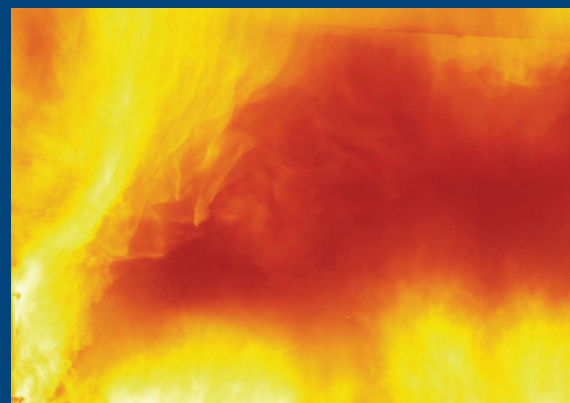


BRE TRUST REVIEW 2010



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The mission of BRE Trust is 'Through education and research to promote and support excellence and innovation in the built environment for the benefit of all'. Through its research programmes the Trust aims to achieve:

- a higher quality built environment
- built facilities that offer improved functionality and value for money
- a more efficient and sustainable construction sector, with
- a higher level of innovative practice.

A further aim of BRE Trust is to stimulate debate on challenges and opportunities in the built environment.

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FOREWORD

These have been challenging times for the construction industry, which has had to face the consequences of recession at the same time as developing innovative ways of addressing dwindling natural resources and reducing the environmental impact of new buildings and refurbishment.

BRE is playing a major role in helping government and industry find practical, safe and durable solutions to new build and refurbishment that stand up to scientific scrutiny. The importance of this was confirmed when the Prime Minister visited BRE in December 2010 to discuss the issues faced by those involved in the built environment. He visited the Victorian terrace refurbishment project and the innovative energy-efficient houses and health building on the BRE Innovation Park. The international relevance of BRE's work was confirmed when this meeting was followed by a similar visit from the Vice-Premier of China in January 2011.

Though these are testing times, BRE has been able to increase its gift aid of profits which BRE Trust uses to support research, publications and the work of the BRE University Centres of Excellence.

This *BRE Trust Review* provides an opportunity for BRE Trust to share summaries of the recently completed work that it has funded through various programmes of research and education including the thematic and responsive research programmes, the publications programme, the BRE publications archive and the Building4Change online knowledge hub.

In addition to the programmes of work, of particular note during the year has been the completion of Phase 1 of the Victorian terrace refurbishment project and the BRE University Centres of Excellence PhD students conference.

This year, a new section of the *BRE Trust Review* covers BRE publication activities and is introduced with a Foreword by Hugh Ferguson, Chairman of the Trust Publications Committee. The publications programme, funded by the Trust, has given BRE Group an opportunity to share knowledge on a wide range of issues that affect the built environment. The research section is again introduced with a Foreword by Professor John Burland, Chairman of the Trust Research Committee.

On behalf of the Trustees, I would like to thank BRE, BRE Global, the five BRE University Centres of Excellence, the PhD students, the BRE Trust partners and other organisations who have contributed to this *Review* by highlighting and summarising their important research activities and publications.

A handwritten signature in black ink that reads "Neville Simms".

Sir Neville Simms FEng
Chairman
BRE Trust

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BRE TRUST HIGHLIGHTS OF 2010

SOME KEY ACTIVITIES IN 2010

- Completion of Phase 1 of the Victorian terrace refurbishment project
- Closer links with the University Centres of Excellence
- Prime Minister's visit
- Visit by Vice-Premier of China
- Development of the Publications Programme
- Growth of Building4Change
- Launch of the BRE Archive
- First PhD students conference
- First outputs delivered in the Thematic Research Programme

Also, BRE Trust supported:

- NHBC Foundation
- Partnership with WRAP
- BRE Trust Research Conference
- RIBA Research Conference
- LED Lighting Conference
- Support for Parmiter's School, Watford
- A new Responsive Mode Programme

Buildings contribute 44% of the UK's overall annual carbon dioxide (CO₂) emissions. Those involved in the built environment have a major role in helping to counteract climate change and reduce use of non-renewable resources. This is not just a matter of meeting Government Targets of 80% CO₂ reduction by 2050, but more importantly ensuring that we leave a viable, safe and sustainable world for our successors. The vital research being carried out both at BRE and the BRE Trust University Centres sponsored by BRE Trust ensures that sound science supports the innovation and changes needed when designing new buildings and refurbishing existing ones.

There have been significant developments in BRE Trust activities in 2010 in connection with the BRE University Centres of Excellence and in the BRE Trust Publications Programme which was launched in 2009.

COMPLETION OF PHASE 1 OF THE VICTORIAN TERRACE REFURBISHMENT PROJECT

The Victorian terrace refurbishment project at BRE's Watford site first opened its doors in October 2010, and is serving as a 'living' laboratory for the testing and monitoring of retrofit solutions. The project has a key role in developing knowledge of retrofit and solutions in the run-up to the government's introduction of the Green Deal in 2012, which will allow people to take out loans to improve energy efficiency of properties. Under the first phase of the project, the exterior of the



building has been renovated, and the first two terraced homes retrofitted with both conventional and innovative products such as aerogel ultra-thin insulation, self-levelling floor compound, and phase-change ceiling tiles. In all, the project features 20 types of floor and wall insulation. Since completion of the first phase, the Victorian terrace has received a number of high-profile visitors, including Prime Minister David Cameron and Chinese Vice-Premier Li Keqiang, and has featured in a host of magazines and newspapers.

BRE UNIVERSITY CENTRES OF EXCELLENCE

BRE Trust supports the BRE University Centre of Excellence Chairs with a budget to April 2011 of around £175k and with a further £360k to support PhD students.

The five BRE University Centres of Excellence (UCE) are:

- University of Edinburgh (Fire safety engineering)
- University of Strathclyde (Energy utilisation research)
- University of Bath (Innovative construction materials)
- Cardiff University Welsh School of Architecture (Sustainable building design)
- Cardiff University School of Engineering (BRE Institute in Sustainable Engineering).

Box 1 gives some data on the UCE.

Twice-yearly meetings between BRE and the Chairs of the UCE commenced in June 2009. The meetings are held alternately at BRE in June and one of the University Centres in December. The meetings are attended by representatives of the BRE Trust, the University Centre chairs, The Chief Executive and Senior Directors of BRE, and the BRE supervisors and coordinators. The purpose is to share knowledge and identify opportunities for integrated working and collaboration.

Each of the BRE UCE specialises in a particular aspect of research into the built environment (Table 1) and complements the diversity of the work being carried out by the other UCE and the specialist areas at BRE. As can be seen in the report on the most recent collaborative

Box 1: BRE University Centres of Excellence

PhDs

- 61+ active – (25 BRE Trust funded)
- 30+ completed to date (since 2005)

Staff

- 35.5 full-time employed academic staff
- 18 research associates/technicians

Funding

- £500k pa BRE Trust (£2m total since 2004)
- £18m total leveraged
- £15m bids in preparation

Conferences

- PhD student conference 2010 was held at the University of Bath
- PhD student conference 2011 will be held at the University of Edinburgh
- 3 workshop meetings between the University Centres of Excellence

meeting of the UCE, at the University of Strathclyde (see report on page 3), it is clear that the meetings are beginning to meet their objective of integrating the work that is being done, to ensure that the research is relevant, the effort is shared and the value of outcomes for public benefit are maximised.

Table 1: BRE University Centres of Excellence

Organisation	No. of PhD students and full-time staff	Funding from BRE Trust/ BREGroup + secured funding	Active research areas
University of Bath BRE Centre for Innovative Construction Materials Professor Peter Walker	31 PhDs 12.5 staff 5 Research Associates	£1.7m	Advanced and natural composites, low-carbon materials, timber, concrete, steel and masonry
University of Strathclyde BRE Centre for Energy Utilisation Professor John Counsell	8 PhDs 7 staff 2 Research Associates	£745k (£1.1m by the Centre)	Dynamic simulation, building controls, energy demand management, energy efficiency and carbon reduction, low-carbon offices, intelligent controls, energy reduction in homes
University of Edinburgh BRE Centre for Fire Safety Engineering Professor José Torero	9 PhDs 9 staff 4 Research Associates	(£8m by the Centre)	Modelling, design, materials, structures and fire protection
Cardiff University BRE Centre for Sustainable Design of the Built Environment Professor Chris Tweed	6 PhDs 1 staff 3 Research Associates	£1.15m (£6.7m by the Centre)	Design for sustainable refurbishment, occupancy behaviour related to energy efficiency, neighbourhood dashboards
Cardiff University BRE Institute in Sustainable Engineering Professor Yacine Rezgui	7 PhDs 6 staff 4 Research Associates	£1.1m	Resilience of the built environment, assisted living/ageing, renewable energy for the domestic sector, low-carbon design
Total	61 PhDs 35.5 staff 18 Research Associates	£20.5m	

To further encourage opportunities for collaboration, the BRE Trust founded and sponsored the first annual BRE Trust PhD students conference. It is unusual for PhD students from different universities to gather together to discuss their research and mix socially and it has proved a great success (see report below).

The combined expertise covers all aspects of the built environment:

- the use of innovative materials at the University of Bath
- reducing demand for energy at the University of Strathclyde
- building systems and informatics at the Cardiff School of Engineering
- studying the implications of fire at the University of Edinburgh
- the relationship of the building with the end user at the Cardiff School of Architecture.

The built environment comprises complex elements and systems which cannot be seen in isolation but need to be understood as an integral part of a whole. BRE Trust with the support of BRE and the Universities is in a unique position to integrate and coordinate research efforts to produce a whole much greater than the sum of the parts.

BRE PhD STUDENTS CONFERENCE 2010

The BRE UCE for Innovative Construction Materials at the University of Bath hosted the first BRE Trust PhD students conference on 1–2 July 2010. This was an opportunity for the BRE Trust PhD students to meet and share what they were doing with others, both formally and informally. The presentations covered diverse related topics, and the students enjoyed the opportunity to exchange ideas with people they would otherwise not have met. The conference was a great success and the experience was so beneficial that the students have asked BRE to set up a dedicated social network group on the web so that they can continue to build on their association.

The BRE Trust Research Committee members who attended commented on the high quality of the student presentations. (Summaries of the work they are doing are included in the Research Section of this Review.)



COLLABORATIVE MEETING OF THE BRE UNIVERSITY CENTRES OF EXCELLENCE

Following the success of the first two collaborative meetings held in 2009, the third meeting of the BRE UCE was hosted by BRE on 14 June 2010 and the fourth was hosted by the University of Strathclyde on 1 December 2010. Despite the closure of several airports, rail routes and many major roads in Scotland due to heavy snow, the fourth meeting was well attended including all members of the BRE Trust Research Committee: Professor John Burland (Chair), Professor Les Clark and Richard Haryott.

These meetings are an opportunity for the UCE and BRE Trust to share information on their current and future research projects and their current bid programmes. They have been successful in identifying opportunities for collaboration and integrated research. BRE Trust are delighted that the UCE Chairs have been successful in obtaining financial support from other sources such as EPSRC and the Technology Strategy Board (TSB).

- Since 2001 BRE Trust has provided £1.8m support to over 60 PhD students.
- BRE Trust/BRE Group funding of more than £1m provided to BRE UCE Chairs.
- The number of research projects BRE Trust has supported or awarded since 2000 is over 180 with funding in excess of £8m.
- In less than two years BRE Trust has commissioned over 100 publications.
- Leverage on BRE Trust funding internally has improved its value by over 120% and through the Universities by 600%.

THE PRIME MINISTER'S VISIT TO BRE

Following a recommendation from senior officers in the Department for Business, Innovation and Skills, UK Prime Minister, David Cameron, visited the BRE site in December 2010 where he met Peter Bonfield, Chief Executive Officer of BRE, and saw at first hand the demonstration houses and buildings on the BRE Innovation Park and the Victorian terrace refurbishment project, a BRE Trust demonstration of refurbishment and retrofit of a 19th-century terrace.

While at BRE, the Prime Minister gave interviews to the press on the government's new energy supply and security. In a lengthy one-to-one meeting, the Prime Minister and Peter Bonfield discussed the changes that are needed in the built environment to meet government objectives and how these could be integrated with cross-departmental government policy. Their wide-ranging discussion covered subjects such as tackling fuel poverty, refurbishment, health care technologies for our ageing population, and economic growth.

Although many members of parliament have been to BRE since it was founded as the Building Research Station in 1921, this was the first visit by a Prime Minister.



VICE-PREMIER OF CHINA VISITS BRE

In January 2011, following the visit by the Prime Minister, the Vice-Premier of China, Li Keqiang, came to BRE accompanied by the UK's Secretary of State for Business, Vince Cable and a number of Chinese Ministers.

During the visit, Peter Bonfield described BRE's research and science base, our world leading products like BREEAM and certification activities, and our strong capabilities that drive positive change across the built environment.

Following a tour of the Innovation Park and the Victorian terrace, Vice-Premier Li said he was extremely impressed by what BRE is doing and expressed his desire for China to cooperate more closely and positively with BRE. Peter Bonfield commented 'It is an honour that he chose to visit us at the recommendation of the UK Government'.



BRE TRUST PUBLICATIONS

The BRE Trust publications committee chaired by Hugh Ferguson held their inaugural meeting in February 2010 to select the BRE Trust publications that would be produced in 2010/2011. 52 BRE Trust proposals were approved for publication which included updating some highly regarded BRE Digests (details of these can be found in the new section on Publications at the end of this *Review*.) BRE Trust support is beginning to make a significant impact on the number and range of publications that are produced by BRE experts.

It is worth noting that up to mid 2009, publications from BRE and BRE Global (Information Papers, Digests, Guides and Reports published by IHS BRE Press) were produced with no financial support from the Trust. BRE Trust recognises that these publications are often definitive sources of data, information and knowledge used by the construction industry, many are referred to in legislation and that it is imperative they are kept up to date and relevant.

