unversity Centres of Excellence, summarising research projects funded by BRE Trust in 2012. The papers demonstrate the breadth and scope of the research that is being supported by the Trust.

BRE Trust titles published by IHS BRE Press

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FB 51, 2012

A guide to the use of urban timber
FB 50, 2012

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