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

BUILDING4CHANGE

The web-based resource, Building4change.com, was launched in late 2009 with BRE Trust funding to provide a freely accessible online news and knowledge hub on sustainability policy, practice, research and innovation in the built environment. Since its launch, the site has rapidly established itself as a valued resource and by late 2010, it was recording 20,000 users per month and 60,000 page impressions per month. The site's readership is still growing significantly, with followers coming not only from the UK, but also from the USA, Canada, South America, Australia and Europe. A growing number of readers also track the site via its presence on social media such as Twitter and LinkedIn.

Over 2010, the site featured a range of BRE activities, including the visits to BRE by Prime Minister David Cameron and Chinese Vice Premier Li Keqiang, lectures by Professor Steven Cowley, Chief Executive of the UK Atomic Energy Authority and eco-pioneering academic and author Brenda Vale, and the launch of the BRE Archive.

At the end of 2010, Building4change.com was a runner up in the website of the year category in the 2010 International Building Press National Journalism Awards, which rewards excellence in property, construction and architecture journalism. The recognition was a major achievement for such a young website.

BRE Trust has sponsored the site since its launch but in view of its editorial popularity and success, [Building4change](http://Building4change.com) is now planning its next phase of development, which will include providing opportunities for companies and stakeholders to buy recruitment advertising and sponsorship on the website.



Building4change has:

- approximately 20,000 visitors a month and 60,000 page views per month
- links to other sites including:
 - Chartered Institute of Marketing Construction Industry Group
 - The Construction Network and many other industry websites.

BRE ARCHIVE

An extraordinary insight into almost a century of UK construction industry history has been made available through a new online archive of research and guidance publications in a project set up by BRE Trust.

Built environment experts at BRE have been at the forefront of UK construction developments since BRE was founded 90 years ago. The thousands of publications they have produced remain in the care of BRE Trust as BRE's owner.

The first tranche of publications in the archive includes nearly a thousand documents comprising:

- *Current Papers*: 720 research project summaries published from 1968 to 1983
- *Digests*: 130 reviews of contemporary building technologies published from 1948 to 1966
- *Overseas Building Notes*: 125 guidance notes on low-technology building methods suited to conditions in many developing countries, published from 1961 to 1994.

A further set of more than a thousand documents, including detailed research reports, will be added to the site over the next few months.

Much of the information in the documents has been superseded by more recent regulations and standards, but it often provides intriguing details about the research underpinning a number of current practices. In addition, the information on contemporary building standards and techniques can, for example, provide valuable insights to those who are now renovating older buildings.

The archive can be searched and documents downloaded from www.brebookshop.com/archive, for a small fee.

BRE PhD STUDENTSHIPS

In 2010, the following PhD studentships were taken up and new awards made.

BRE Centre for Fire Safety Engineering, University of Edinburgh

Two new fully funded BRE Trust PhD studentships were awarded for the projects:

- Sensor-assisted support tools for live evacuation (from February 2010)
- Real fires for the safe design of tall buildings (from October 2010).

Centre for Energy Utilisation Research, University of Strathclyde

Three students, partly supported by BRE, commenced their PhD research studies in 2010.

The projects are:

- Controls and networks for zero-carbon DC lighting systems (from November 2010)
- Low-impact autonomous power generation systems for commercial buildings and call centres (from December 2010)
- Architectural design processes for fully integrated building design using renewables and pervasive monitoring and control systems (from December 2010).

A fourth commenced in early 2011:

- Deep bore ground source heat pumps for commercial buildings (from February 2011).

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

A fully funded BRE Trust PhD studentship commenced in early 2010 for a project entitled:

- Design interventions to improve sustainability in urban communities (from January 2010).

Centre for Innovative Construction Materials, University of Bath

In 2010, a BRE Trust supported PhD studentship commenced on:

- Thin topping timber–concrete composite floors.

Centre for Sustainable Engineering, University of Cardiff

Three students commenced their PhD studentships (part funded as indicated) for projects entitled:

- Home-centred healthcare management in an assisted living context (Cardiff/BRE Trust)
- Building adaptability (EPSRC/BRE Trust)
- Renewable energy (a BRE Trust funded student in connection with a Knowledge Transfer Partnership).

Other universities

BRE Trust supports two other PhD students.

- *Imperial College London*. An award was granted to a PhD student to research 'An innovative deformation-based design approach for steel structures'.
- *University of Hertfordshire*. A part-funded PhD student commenced a research project to study 'Improving the properties of natural fibre composites through surface modification of fibres in relation to matrix'.

PhDs completed in 2010

The following PhD research projects were completed in 2010 and final submissions were being drafted at the time this Review went to press.

Edinburgh:

- Material flammability as CFD model input

Strathclyde:

- Intelligent controller and system design methodologies for systems in buildings with adaptive climate control
- Energy demand control and profile restructuring to improve building energy performance and carbon footprint
- Carbon assessment methodologies for buildings and organisations

Bath:

- Development of hemp-based composite materials for construction.
- Fibre-reinforced polymer (FRP) stay in place (SIP) participating formwork for new construction

THEMATIC RESEARCH PROGRAMME

The way buildings are constructed and refurbished can have a significant impact on the environment. There is much innovation but sadly it is not all supported by rigorous science. In 2009 the Trust committed £1.5m to a three-year Thematic Research Programme on 'Low-impact materials, products and processes' to provide an opportunity for some evidence-based research to test the robustness of some of the ideas being considered.

In early 2010 18 projects commenced, one of which on sustainable shopfitting display equipment is complete (see page 80). Large well-known high street retailers collaborated in the project to design a toolkit to

help with selection of equipment in order to minimise environmental impact. BRE Trust was pleased to have supported this project which will lead to a significant reduction in the impact of shopfitting on the built environment in line with the thematic research objectives.

Other projects currently in progress explore some of the ideas through the low-energy houses on BRE's Innovation Park and the Victorian terrace refurbishment project (part-funded by BRE Trust) at BRE's Watford site. These projects mean that many innovative low-impact solutions can be thoroughly tested at full scale in semi-controlled conditions.

Box 2: Case study BRE Trust funding acts as a catalyst to further research

The thematic research topic on low-impact materials, products and processes is closely allied with that of the Technology Strategy Board (TSB). A key issue for the user is that simple ways are needed to control complex systems, which need to work together and not against each other, to make the best use of available resources.

Four BRE publications were produced to share knowledge on the potential of information technology in housing:

- *Smart home systems and the Code for Sustainable Homes* (BRE Report BR 506) was funded by the Knowledge Transfer Network for the Modern Built Environment (MBEKTN)
- Information Paper IP 8/10: *Digitally enabled communities* and Good Building Guide 77: *Installing smart home digital networks* were written with shared funding from MBEKTN and BRE Trust
- An Information Paper on smart meters is to be published in 2011 by IHS BRE Press.

This background work led to a BRE Trust funded award of £85k from the Thematic Research Programme (Low-impact materials, products and processes) for a project with the title 'Energy zone programme: energy-efficiency measures for housing'.

This catalysed the application for, and subsequent award of, three parallel TSB-funded projects:

- Service aggregation for smart homes (SASH), £500k, with partners: EDF, Tridium
- TAHI3ID@BRE TAHI Integration, Interoperability, Installation demonstrator at BRE, with partners OpenHub, Trusted Renewables, University of Hertfordshire, Birmingham City Council, Schneider, Birmingham University
- ETI Thermal Efficiency project, £800k, with consortium members including Wates and EDF R&D (France).

This demonstrates how BRE Trust funding can be used to establish initial key research findings and provide confidence to other parties and funding organisations that further research is beneficial, or even essential, for improving the quality of life in the built environment.

Topics that are covered by Thematic Research Projects in the Low-impact materials, products and processes category include:

- Historic estates: back to grass roots.
- Whole-building life-cycle assessment
- Extending LCA methodology to the evaluation of building services and other non-building materials
- Fire retardants: a balancing act
- Implications of LCA methodology choices for the evaluation of construction materials
- Phase-change materials
- Wireless technologies: providing low-impact solutions
- High-value, low CO₂ activated binder concrete products: whole-life performance
- Integrating organic PV into the built environment
- Service-life performance of low-impact materials and products.
- Do green credentials fade over time?
- Liability of buildings at the end of their life
- Low-impact materials in low-impact buildings (LIMILIB)
- Energy zone programme: energy-efficiency measures for housing
- Sustainable substructures
- Whole life-cycle assessment of off-site manufacturing versus traditional methods of construction
- Sustainable shop fit and equipment
- Long service life concrete structures for aggressive environments: minimising sustainability impacts and whole life
- The integration of renewable technologies, innovative control systems and materials in the Standard Assessment Procedure
- Measuring the wellbeing benefits of interior material selection

NHBC FOUNDATION

NHBC Foundation was established by NHBC in partnership with BRE Trust at the end of 2005 to facilitate research and development, technology and knowledge sharing, and the capture of industry best practice with a focus on housebuilding. By developing pragmatic and relevant research for the industry, the NHBC Foundation seeks to address the challenges of the Code for Sustainable Homes and the drive towards zero carbon, while considering broader environmental issues.

The NHBC Foundation commissions work that is managed independently from BRE Trust's other programmes and in 2010 has published three new projects which are listed in Box 3. All three titles are available in hard copy from NHBC and as pdfs on the NHBC Foundation web site (www.nhbcfoundation.org).

Box 3: 2010 NHBC Foundation printed reports

Ref. no.	Title
NF 21	Efficient design of piled foundations for housing
NF 22	Sustainable drainage systems for housing
NF 24	Ageing and airtightness



WRAP/BRE TRUST PARTNERSHIP

In the year 2009/10, WRAP agreed to provide a grant of £160k to work in partnership with BRE Trust to commission research relating to the development of resource efficiency plans for three sectors. The preparation of these plans is of strategic importance and forms part of the Construction Products Association commitment as detailed in the UK Government's Strategy for Sustainable Construction.

What are resource efficiency plans?

Resource plans provide a framework for a sector to set targets and objectives in the area of resource management and sustainability to improve economical, environmental and social aspects of the sector. Both industry and government support this focused approach to managing resources over defined timescales and the actions that need to be taken.

Joinery, flooring and packaging resource efficiency plans

The BRE Trust in partnership with WRAP has funded the development of resource plans for three sectors:

- joinery
- flooring
- packaging.

Two of the plans (joinery and flooring) were launched at the Building Environment Solutions Technology (BEST) show at Birmingham's NEC on 20 October 2010.

The Conservative peer and Under Secretary of State with responsibility for waste management and recycling, Lord Henley, said as he launched the conference: *'These plans are great examples of the initiatives the construction industry has developed to take responsibility to address the challenges of sustainability, at various lifecycle stages.'*

For example, the flooring plan, among other objectives, identifies the opportunity for the increased recycling of floor covering and has set a 25% diversion from landfill target for carpets to be met by 2015. This figure currently stands at only 2%.

The packaging plan is being developed to look specifically at actions that will help achieve the industry's own target of decreasing packaging waste by 20% by 2012. It aims to achieve this reduction by the increased repatriation and reuse of wooden pallets.

The joinery plan has among several core areas of action identified the need to challenge this traditional industry and the way in which they traditionally procure timber for joinery purposes which can be extremely wasteful; in some instances, up to 50% of the timber purchased goes to waste in the manufacture of joinery products.

The support of the BRE Trust and WRAP has been considered invaluable in this extremely successful and progressive area of work and continues in 2011 with the creation of three partnership groups to take these resource plans forward and ensure their longevity:

- Flooring Sustainability Partnership (FSP)
- Timber Resource Efficiency Partnership (TREP)
- Packaging and Waste Group.

CONFERENCES AND SPONSORSHIP

BRE Trust Research Conference 2010, 1 June 2010

The fifth annual research review event presented a selection of BRE Trust funded research projects completed in the financial year ending March 2010 to the BRE Trust Research Committee (Professor John Burland, Professor Les Clark and Mr Richard Haryott) and an invited audience. In 2010, it included presentations from final-year BRE Trust funded PhD students from the BRE University Centres of Excellence at Strathclyde and Edinburgh. Opening words were provided by Peter Bonfield, CEO of BRE. It covered a selection of research projects on:

- Ventilation and air quality (BREVAQ) tool for good indoor air quality in urban buildings
- Renewable energy research at Strathclyde University
- Dynamic SAP modelling
- PV systems on commercial buildings
- Flood resilience in buildings
- Power over ethernet
- Using building systems for predicting behaviour of fire
- External fire spread on high rise buildings
- Carbon footprint for housing.

Although these research review events were set up initially to enable the members of the research committee to assess the quality of the research projects funded by the Trust in front of an invited audience, it is now clear that many of the topics will be of interest to a wider audience and particularly those involved in setting standards, regulation and legislation. Therefore, in 2011 the research conference will be held in the Saatchi

Gallery in London on 24 May in conjunction with the BRE Conference as part of the 90th Anniversary of the founding of BRE.

RIBA Research Conference, 23 September 2010

BRE Trust was pleased to sponsor the RIBA Research Conference 'Does beauty matter?' chaired by Phillip Blond and Albert Taylor with keynote speaker, John Gummer. One of the speakers was BRE Trustee (now retired), John Calcutt. Other speakers were John Andrews, Irena Bauman, Tom Bolton, Sue Clifford, Eric Parry, Pam Warhurst.

BRE Trust support enabled the entire proceedings to be recorded and the audio transcript is available to download from the RIBA website*.

The symposium tackled the significance and function of beauty today. Delegates debated with architects, developers, community activists and politicians, informed by new research. High profile contributors gave their perspectives on the future of beauty, and its important implications in our society.

LED Lighting Conference, 2 November 2010

BRE Trust sponsored the well-attended LED Lighting Conference held at BRE and chaired by Dr Paul Littlefair, BRE. Of particular interest was the colour performance and brightness of LED lighting which is beginning to match the much higher wattage halogen lighting. The topics included:

- application and performance of LEDs
- test methods
- new developments
- organic LEDs
- lighting design.

Speakers included:

- Steve Pool, The Lighting Association
- David Chan, WUELC, Swansea University
- Ian Turner, Juice Technology
- Fenella Frost, Photon Star
- Geoff Williams, Thorn Lighting
- Kevin Theobald, KTLD
- Paul Littlefair and Hilary Graves, BRE.

Royal Society Conference, 10–11 November 2010

BRE Trust was pleased to provide sponsorship towards a two-day conference organised by the IOM3 Sustainable Development Group and entitled 'Innovation towards sustainable materials'. Peter Bonfield, CEO of BRE, was one of the speakers in the first session.

The conference set out to demonstrate that materials have a key role in sustainable development, against a background of mitigating and adapting to climate change,

* www.architecture.com/TheRIBA/AboutUs/InfluencingPolicy/ResearchAndDevelopment/ResearchSymposium/RIBAResearchSymposium2010.aspx

which remains the primary challenge of the 21st century, while yet improving living standards and quality of life for all in the long term.

PARMITER'S SCHOOL

For the fifth consecutive year, the 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. This scheme gives pupils the opportunity to work on a project, guided by a mentor from a company, in this case BRE Global Limited, so they can experience science, engineering and technology first hand. The students' project on 'Research into the energy-saving properties of phase-change materials in a cavity wall' gained them a gold CREST award in the British Association for the Advancement of Science CREST scheme.



RESPONSIVE MODE PROGRAMME

In September 2010, the BRE Trust Research Committee agreed to support 12 new research projects with a total budget of £300k. The projects, which are not part of the Thematic Research Programme, are wide ranging in scope and will include investigation into topics such as the novel use of landfill waste in composite construction materials, light pollution from street lighting, integration of renewable energy in district heating networks, fire performance in timber frame construction, non-intrusive examination of buildings for fire risk assessment, profiling FITS opportunities.

OTHER NEWS

During 2010, in addition to the publications produced as part of the BRE Trust Publications programme (see final section of this Review), the reports and Information Papers listed in Box 4 were published based on the outcomes of the BRE Trust Research Programme.

Box 4: Titles published in 2010 as a result of BRE Trust funded research

Ref. no.	Title
FB 26	Energy efficiency in new and existing buildings
FB 28	Integrating BREEAM throughout the design process
IP 14/10	Consumer feedback on low-carbon housing
IP 15/10	Specifying LED lighting
IP 17/10	Creating a funding mechanism for UK carbon reduction projects



BRE Trust published its first annual Review in May 2010 with a section describing the highlights of BRE Trust activities in 2009 and a summary of the research projects completed in 2009. It has provided a valuable forum for those who have benefited from BRE Trust funding to summarise their work and for BRE Trust to demonstrate the outcome of its funding activities. An electronic version of this and the 2010 Review can be downloaded from the BRE Trust website (www.bretrust.org.uk).



FOREWORD TO THE BRE TRUST RESEARCH PROGRAMME



The primary objective of BRE Trust is to support research that improves the built environment and protects the health, safety and wellbeing of all who live, work and relax in it.

Buildings are a major contributor to UK carbon emissions. The above objective is particularly important at the present time when industry is exploring ways of reducing energy use, refurbishing existing buildings and constructing new ones with the aim of reducing carbon emissions and the use of non-renewable resources. This is driving innovation in construction and refurbishment and reducing energy use in buildings. Research is essential so that the lessons learned about the actual performance of traditional forms of construction and systems are passed on to, and understood by, the innovators.

Rigorous and robust research of the kind described in the following pages is essential to finding new solutions and to ensuring that novel materials and systems give the required performance in terms of energy conservation, fire safety, durability, environmental impact and structural integrity. To this end BRE Trust since 2001 has:

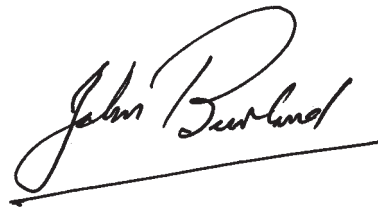
- provided £1.8m grant support to over 60 PhD students
- given £1m to support BRE University Chairs
- supported or awarded over 180 research projects with funding in excess of £8m.

In 2010, BRE Trust has been encouraging more collaboration between the five BRE University Centres of Excellence and more integration between their research activities and those of BRE. The challenges for those involved in the built environment are huge. As can be seen from the following pages, BRE Trust is in a unique position to draw together expertise and knowledge to carry out its research and maintain the status of BRE

as an impartial and highly respected strategic research organisation.

This is the second BRE Trust Review. Those who have completed or are about to complete BRE Trust-funded research at BRE and the BRE University Centres of Excellence have been invited to provide a summary of their work and findings so far. The research covers a wide range of topics from fire prevention to low-energy lighting, from carbon footprint for housing to design for areas vulnerable to flooding.

We live on a planet that is facing unprecedented challenges, and I am proud that the research that BRE Trust supports is targeted and focused on tackling some of the most pressing problems in our built environment.



Professor John Burland
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



USE OF SUSTAINABLE AND LOW-ENVIRONMENTAL-IMPACT MATERIALS IN REFURBISHMENT PROJECTS

Tim Yates, Rob Mobbs and Sarah Billcliffe

Building Technology Group, BRE

SUMMARY

This project explores the scope for specifying sustainable and low-environmental-impact materials for refurbishment schemes. These specifications must be supported by robust advice and guidance on the materials and components that can be used to achieve the required performances. However, the project showed that unfortunately the scope for refurbishment using these more sustainable materials is limited. Many of the natural materials that are proving to be viable options in a drive towards sustainable construction depend on entire wall thicknesses to comply with current Building Regulations, and so require a different form of construction from that found in many existing buildings.

BACKGROUND

There is renewed interest in the refurbishment of domestic and non-domestic buildings in response to both the requirement to improve the living conditions in many older houses and to reduce emission of greenhouse gases. It is estimated that around 20% of the building stock (around 4.2 million houses) date from before 1919 and many of these are in need of refurbishment and upgrading. In addition, there are an additional 2 million houses dating from after 1919 which fall below or only just meet the current 'decent homes' level. Total investment required to improve these houses

both to improve living conditions and to reduce energy consumption by 60% is estimated to be of the order of £100 billion at present costs.

Upgrading the current housing stock to meet current demands for an 80% reduction in carbon emissions, or even for a 60% reduction, will be a complex and costly process, but by using sustainable low-impact materials the overall reduction in environmental impact should be greater than the apparent improvement in thermal performance. The potential for refurbishing especially terraced housing is significant. Projects have found that a solid-walled building with the insulation externally

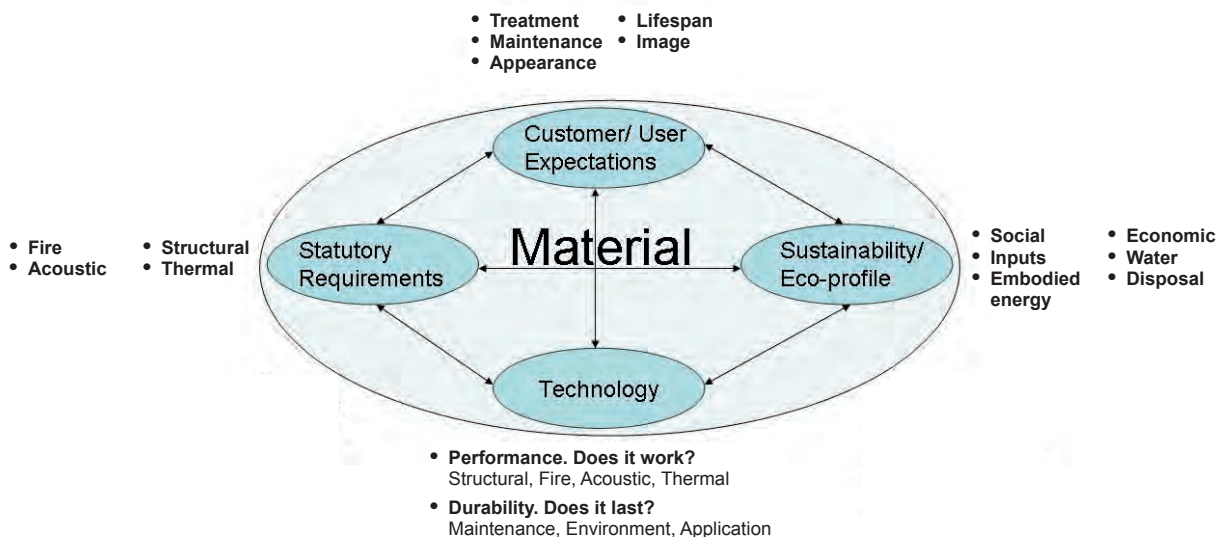


Figure 1: The different pressures that need to be evaluated or assessed when considering the requirements of a material

applied could have a performance equal to a cavity-walled building but the impact of the materials and the impact on the building fabric need to be taken into account.

RESEARCH PROGRAMME

This research indicated that natural composites, natural insulations and glulam could potentially be used in sustainable refurbishment. The use of crop fibres, wool fibres and engineered timber within buildings is already becoming established in the new-build market but there have been few studies related to their use in refurbishment. Therefore, at present there is only limited technical information and few practical examples to support their use in refurbishment (Figure 1).

The use of crop fibres as reinforcement with composites is increasing but does not as yet appear to offer the same characteristics as glass-reinforced composites. However, the use of natural-fibre-reinforced composites is common in the automotive industry within components that are not required to be of high strength. Hybrid composites of natural-fibre and glass-fibre-reinforced composites are close to the characteristics of glass-fibre-reinforced composites.

Research into the use of natural fibres and wool is promising with insulation levels close to oil-based and mineral-based products.

Glulam has proven potential to replace steel and concrete to form a building's structural frame. Research reviewed has investigated with positive results, methods which improve its strength and durability potentially increasing its application.

However, the case study at The Close, Selly Oak (Figure 2), showed that unfortunately the scope for refurbishment using these more sustainable materials is limited. Many of the natural materials that are proving to be viable options in a drive towards sustainable construction depend on entire wall thicknesses to comply with current Building Regulations, particularly Part L^[1], and so may require a different form of construction.

In addition, there are tensions between the requirements to protect a building's heritage and the need to improve thermal performance even when more sustainable materials are proposed. Removing this tension and, therefore obtaining a better balance, may need a greater degree of flexibility both with respect to environmental requirements and expectations when protecting the built heritage. It is acknowledged that upgrading the current housing stock to meet current demands for an 80% reduction in carbon emissions, or even for a 60% reduction, will be a complex and costly process for all buildings. However, by using sustainable low-impact materials the overall reduction in environmental impact should be greater than the apparent improvement in thermal performance provided that the most appropriate materials are selected and that reliable data is available to make an informed decision.

PROJECT OUTCOMES/CONCLUSIONS

This project has made a significant contribution to the alignment of construction with the low-carbon agenda, which will allow the industry to deliver social and environmental benefits while exploiting new markets. The importance of the project lies in the fact that although there is increasing expertise in the specification of refurbishment schemes as a result of work by BRE and others, these specifications must be supported by robust advice and guidance on the materials and components that can be used to achieve the required performances. This project delivered aspects of the groundwork that will support environmentally friendly refurbishment and will support informed decision-making.

REFERENCE

[1] Communities and Local Government (CLG). The Building Regulations (England & Wales) 2000. Approved Document L: Conservation of fuel and power, Volumes 1A and 1B (Dwellings). 2010 edition. Available from www.planningportal.gov.uk

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Figure 2: General view of the south side of The Close, Selly Oak, University of Birmingham

SUSTAINABLE HIGH-VALUE CONSTRUCTION PRODUCTS FROM MUNICIPAL AND DOMESTIC BLACK BAG WASTE

Andrew Dunster

Building Technology Group, BRE

SUMMARY

This project evaluated the range of waste-derived output materials that arise from commercial steam autoclaves, a technology which is becoming increasingly available in the UK for the mechanical heat treatment and separation of mixed domestic waste or municipal solid waste (MSW). Some of the output materials from the autoclave, particularly the cellulose fibre fraction (which is the major output material in terms of quantity), have potential applications as an ingredient in construction and landscaping products. The opportunities for utilising the fibre in these applications were reviewed as well as the main barriers to wider adoption of the autoclave output materials.

BACKGROUND

At present, a large proportion of municipal solid waste (MSW) is sent to materials recovery facilities (MRFs) where, typically, a combination of automated and manual sorting takes place to enhance the proportion of material recovered for recycling. These can be:

- 'clean' MRFs which accept mixed (or co-mingled) recyclable materials that have been collected from households and businesses
- 'dirty' MRFs which accept unsorted waste.

Commercial autoclaving is best suited to the unsorted fraction of MSW. Autoclaves, which have been used to process waste since 1982^[1], operate on the principle that water can be heated above its conventional atmospheric boiling point in a pressure vessel. At present (2010), there are at least three UK companies investing in the use of

autoclave technology as a means of processing municipal solid waste (MSW). Each facility is potentially capable of processing between 100,000 and 350,000 tonnes of mixed MSW per annum.

Commercial autoclaves for the treatment of MSW operate on a batch process, having processing times, temperatures and pressures that sterilise and stabilise the waste. Most plants employ mechanical agitation and/or fins within the cylindrical autoclave to break up the waste and expose it fully to steam. A major proportion of the autoclave output is a sterilised cellulose fibre which is derived from the breakdown of the organic material in the waste. At the end of the cycle, the autoclave is emptied and the sterilised materials are separated into various fractions: fibre, glass, polymer, ferrous and non-ferrous metals and other residues as represented in the schematic diagram (Figure 1).

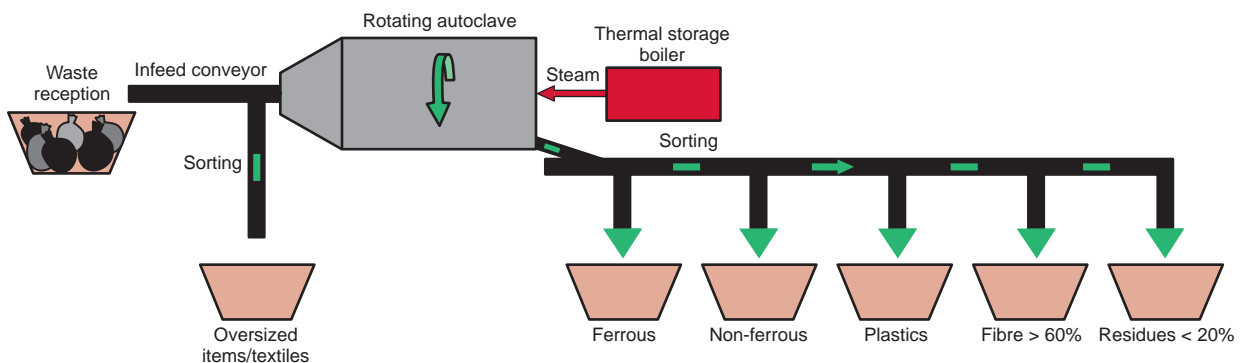


Figure 1: Schematic diagram of a commercial autoclave
Modified from Carbon-info.org



Figure 2: Sample of milled fibres produced from typical municipal black bag waste

The autoclave fibre makes up approximately 60–65% (by mass) of the output materials. If the fibre requires storage after treatment, it must be dried and maintained at a moisture content of approximately 13% by mass or lower to avoid biological deterioration. The fibres themselves are sterile on discharge from the autoclave but they need to be dried or treated with antifungal agents to prevent biological deterioration.

Once dried, the autoclaved fibre can be milled to give a ‘fluffed’ fibrous product with a lower density than the raw dried fibre and within which a significant proportion of the individual fibres have been separated. Figure 2 illustrates a sample of these fluffed fibres produced from waste from a typical kerbside collection.

Technologies are becoming available and are being installed by autoclave operators to upgrade the fibre by removing grit and mineral impurities, as well as optical sorters to remove rubber and plastics.

RESEARCH PROGRAMME

This project has identified a range of building products which could be manufactured from the autoclave fibre output materials. The work has also established knowledge and expertise at BRE in the processing of the fibre fraction and its successful application in construction markets.

PROJECT OUTCOMES/CONCLUSIONS

The following potential construction applications have been identified for the autoclave fibre.

- A type of asphalt (stone mastic asphalt or SMA) that is used for surface courses in road construction, currently incorporates a small proportion of cellulose fibre^[2,3] as an additive to prevent migration or drainage of the bitumen binder within the asphalt mixture.

- Autoclave fibres have some potential as an alternative raw material (ARM) in the manufacture of clay bricks, although the effects in terms of colour and other aesthetic effects remain to be determined fully. ARMs for brick manufacture are not likely to attract a premium price unless they give an ‘added value’ (eg a sought-after colour or a lower fluxing temperature and hence energy consumption). Currently, such fibres act primarily as a source of energy within the brick body (a body fuel). Competitor materials as brick body fuels include sawdust, paper sludge and waste carpet yarn^[4].
- The autoclave fibre has a high potential as a cost-effective partial replacement for conventional blown cellulose fibre insulation with minimal changes to the production process. Cellulose-based insulation is conventionally produced from recycled paper and is suitable for insulating roofs, walls and floors^[5]. It is the most common renewable insulation material available in the UK. Prior to use as an insulation material, cellulose needs to be treated to improve the biological and fire resistance of the material. Cellulose-based insulation is commonly manufactured as boards, or installed as a loose-fill material that is blown into cavities.
- There is increasing interest in bio-resin-based fibre composites integrating renewably sourced or recycled fibres which can either be safely biodegraded or, alternatively, selectively degraded by means of a physical, chemical or radiological process. In this way, the fibres from the composite are reclaimed for reuse in future products^[6].
- An alternative raw material in the manufacture of board products.
- A component in concrete block manufacture.

Commercial autoclaves provide one option in the mechanical heat treatment of municipal waste and are being adopted as one of a series of technologies to divert waste from landfill.

Sterile cellulose fibre, derived from the modification of organic materials in the waste, is the major input in terms of volume and this has several potential applications in construction and landscaping products. The environmental benefits have yet to be fully evaluated. Nevertheless, the fibre has great potential as an economical raw material in high-value products provided the required levels of safety, performance and cost can be demonstrated.

RESEARCH OUTPUT

More information about the findings of this research project will be given in a BRE Information Paper, *Sustainable construction products from domestic black bag municipal solid waste*, which will be published by IHS BRE Press in 2011.

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BRE CENTRE OF EXCELLENCE FOR INNOVATIVE CONSTRUCTION MATERIALS, UNIVERSITY OF BATH

Peter Walker

BRE Trust Professor of Innovative Construction Materials

The BRE Centre for Innovative Construction Materials (BRE CICM) was founded in July 2006; its primary aim is to conduct internationally leading and interdisciplinary research in the development of innovative and sustainable construction materials and technologies. BRE CICM is a multi-disciplinary centre of over 40 researchers (full-time academics, contract research staff, and postgraduate students) drawn from across the Faculty of Engineering & Design at the University of Bath. The main research activities of BRE CICM continue to include work in the fields of advanced composites in construction, concrete structures, low-carbon building materials, timber engineering and materials, structural masonry, seismic engineering, structural conservation and vulnerability assessment.

In 2010, the centre expanded with the appointment of three new staff members.

- In September, Dr Wen Shao Chang joined from Kyoto University (Japan). His field of expertise is timber engineering and low-impact construction materials.
- Also in September, Dr Richard Ball joined the team from the University of Bristol. Richard is a materials scientist with particular expertise in lime-based materials.
- Dr Aykut Erkal joined the centre as a research officer working full-time on the Parnassus Project (described in one of the papers that follows).

Centre staff received two best paper awards from the Institution of Civil Engineers.

- *Deep embedment of FRP for concrete shear strengthening*, authored by Dr Pier Valerio, Professor Tim Ibell and Dr Antony Darby, won the 2010 Bill Curtin Award for the best innovation-in-design paper.



BRE Trust PhD Student Conference, University of Bath, July 2010

- *Limit-equilibrium assessment of drystone retaining structures* by Dr Chris Mundell, Dr Paul McCombie, Claire Bailey, Dr Andrew Heath and Professor Peter Walker won the ICE's 2010 John Mitchell Medal, awarded for the best paper in geotechnical practice, site-based innovation, or geotechnical safety.

BRE CICM hosted the inaugural BRE Trust PhD student research conference in July 2010. The event was attended by over 60 delegates, including two BRE Trustees (Richard Haryott and Professor Les Clark) as well as staff from BRE and the PhD students and staff from the university centres of excellence.

For further information on the projects that follow, contact Professor Peter Walker,
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STRENGTHENING RECTANGULAR COLUMNS USING FIBRE-REINFORCED POLYMERS

Antony Darby, Rachel Coonan and Tim Ibell

BRE Centre of Excellence for Innovative Construction Materials
University of Bath

SUMMARY

This project aims to develop a practical model for analysing realistically dimensioned and loaded rectangular columns strengthened using fibre-reinforced polymers. When a concrete column is loaded in compression, it expands laterally, as the concrete squashes out. Wrapping with FRP resists this squashing, leading to confinement and increased capacity. The difficulty is in understanding this interaction in the case of a rectangular column. This recently concluded EPSRC-funded project has developed this understanding, resulting in design guidance to be included in the next edition of the UK's design manual for FRP strengthening of concrete structures.

BACKGROUND

Due to changes in loading and building use, it is often necessary to increase the load-carrying capacity of concrete structures. Using fibre-reinforced polymers (FRPs) to achieve this rehabilitation has proved to be efficient, reliable and cost-effective. However, some aspects of FRP strengthening are not fully developed and, therefore, have had limited adoption by industry.

One such aspect is the technique of wrapping rectangular reinforced concrete columns with FRP to increase axial load capacity. FRP wrapping of structural columns confines the concrete in compression so that it can develop a considerable increase in strength. As the column is loaded in compression, the FRP wrap resists the lateral expansion of the concrete so achieving confinement. For circular columns, the confining pressure occurs around the whole perimeter leading to increases in the strength of up to 200%. However, for FRP-confined rectangular columns the confining forces can only act at the curved corners. This has been seen to result in an increase in capacity of up to 50% for small-scale specimens.

Until now, design methods have been based on the results of these small-scale, concentrically loaded test specimens. This is not representative of the typically large-scale columns under the action of combined axial and flexural load conditions found in practice. Therefore, the technique has not been able to be used with confidence in practice, despite the potential benefits.

This recently completed project has investigated the behaviour of FRP-confined rectangular columns at large scale under realistic types of loading, resulting in design guidance which represents behaviour of strengthened columns under typical conditions.

RESEARCH PROGRAMME

The project had three main aims which were investigated through a comprehensive programme of experimental, theoretical and numerical work.

- *To establish the effect of size on strength enhancement of FRP-wrapped rectangular columns.* Concrete structures do not necessarily behave the same at small scale as at large scale. This 'size effect' was investigated through testing small- to large-scale columns. The small-scale tests were carried out at the University of Bath, while large-scale columns were tested at BRE using both their 500-tonne and 1000-tonne test machines (Figure 1). The results of the tests revealed that, in fact, small- and large-scale specimens behave in much the same way, with the same failure modes and similar strength enhancements. Therefore, it was concluded that a significant size effect does not exist for square columns, implying that small-scale tests can be used to investigate behaviour.
- *To establish the effect of aspect ratio and load eccentricity.* The effect of increasing aspect ratio (the ratio of side lengths of a rectangular column) was investigated through concentrically loaded columns. Specimens were compared for various aspect ratios from 1:1 to 1:2.5. The tests showed that very little increase in strength occurred when aspect ratio increased beyond 1:1.5. This was because any confinement which did exist was localised at the corners, comprising a small proportion of the total area for large aspect ratio columns. The effects of load eccentricity were investigated by square and rectangular specimens. Eccentricities were chosen to represent a range of column load conditions.



Figure 1: Large-scale testing at BRE

Three important observations were made:

- the stress in the FRP varied along the column sides leading to debonding (Figure 2) which limited the confining forces at the corners
- when only part of the concrete is in compression the internal steel reinforcement dominates behaviour so that the concrete confinement has negligible effect on the column capacity
- strengthening does not increase stiffness of the column, so lateral deformation and buckling of the column under high loads prevent the columns from reaching their full capacity.

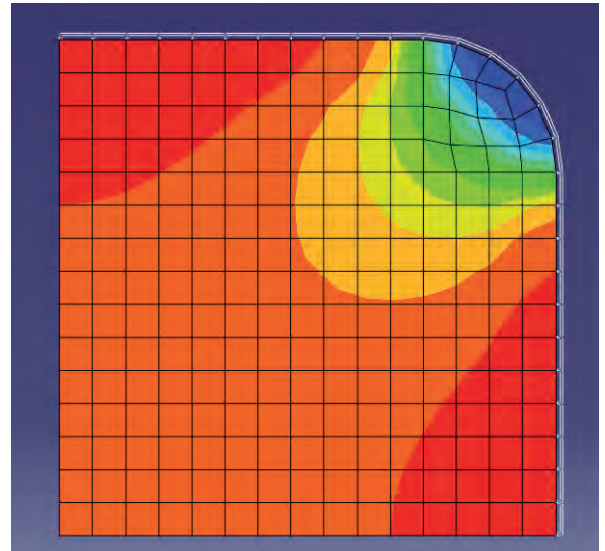


Figure 3: FEA of confinement stresses (quarter model)

- To develop a rational model for predicting strength. The results of the first two aims assisted in the primary objective of producing rational design guidance which represents the mechanics of behaviour. The internal stresses in the concrete were initially investigated using qualitative finite element analysis (FEA). This demonstrated that the confining stresses vary throughout the cross-section, being very high at the corners and reducing towards the centre and sides of the section (Figure 3). This variation becomes crucial when examining columns under eccentric loads since knowing the stress at a particular location is important. A theoretical basis for these confining stresses was developed, based on an analogy with cohesive soils, producing a stress distribution within the concrete in excellent agreement with the FEA, and, more importantly, with the tests. Considering this ability to calculate the internal stresses in the confined concrete, based on the confining forces in the FRP at the corners (which in turn are limited by either debonding or rupture of the FRP), a theoretical model has been developed which captures the mechanics of the behaviour under concentric and eccentric loading.

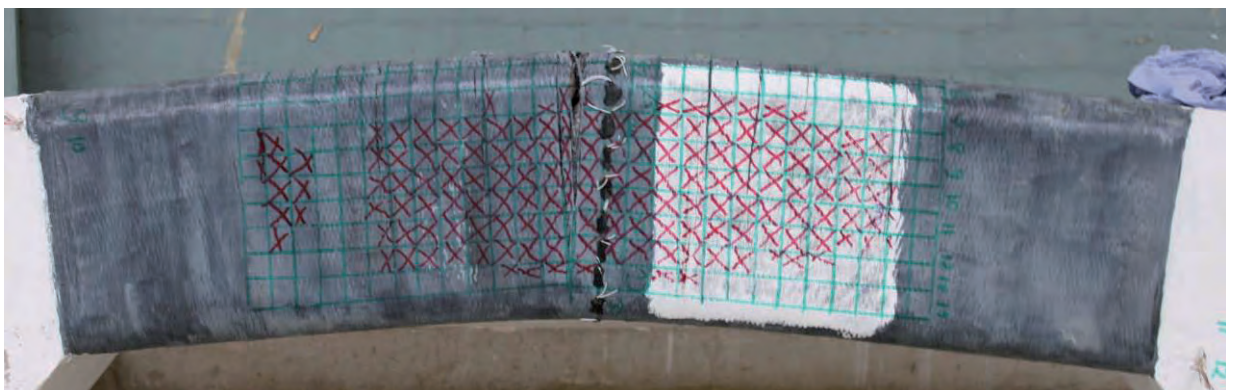


Figure 2: Regions of debonded FRP (indicated by red crosses)

RESEARCH OUTPUT

Research output has, to date, been in the form of two conference papers which have covered the first two aims.

More importantly, the third aim has formed the basis for the design recommendations provided in the third edition of the Concrete Society's Technical Report, TR55, *Design guidance for strengthening concrete structures using fibre composite materials*, the UK's internationally

recognised design guidance on strengthening concrete structures using FRPs, to be published in 2011. Thus, the research has significant international impact, allowing rectangular column-strengthening schemes to be properly and safely designed for any normal load condition.

Two more journal articles are in preparation which describe in more detail the experimental results and theoretical modelling.

THE PARNASSUS PROJECT

Dina D'Ayala, Aykut Erkal, Victoria Stephenson and Enrico Fodde

BRE Centre of Excellence for Innovative Construction Materials
University of Bath

SUMMARY

The PARNASSUS project is a collaborative project set up to investigate the potential impacts of climate change on heritage sites in the UK. The project brings together archaeologists, engineers, hydrologists and conservation professionals to study the potential increase in risk due to the effects of climate change on our built cultural heritage and archaeological sites. The findings of this project will be disseminated through the conservation community so that conservation professionals are prepared for these increases in risk and able to work to mitigate them.

BACKGROUND

PARNASSUS is an interdisciplinary research project investigating the adverse environmental effects and adaptation measures needed for the protection of cultural heritage from climate change impact. The project is implemented under the AHRC/EPSRC Science and Heritage programme and the academic partners are: University of Bath (BRE Centre for Innovative Construction Materials [BRE CICM], Department of Architecture and Civil Engineering), University of Bristol (Department of Civil Engineering and the School of Geographical Sciences), and University of Southampton (School of Humanities).

RESEARCH PROGRAMME

The overall aims of the project are to:

- understand and quantify the impacts of flooding and driving rain due to climate change on the structural integrity and material properties of historic buildings and archaeological sites
- evaluate resilience and adaptation measures able to counteract and prevent adverse effects

- disseminate findings to conservation practitioners via guidance documents and seminars.

To achieve these aims, the project will focus on case studies chosen for their exposure and vulnerability to wind-driven rain (WDR) and flooding. The research activity is organised in work packages coordinated by the academic partners according to their expertise.

- Wind-driven rain and flood impact on structural integrity of historic construction systems is being investigated by University of Bath in collaboration with BRE Watford.
- Monitoring of environmental effects and numerical modelling of building performance are being designed and developed by the University of Bath.
- Wind-driven rain and flooding scenarios for the next 100 years, and their hydraulic modelling are being conducted by the School of Geographical Sciences, University of Bristol.
- The Civil Engineering Department, University of Bristol, is responsible for assessing the performance of various masonry materials exposed to extreme

weather cycles, using an environmental chamber with mechanical loading developed specifically for this purpose.

- Assessing failure behaviour using virtual models, to be developed in collaboration with Southampton University, and advanced laser scanning and restitution techniques.

Environmental monitoring and numerical modelling

Dr Aykut Erkal, research associate to BRE CICM, is responsible for the design and management of the environmental monitoring system, numerical modelling, dissemination, and project web-site design and development. To date, the main output includes:

- literature review of wind-driven rain effects on material deterioration
- on-site building survey
- preliminary report on a monitoring strategy
- design of a monitoring system in cooperation with Eatec Engineering Consultant and Omni Instruments Company and ordering of monitoring instruments for two historic buildings in Tewkesbury (Figures 1–3)
- design of the project website (<http://www.bath.ac.uk/parnassus/>).

Other activities include laboratory experimentation on the impact of rain drops on masonry materials (Figure 4).



Figure 1: The Abbey Mill in Tewkesbury, chosen for monitoring due to its exposed location on the bank of the River Sever



Figure 3: Instrumentation on 1 Mill Bank, Tewkesbury

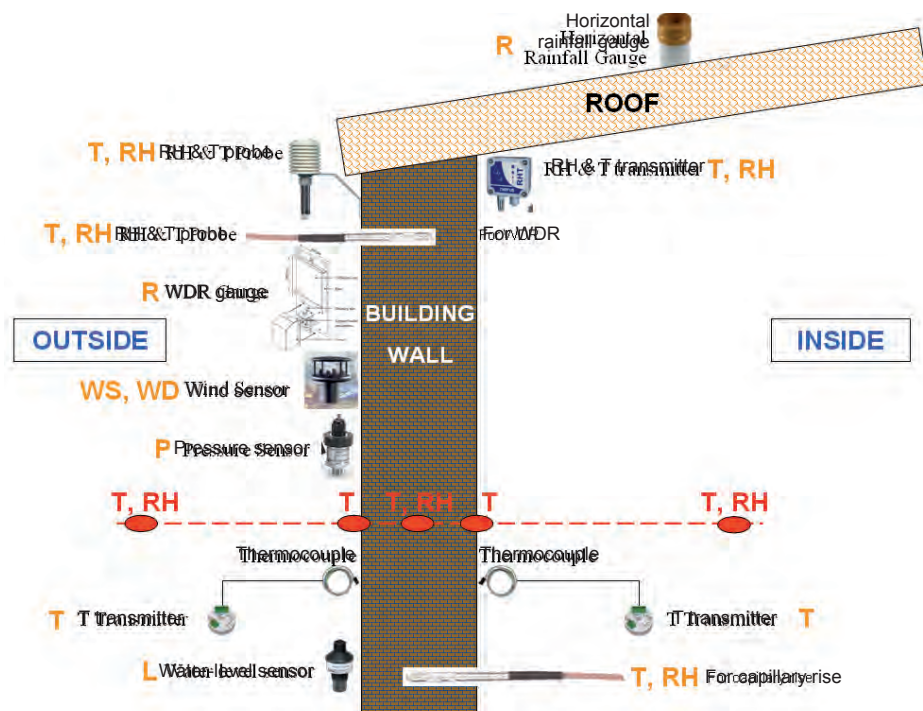


Figure 2: Sketch of monitoring installation on buildings



Figure 4: Laboratory experimentation to explore the behaviour of rain drops on masonry

Effects of wind-driven rain and flooding on historic structures

Victoria Stephenson, doctoral candidate at the University of Bath, is investigating the impact of potential increases in frequency and severity of extreme wind-driven rain and flood events on historic construction systems.

Our knowledge of these buildings, which are constructed of materials that are particularly susceptible to damage from moisture ingress, suggests that increased exposure to wind, rain, and flood water will eventually lead to the compromising of their structural integrity, and in the worst cases bring about complete collapse. Victoria's work on the project to date has focussed on a series of case study appraisals. The case study sites were chosen based on a combination of:

- their historic and archaeological significance and
- the climatic risks associated with the sites.

The work on two of the sites, Tewkesbury and Winchester, included on-site street and building scale surveys, and a survey of building users.

Information collected from the survey work was used to identify:

- the typology of the building stock being investigated, including such characteristics as materials, construction systems and building condition;
- a numerical profile of the spread of such characteristics;
- which material and construction combination was most exposed.

Following the case study appraisal work, development of the test procedure and design of the test specimens have begun. The selection of materials for the laboratory work will be based on an understanding of which are most predominant within the UK historic building stock, and are also particularly susceptible to damage. The test conditions will be derived through the analysis of observed data, at both a long-term seasonal scale, and single extreme event scale. Load testing and monitoring of the specimens will take place at specified locations within the time-frame of the climatic simulation to provide a picture of the structural integrity of the wall under different climatic conditions. The intended outcome is the identification of how the structural capacity and integrity of the wall are compromised through exposure to climatic conditions of differing severity.

DURABILITY OF ALKALI-ACTIVATED CONCRETE: Compositional effects on alkali–silica reaction

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SUMMARY

Over recent years, research on alkali-activated binder technology has been a focus for the scientific community due to its potential as a possible solution to the likely increase in demand for concrete, especially in the developing world. Another aspect of its potential is its enhanced durability and reduction of CO₂ emission in the construction industry. However, before alkali-activated technology can be used as a viable construction material, the effect of compositional variability on the long-term durability of the concrete has to be clearly understood. One such area of concern due to the high pH alkali solution required for the activation of the binders is alkali–silica reaction (ASR), and is the focus of this BRE Trust funded study.

BACKGROUND

Portland cement (PC), and other traditional binders such as lime, produce considerable amounts of CO₂ during manufacture. With the demand for cements likely to increase to over four and a half billion tonnes per annum by 2050, alternative technologies that utilise locally available waste materials and industrial by-products are considered to have an important role in reducing environmental impact associated with the construction industry.

Alkali-activated binder technology (AAT), which has been in existence since the 1940s, uses less energy and emits less CO₂ in production than traditional cements and limes. However, there has been little work published on long-term durability of concretes made from these systems (Figure 1). In particular, there has been concern with the durability of concrete due to alkali–silica reaction (ASR), a mechanism that occurs when alkalis in the pores of the concrete come in contact with reactive silica found in certain aggregates, leading to expansion and cracking.

The importance of investigating ASR for alkali-activated technology is due to the fact that the use of the high pH alkali solution required to create the alkali-activated system may not become entirely bound within hydration products and could initiate the deterioration mechanism associated with ASR. This clearly raises concern as to whether alkali-activated technology can be used as a viable construction material.

With the limited knowledge available, most durability work to date worldwide has been based on either alkali-



Figure 1: AAT wall block

activated fly ash or alkali-activated slag binders, however extensive review and trials during this research identified that producing an alkali-activated system with a blend of fly ash and slag provides further advantages. This is because no thermal curing is required and consequently there is a further reduction in CO₂ emissions.

RESEARCH PROGRAMME

To help undertake further durability studies into AAT, the following comprehensive and preliminary studies have been investigated.

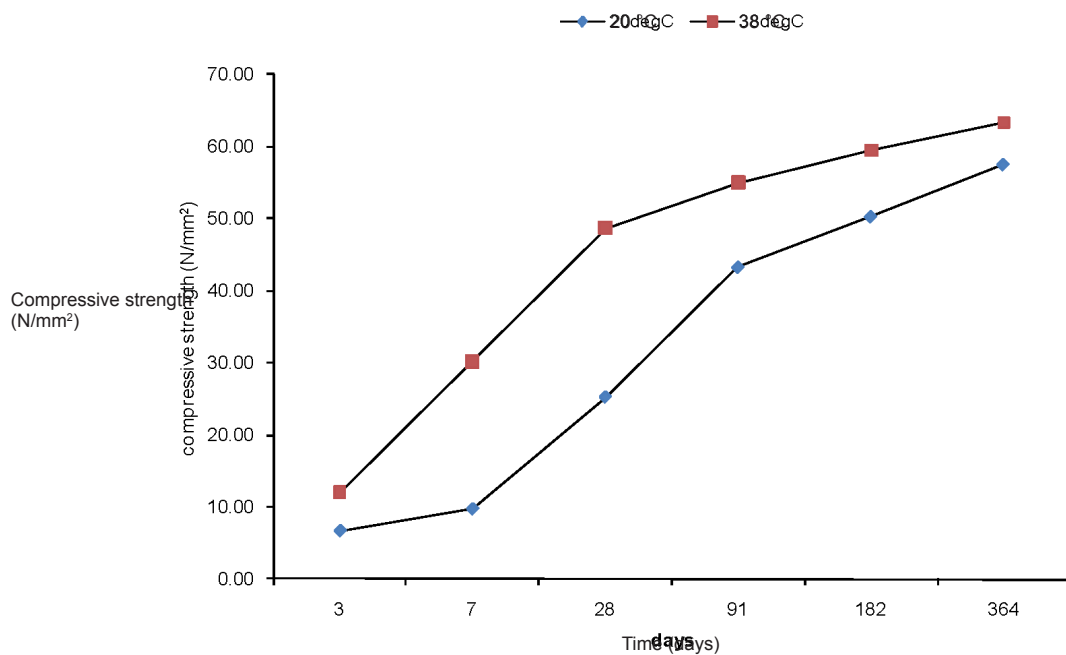


Figure 2: Effect of curing temperature on strength development

Compressive strength development

One variable identified with AAT concrete is its rapid change in consistence over a short period of time, especially if the mix design is not appropriate, making the fresh concrete difficult to place. To ensure a mix of reasonable consistence with the various alkaline solutions, initial trials of the mix design used a blend of fly ash and granulated ground blastfurnace slag. The effects of varying the concentration of the alkaline solutions as well as the curing environment (Figure 2) on the strength development of the concrete specimen were investigated.

Alkali-silica reaction

Following the initial trial of the mix design, an optimum mix for the AAT concrete was proposed to investigate the impact of exposing AAT concrete under ASR environmental conditions. The method adopted was that specified in RILEM AAR-3 (Figure 3). The changes in length and mass were monitored from day one until extreme deterioration was observed or an expansion of more than 0.05% was identified, which according to RILEM AAR-3 is detrimental if it happens before one year.

Current observation of all prisms indicate that the AAT concrete is performing better under ASR conditions than the PC concrete (control) and that these concretes are showing no signs of major expansion or cracking. This, however, does not confirm the absence of ASR gel and thus further detailed analysis of the specimen under a microscope at the end of the testing programme will be required to determine if ASR gel is present or not.



Figure 3: Expansion measurement for the ASR test

Water-soluble alkalis

The presence of alkalis within the concrete that are readily soluble can be associated with the occurrence of ASR, thus analysis of the pore solution is essential to understanding the rate of reaction of the alkalis within AAT concrete exposed to ASR over time. Initial analytical study of the water-soluble alkalis has found that much of the sodium is bonded in the reaction, resulting in a high percentage drop in concentration from the initial mix. However, this is still a considerable concentration compared with the profile for water-soluble alkalis within ASR-susceptible PC concrete.

Environmental impact assessment

An initial review of the environmental profile of AAT concrete indicates that the alkali solution (sodium silicate) makes a major contribution to the water use, climate change potential (CO₂eq) and nuclear waste impact categories. Manufacture of the activator uses significant electricity, heat and water in its manufacture (via its hydrothermal manufacturing route) and thus, contributes the highest Ecopoints, associated with production of AAT concrete than the total combined materials.



Figure 4: Alkali-activated concrete mix

RESEARCH OUTPUT

The research carried out to date was presented at an international conference in 2009 and has been the subject of a BRE Information Paper. A further Information Paper, conference presentations and journal papers are in preparation.

Abora K, Quillin K, Paine KA & Dunster A. Effect of mix design on consistence and setting time of alkali activated concrete. Proceedings of 11th International Conference on Non-conventional Materials and Technologies, Bath, 2009

Dunster A, Abora K & Quillin K. Alkaline ash binders: reduced environmental impacts for precast concrete products. BRE Information Paper IP 9/10. Bracknell, IHS BRE Press, 2010



PERFORMANCE OF CALCIUM SULFOALUMINATE-BASED CONCRETES

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SUMMARY

Non-Portland cements based on calcium sulfoaluminate have the potential to achieve intrinsic reductions in the embodied CO₂ emissions (eCO₂) of concrete. Already being standardised in China, these cements exhibit high compressive strengths, and very good resistance to sulfate attack when used in concrete. A range of long-term durability aspects, however, need to be explored before they can be accepted for mainstream use in the UK. The research is currently investigating the performance characteristics of composite cement concretes based on calcium sulfoaluminate cements rather than Portland cement (PC)

BACKGROUND

The energy-intensive manufacture of Portland cement (PC) (accountable for 930 kg of CO₂ emitted per tonne of clinker produced) and the high annual demand for concrete (approximately 25 billion tonnes worldwide per annum) has led the cement and concrete industry to consider strategies for reducing the embodied CO₂ (eCO₂) of concrete. By incorporating industrial by-products with PC, Portland composite cements of lower eCO₂ have been developed — these are now the current established technology.

However, even more sustainable opportunities may lie in the utilisation of non-Portland cements. Possible alternatives are those cementitious systems based on use of ettringite as the principal cementing compound, such as calcium sulfoaluminate cements (CSAC) and supersulfated cements (SSC).

CSAC have an embodied CO₂ of approximately 600 kg/t (35% lower than that of PC). The primary raw materials are limestone, bauxite, gypsum and sometimes fly ash. The calcination of the raw materials takes place at temperatures in the range 1300–1350 °C, which is 100–150 °C lower than that of PC manufacture, thus requiring lower energy input. Furthermore, the resulting clinker is easier to grind than PC clinker which leads to savings of 15–30 kWh in energy consumption in the mill. Although the chemistry, hydration and microstructural aspects of these cements have been extensively studied, there is, however, a lack of data on the durability of CSAC concretes.

Because CSAC has rapid hardening and high-strength properties, its use at normal water/cement ratios leads to performance characteristics that are inappropriate for most applications when used as a pure clinker. However, concretes of more appropriate strength, with lower eCO₂,

can be achieved through the combination of CSAC clinker with low-carbon additions.

RESEARCH PROGRAMME OBJECTIVES

This research project aims to:

- develop CSAC-based concretes with appropriate strength, deformation, permeability and durability characteristics for use in the UK.
- explain the mechanisms behind performance levels achieved, through analytical study of the hydration mechanisms, microstructure and chemistry of CSAC-based concretes, to provide long-term confidence in use of these cementitious systems.
- carry out a theoretical eCO₂ analysis on concretes normalised for a given level of performance, so as to determine the emissions for given design requirements, and quantify the benefits of using CSAC-based concretes.
- compare the environmental performance of CSAC-based concretes with that of PC-based concretes for a range of mechanical, deformation, durability and permeability requirements.

METHODOLOGY

Calcium sulfoaluminate-based concretes investigated have included:

- combinations of commercially available CSAC clinker with gypsum, limestone, fly ash and other low-carbon additions
- commercially available SSC
- innovative SSC created through judicious blending of ggbs, gypsum, lime, PC and other additions in the laboratory.

Table 1: Concrete mix proportions

w/c ratio	CEM I			III/A			CSAC/G		
	0.35	0.5	0.65	0.35	0.5	0.65	0.35	0.5	0.65
Water content, l/m ³	230	230	230	230	230	230	230	230	230
Cement content, kg/m ³	660	460	355	660	460	355	660	460	355
Sand content, kg/m ³	590	705	790	570	690	780	500	670	740
Aggregate content 5/10, kg/m ³	380	400	405	380	400	405	641	400	405
Aggregate content 10/14mm, kg/m ³	530	565	570	530	565	570	530	565	570

In all work, PC (CEM I) and PC/ggbs (III/A) concretes have been used as controls to quantify the performance of these concretes.

As an example of the methodology used, the mix proportions of three concretes (CEM I, III/A and a combination of CSAC/gypsum [65:35 ratio]) are given in Table 1. The latter combination was chosen after a comprehensive preliminary study on mortars that investigated the role of gypsum on the strength of CSAC-based cement combinations. All concretes were proportioned at three different water/cement (w/c) ratios: 0.35, 0.5 and 0.65.



Figure 1: CSAC-based concrete

The cube strength of concrete mixes was determined by testing 28-day water-cured 100 mm cube samples in accordance with BS EN 12390-3. The results indicated that CSAC-based concrete exhibited comparable strengths to the CEM I and III/A concretes for the typical range of w/c ratios and consistence classes used in the UK (Figures 1 and 2). From Figure 2, the w/c ratio required to achieve a given design strength can be determined, and consequently from this it is possible to determine the corresponding mix proportions required to achieve the design strength.

Based on the known eCO₂ of the constituents used in the mix, the corresponding eCO₂ of concretes for any design strength can be calculated, as shown in Figure 3. For example, the results for these particular concretes showed that there was a 24% reduction in the eCO₂ of concrete when using CSAC/G to achieve a strength of 50 N/mm² than when using III/A concrete.

Clearly, strength is only one aspect of the research, and a similar concept can be applied to the achievement of a given level of performance with respect to permeability, deformation properties and resistance to chemical attack, chloride ingress and carbonation. For example, the resistance of 300 × 75 × 75 mm concrete prisms to sulfate attack was investigated by monitoring the dimensional changes at two-week intervals, when immersed in a 5% Na₂SO₄ solution at 20 °C. It was observed that CSAC/G expanded less than both Portland and Portland composite cement-based concretes throughout 40 weeks of immersion to the solution (Figure 4).

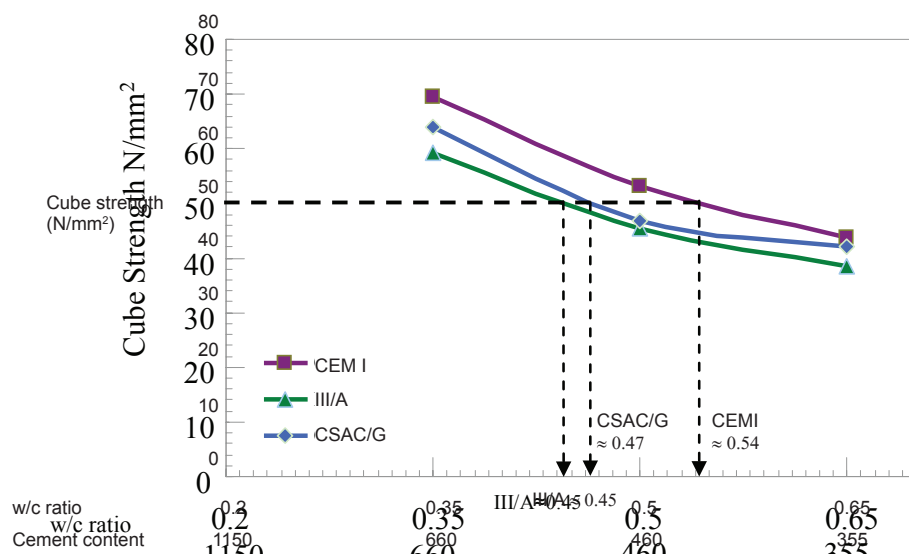


Figure 2: Relationship between w/c ratio and cube strength for CEM I, III/A and CSAC/G concretes, indicating approximate w/c ratio to achieve a 28-day concrete cube strength of 50 N/mm²

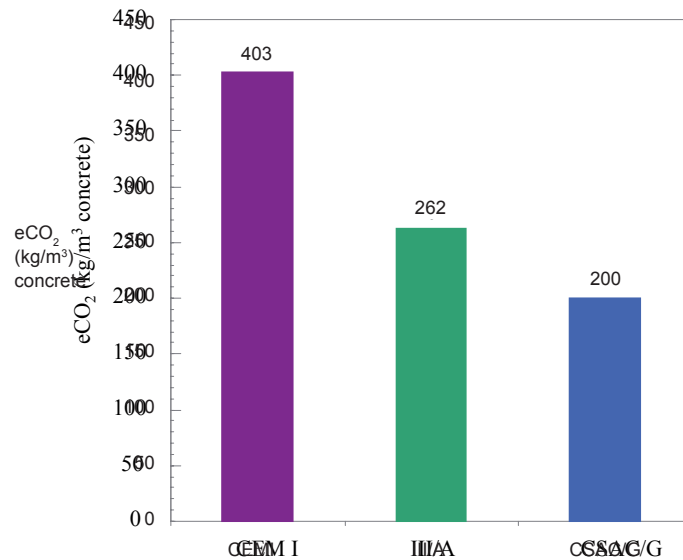


Figure 3: eCO₂ yielding from mix design of concretes to achieve a 28-day compressive strength of 50 N/mm²

CONCLUSIONS

The following conclusions have been drawn from this study to date.

- CSAC/gypsum combinations have the potential to reduce the eCO₂ emissions associated with concrete by up to 24% compared with III/A concretes for a given design strength.
- Optimisation of combination levels and the use of alternative additions, particularly limestone, have the potential to reduce these savings further.
- The combination of additions to CSAC does not adversely affect the ability of concretes based on CSAC

to withstand external sulfate attack, and they perform better than III/A and CEM I concretes.

- Studies to investigate durability are on-going.

RESEARCH OUTPUT

The research carried out to date was published at an international conference in 2010 and has been accepted for publication at a forthcoming international conference in Greece. A journal paper is also currently in preparation.

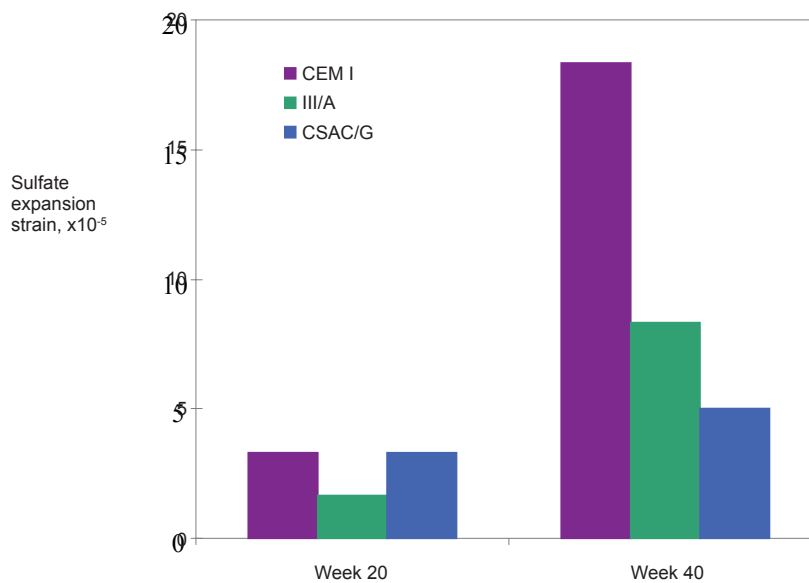


Figure 4: Sulfate expansion of concrete mixes, w/c ratio = 0.5, immersed in 5% Na₂SO₄ solution

DISSIPATIVE ANCHOR DEVICES FOR THE SEISMIC RETROFIT OF HERITAGE BUILDINGS

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SUMMARY

Despite the progress achieved in the field of seismic protection of buildings, historic centres are still seriously affected by earthquakes, due to the lack of methodical strengthening interventions carried out because of respect for heritage materials and construction techniques. This research programme focuses on the development of a set of dissipative anchoring devices for masonry buildings that will tackle this technical gap.

BACKGROUND

In the last decades, drawing on the experience derived from earthquakes such as Northridge, California, USA, in 1994 and Kobe, Japan, in 1995, structural engineers have progressively abandoned capacity methods and moved on to performance-based techniques^[1], which focus on the enhancement of the ductility and the use of additional dissipative elements rather than rely on stiffness and strength for the purpose of improving the seismic behaviour of structures.

Nevertheless, current codes still continue to use traditional stiffness-based systems for the retrofit of historic buildings (eg EN 1998 Eurocode 8^[2]), while the application of techniques involving ductility and energy dissipation, despite being allowed in principle, are limited since innovative systems rarely meet some of the requirements (eg reversibility, low impact) required for interventions on historic structures. Few high-profile case studies appear in the literature^[3,4].

Considering that a substantial number of European and Mediterranean historic centres are located in earthquake-prone areas and that generally the whole urban fabric should indeed be considered as a heritage asset, the state of the art raises concerns. The drawbacks of strength-based systems were brought once more to the fore by the L'Aquila earthquake, Italy, in April 2009. Inadequate compatibility of materials in terms of mechanical properties (stiffness, weight, connections) can indeed be highly detrimental, as shown by the examples in Figure 1^[5].

In the case of elements such as concrete ring beams, the high mass and stiffness, often aggravated by inadequate connections, can cause catastrophic collapses and make this system unsuitable for historic low shear capacity masonry walls. Conversely, cross-ties, which have been and are still commonly applied in rehabilitation practice all over Europe^[6] restore a box-like behaviour, allowing for the redistribution of horizontal load in sets



Figure 1: Failures connected to stiffness-based reinforcement (on-site survey, L'Aquila, Italy, May 2009). Detail of reinforced masonry ring beam (a), timber ties (b)

of perpendicular walls without substantially increasing the mass. Thus, traditional cross-ties are able to provide a connection at the joints of perpendicular sets of walls, where poor quality, previous damage, or general wear and tear facilitate crack onset and eventually out-of-plane failure. Nonetheless, anchors can also cause pull-out damage at the head of the anchorage and increase in-plane diagonal cracking because of the different deformation characteristics of steel and masonry. This might become a major problem when damage limitation should be pursued also avoiding cracking in precious plasters, frescoes, or other culturally valuable finishes.

RESEARCH PROGRAMME

Drawing on the above observations, the authors developed, within the framework of a two-year Knowledge Transfer Partnership (KTP) between the University of Bath and Cintec International Ltd, a dissipative device specifically designed to address the lack of passive systems for the seismic protection of heritage buildings (Figure 2).

The device is conceived as an add-on for stainless steel ties. Thanks to either the hysteretic properties of a stainless steel element, shaped to optimise its post-elastic behaviour, or a friction mechanism set to be triggered for a certain level of pulling force, the device allows small relative displacements, dissipating energy and hence reducing the impact of seismic force on the walls, and controlling damage. The system has the considerable advantage of being compatible with existing as well as post-installed anchors.

The experimental validation performed during the KTP project included cyclic tests in pseudo-static and dynamic regimens of the dissipating devices on their own. A target displacement of ± 10 mm, comparable with the allowable inter-storey drift required by current guidelines, was achieved for both devices^[7].

Additionally, the devices underwent a set of pull-out tests aiming at characterising the behaviour of anchors in

low shear capacity walls (Figure 3); tests proved that the devices can reduce the damage to the substratum due to the transmission of an axial load to the anchorage^[8].

Since the KTP partnership finished at the beginning of 2010, the project has continued with funding from the EU within the FP7 NIKER European consortium (project no. 244123, call no. FP7-ENV-2009-1). The *New integrated knowledge based approaches to the protection of cultural heritage from earthquake-induced risk* (NIKER) project aims to tackle the problem of earthquake-induced damage on the basis of a 'minimal intervention' approach.

Such an approach involves the development of new techniques relying on the strength and energy dissipation capacity of existing materials and components for the purpose of achieving compatibility and minimal intervention, as well as optimal seismic performances. The process relies on both experimental and computational tools, databases and the know-how of the 17 academic and commercial partners involved in the project; validation is performed under specific, real-life conditions. The consortium will eventually deliver a set of guidelines for end-users for the systematic improvement of the seismic behaviour of cultural heritage assets.

Within this framework, the authors will focus on structural connections and, in particular, on:

- The completion of the experimental assessment of the dissipative devices by:
 - dynamic tests on the isolated devices using an accelerogram as input signal
 - pseudo-static tests of the devices embedded in two orthogonal walls undergoing cyclic loads
 - shaking table tests of masonry buildings reinforced either by traditional anchors or dissipative devices. The experimental campaign will be carried out within the framework of another FP7 project, the SERIES project. The authors successfully applied together with Cintec Ltd to the European bid and gained access to the testing facilities of LNEC in Lisbon, Portugal. Tests will rely on the use of half-scale models of two-storey structures undergoing recorded seismic accelerations, thus allowing for the extensive assessment of the strengthening systems under lifelike conditions.
- The development of an instrumented anchor, which will be validated by installation in a church in L'Aquila, Italy. The system will be monitored remotely and used both for reinforcing the building, which was damaged during the last earthquake, and for recording the performance of the devices in a real case study.
- The completion of the finite element modelling that was initiated during the KTP by tuning the models with experimental data; models will be used to simulate further scenarios and complete the experimental output by computational results.
- The development of a procedure for sizing and positioning the devices within a building so as to achieve an ad-hoc optimised strengthening solution.



Figure 2: Pull-out test using a frictional device: set-up and instrumentation

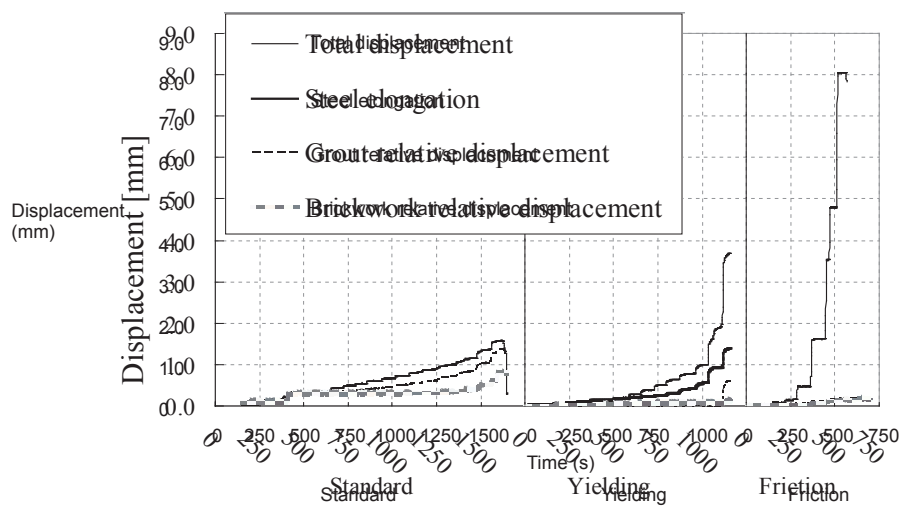


Figure 3: Displacements within the assembly for: standard, yielding and friction anchors

RESEARCH OUTPUT

The extensive results of the experimental and computational validation of the devices as well as the design procedure will eventually feed into the author's PhD thesis.

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CREEP PROPERTIES OF THIXOTROPIC ADHESIVES FOR BONDED-IN CONNECTIONS IN TIMBER STRUCTURES

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SUMMARY

Adhesively bonded connections provide a rapid and efficient solution for bonding steel or GFRP pultruded rods into timber for the purpose of repair, reinforcement or making structural connections. For overhead repairs in, for example, bridges it is essential that the adhesive is thixotropic, such that in its uncured state it thins under application in shear but retains a gel-like consistency at rest. Such adhesives are cured under ambient conditions which, in general, results in a low glass transition temperature of ~30–40 °C. The research reported here is concerned with an investigation of time- and temperature-dependent creep in thixotropic adhesives under constant load in order to determine the structural integrity of these adhesives at elevated temperatures.

BACKGROUND

Adhesives are used to bond together primary elements of timber structures including bridges and buildings where threaded steel or pultruded composite rods are bonded into timber sections to transfer load^[1,2]. A precise quantity of adhesive is injected into oversized drilled holes or routed slots in the timber and the rods or pultrusions are inserted into the holes or pressed into the slots. This paper is concerned with the creep of thixotropic adhesives which are shear thinning in their uncured state and may be employed where overhead injection is necessary.

Once cured, the glass transition temperature (T_g) of shear thinning adhesives is often of the order of 30–40 °C although post-curing will increase T_g to a modest extent^[3]. Specifiers of adhesives may be unwilling to select an adhesive for bonding in rods with a low T_g on the basis that creep under constant load is likely to occur at elevated temperatures and under high stresses^[4]. However, Richter & Steiger^[5] report no significant loss in strength and only minor creep deformation in epoxy adhesives used to bond CFRP to wood up to 50 °C. Experience, over many years, of using thixotropic epoxy adhesives to bond in rods in construction applications demonstrates that no failures have occurred in creep.

This research investigates the mechanical response of a low T_g , thixotropic epoxy adhesive subjected to multi-stage creep loads in a dynamic mechanical thermal analyser (DMTA). Properties are evaluated in tension and also in shear using a DMTA specimen with a unique micro-shear geometry.

RESEARCH PROGRAMME

The adhesive system under investigation is marketed as Rotafix Structural Adhesive (RSA) and is manufactured by Rotafix (Northern) Ltd. RSA is a thixotropic, non-Newtonian two-part, epoxy gap-filling adhesive system that is generally used in the thickness range 2–12 mm. It is formulated to form a strong bond between timber and GFRP or CFRP pultruded rods. The base adhesive is a mixture of diglycidylether of bisphenol-A + (DGEBA/F) and mono-functional and di-functional reactive epoxy diluents together with treated silica fume nanoparticles which control thixotropy. The curing agent contains polyetheramines combined with a rheology modifier.

The assessment of the dynamic mechanical properties of the RSA adhesive and deformation under creep load was performed with a Tritec 2000 DMTA manufactured by Triton Technology of Keyworth, Nottinghamshire, UK. Creep tests on RSA specimens were performed in static mode using software that allowed a constant force to be applied to the specimen in tension. The temperature was held at 20 °C for fixed periods of time and then ramped up in steps of 5 °C with the dwell periods repeated until 80 °C was reached. Creep was also performed in shear using a miniature shear specimen designed to simulate a bonded interface (Figure 1) by laminating an RSA adhesive layer (2 mm) between two beech wood veneers (each 0.5 mm thick).

Offset cuts were then made so that an isolated zone of adhesive, 6 mm in length could be subjected to static shear in the DMTA through the application of a tensile



Figure 1: Miniature laminated veneer/adhesive/veneer specimen with offset cuts for creep in shear

force to the ends of the specimen. Shear strain was estimated by dividing the specimen elongation by the thickness of the adhesive layer. RSA specimens were loaded with a static force of 1.75 N (tensile stress = 0.12 MPa) and the temperature was raised in 5 °C steps from 25 °C up to 80 °C with a dwell time of 30 minutes at each temperature step (Figure 2). At 25 °C and 30 °C the strain experienced in the sample is very small but at 35 °C there is a clear indication of time-dependent creep with acceleration in creep rate at 40 °C.

The RSA adhesive behaves as an elastic solid below T_g and as a viscoelastic material, creeping to a limit, between T_g and $(T_g + 15)$ °C. Above $(T_g + 15)$ °C the strain in RSA increases by approximately 0.2% for each 5 °C increase in temperature which is equivalent to a thermal expansion coefficient $\alpha \sim 4 \cdot 10^{-4}$ °C⁻¹. Measurements of thermal expansion coefficient in the DMTA confirmed an α value of this order. Creep experiments with longer dwell periods at each temperature step indicates that the RSA is partially cross-linked with some rubbery character to the deformation as some creep recovery occurs above $(T_g + 15)$ °C. Novel miniature shear specimens were subjected to the same temperature versus time history with an applied constant static force of 1.75 N (shear

stress = 0.06 MPa). Shear strain and temperature versus time are plotted in Figure 3 from 20 to 80 °C.

At the end of the creep history the strain reached a value of 7% which is not unexpected as the shear modulus of RSA is lower than the tensile modulus. The magnitude of the strain steps at high temperatures is much less than for the tensile creep (Figure 2) because the shear sample will be little affected by thermal expansion and long-term viscous deformation is not evident.

It can be concluded that under small applied tensile and shear loads the thixotropic RSA adhesive, with a T_g of ~ 35 °C, is capable of withstanding creep loads at well above T_g without extensive viscous deformation. The RSA is thought to behave as a partially cross-linked rubber above T_g .

RESEARCH OUTPUT

A paper based on the research reported here was presented at the World Conference on Timber Engineering in July 2010:

Ansell MP, Roseley ASM & Smedley D. Environmental stability of room temperature cure epoxy adhesives for timber structures under static and creep loading. In: Proceedings of World Conference on Timber Engineering, Trentino, Italy, June 2010, Paper No. 251

The results of research on the creep of three thixotropic adhesive systems are reported in a paper submitted to the International Journal of Adhesion and Adhesives:

Roseley ASM, Rojo E, Ansell MP & Smedley D. Creep response of thixotropic ambient temperature cure adhesives measured by DMTA in static tension and shear. Submitted to Int. J of Adhesion and Adhesives

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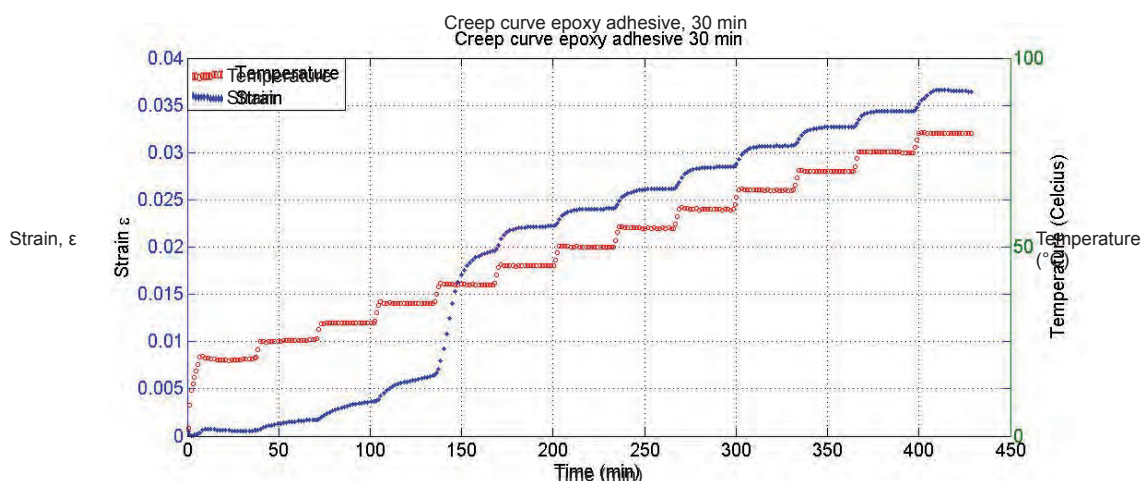


Figure 2: DMTA thermal scan for RSA in tension with 30 minute dwell times

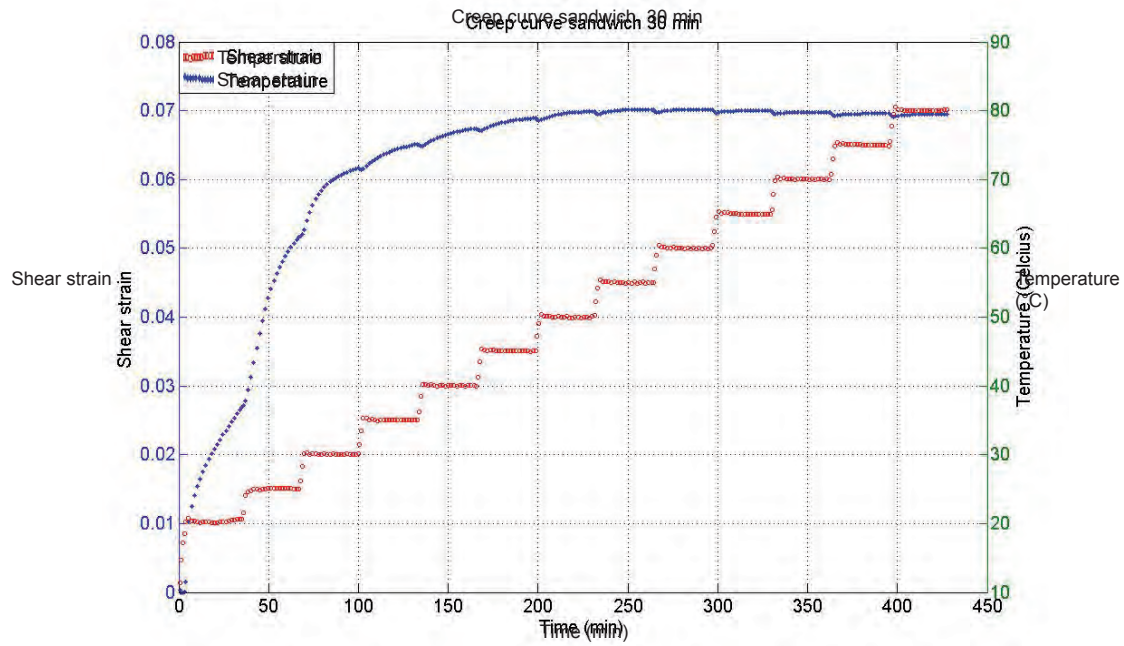


Figure 3: DMTA thermal scan for RSA in shear with 30 minute dwell times

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RENEWABLE CONSTRUCTION MATERIALS: Research, development and dissemination

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BRE Wales and South West⁺

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SUMMARY

Increasing the use of traditional renewable materials in construction, such as straw, hemp and flax, offers opportunities to significantly reduce the impact of new building and provide new markets for agriculture. This paper summarises current on-going work at the BRE Centre for Innovative Construction Materials to explore and develop the use of two renewable construction technologies: prefabricated straw bale and hemp-lime. To develop an understanding of building performance, two experimental full-scale buildings have been completed, tested and monitored at the University of Bath.

BACKGROUND

The BRE Centre for Innovative Construction Materials at the University of Bath has been leading research and dissemination activities on the development of renewable (plant-based) construction materials. This work has included construction and performance testing of two full-size buildings:

- BaleHaus
- HemPod.

RESEARCH PROGRAMMES

BaleHaus

BaleHaus, developed by ModCell Ltd, uses prefabricated timber-framed panels insulated using either straw bale or hemp-lime (Figure 1). As part of a Technology Strategy Board funded project a full-sized two-bedroom prototype house has been built on campus at the University of Bath. Research work has been monitoring the performance of this low-carbon house. Simulated occupancy, combined with continuous temperature and relative humidity measurements, using over 200 sensors, within the internal space and within the fabric of the walls, have captured thermal performance and condition of the straw bales. Air permeability ($0.86 \text{ m}^3/\text{hr}/\text{m}^2$ at 50 Pa), co-heating tests and thermal imaging surveys have also been completed.

Prefabrication is a key aspect of the ModCell concept. The panels are made off-site in a 'flying factory', typically a farm building, located as close to the site as possible. For the 'BaleHaus @ Bath' project, the factory was just



Figure 1: BaleHaus @ Bath

four miles from campus. Locally sourced straw was used in construction, further reducing the transport impact of the construction. However, the main benefit of prefabrication is delivery to site of the finished product fully weather protected by the lime render. This overcomes a major drawback of traditional on-site straw bale construction that often suffers from delays due to UK inclement weather conditions. The rate of construction is

impressive: the BaleHaus @ Bath was erected from slab level into a completed shell within four days.

Structurally, BaleHaus comprises prefabricated timber-framed panels and solid cross-laminated timber floor and flat roof. The panels measure 1, 2 or 3 m wide (1 m is the modular length of a straw bale) and 2.7 m high. The panels are 490 mm thick. The timber frames support the vertical permanent and variable loads and also provide primary means of resisting lateral (wind) loading. The panels are braced internally to enhance their racking stiffness and resistance. The building's lateral load capacity is further enhanced through the use of internal solid timber shear walls. Racking performance of the ModCell panels has been tested at the University of Bath and through refinement are now capable of providing sufficient lateral load capacity to allow three-storey construction.

HemPod

HemPod (Figure 2) uses a structural softwood timber frame combined with in-situ cast hemp-lime external walls. It is a test building realised as part of a Defra Renewable Materials funded project led by the BRE Centre for Innovative Construction Materials at Bath with eight partners, including BRE.

Combined with laboratory-scale testing of materials and panels HemPod provides the opportunity to monitor performance of walls to assess initial drying times and long-term hygrothermal performance of the hemp-lime. Sensors embedded within the walls and around the building capture data on environmental conditions. Co-heating and air permeability ($0.33 \text{ m}^3/\text{hr}/\text{m}^2$ at 50 Pa) tests have recently been completed. Data collected from HemPod will be used to validate and develop thermal modelling and design guidance for hemp-lime construction.

As well as providing excellent insulation, using plant-based materials such as straw and hemp-lime ensures significantly reduced levels of embodied carbon within



Figure 2: HemPod

the building's fabric, achieved through the carbon dioxide stored within the plant material during photosynthesis. The embodied carbon of the buildings are further reduced through the use of engineered softwood timber for the panel frames, floor and roof structure. The straw and hemp are protected internally and externally using formulated lime plaster renders applied directly onto the infill material.

Knowledge Transfer Account

In June 2010, Andrew Sutton joined University of Bath on a secondment from BRE Wales on the EPSRC-funded Knowledge Transfer Account project *Delivering renewable materials for low energy buildings*. The project aims to:

- disseminate research outcomes to the construction sector to directly support and promote uptake of renewable materials as viable alternatives to existing forms of low-carbon construction
- engage with key stakeholders in the construction sector to raise awareness of renewable materials
- prepare CPD materials to support a training programme for renewable materials.

RESEARCH OUTPUT

As part of this project, a series of BRE Information Papers on hemp-lime, straw bale, natural fibre insulation and other low-impact materials will be published by IHS BRE Press in 2011/2012. Other activities to date have included a conference event at the Innovation Centre in Bath, stakeholder presentations in the South West and an on-line sector survey of attitudes towards renewable construction materials.

ACKNOWLEDGEMENTS

The BaleHaus @ Bath research project is funded by the Technology Strategy Board under their High Value Manufacturing programme. The lead industry partner is:

- White Design Architects.

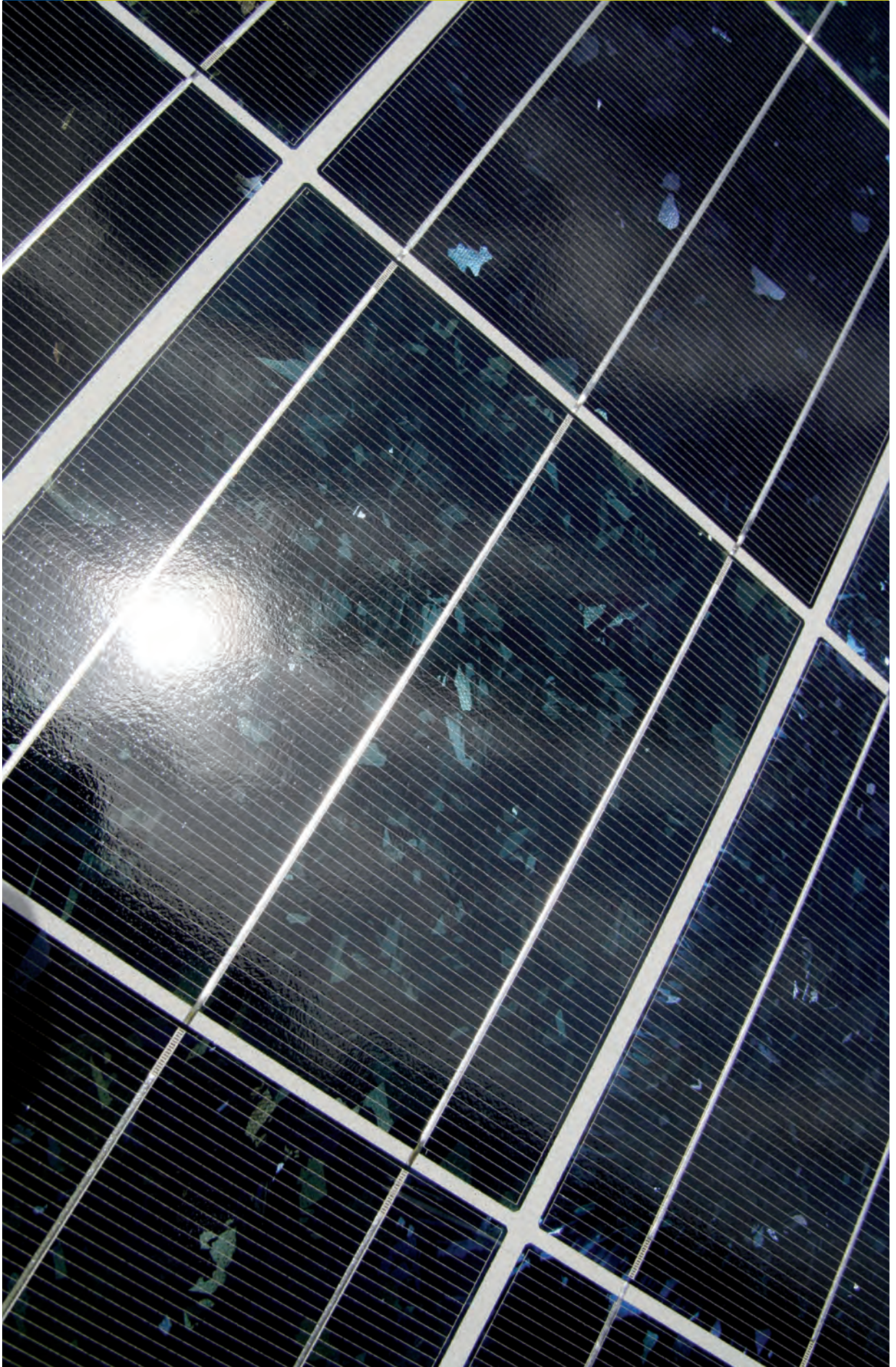
Other industrial partners on the research project are:

- Integral Engineering Design
- Agrifibre Technologies
- Lime Technology
- Eurban
- Centre for Window & Cladding Technology
- Willmott Dixon.

HemPod has been funded as part of a Defra Renewable Materials project led by the University of Bath. Industrial partners include:

- Lhoist UK
- BRE
- Wates Group
- Hanson
- Lime Technology
- NNFC
- Feilden Clegg Bradley Studio
- Hemp Technology.

ENERGY



SOLID-STATE LIGHTING: Overcoming the barriers

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SUMMARY

Solid-state lighting (SSL) using light-emitting diodes is the major growth area in lighting. The technology is developing rapidly; by 2020 it is anticipated that best practice SSL will be twice as energy efficient as the best comparable existing light sources. However, there are several barriers to widespread adoption of SSL of which two are: colour performance and lack of information explaining the benefits available to building owners, designers and installers. This research involves a human factors study of colour performance. The project also provides guidance on the benefits of SSL lighting.

BACKGROUND

Colour performance is a key issue for lighting. White solid-state lighting (SSL) generally has problems with:

- colour appearance (where the lamp looks to be an unusual shade of white)
- colour rendering (making coloured objects look different to their natural colour)
- colour constancy (different batches of lamps may be different colours, or the lamp may drift in colour over time).

Progress is being made by manufacturers to address these issues. However, currently accepted measurements of colour rendering do not necessarily correlate well with user perception of acceptability. Colour rendering is usually measured using the CIE colour rendering index, Ra8 (CRI). The CRI compares the colour coordinates of eight colours when illuminated by a test lamp and a reference lamp. Some issues with the CRI include:

- it does not always work well for spiky emission spectra (like that of most white LEDs)
- calculating the arithmetic mean of the colour differences underestimates the impact of a single large deviation
- eight samples are not enough (Manufacturers can optimize the emission spectra of their lamps to reproduce them faithfully, but otherwise perform poorly.)
- the samples are not saturated enough (they do not include a bright red or bright yellow, for example).

The CIE has concluded that the standard CRI measurement is not adequate for characterisation of solid-state lighting and that another metric should be sought^[1]. The US National Institute of Standards and Technology



Figure 1: Examples of solid-state lighting lamps

is currently working on an alternative metric: the 'colour quality scale' (CQS)^[2]. The metric compares the colour coordinates of 15 samples under a reference and test source. The samples are saturated and span the entire hue circle. When calculating the CRI, any deviations in hue, saturation and lightness from the reference source will decrease the score. The CQS does not penalise (or reward) an increase in saturation since an increase in colour saturation is considered to be more attractive and beneficial. The CQS is calculated by the root mean square of the differences, rather than the arithmetic mean as used by the CRI.

RESEARCH PROGRAMME

A human factors study was undertaken to investigate observed SSL colour quality properties and to compare the results against the different colour rendition metrics. Observers were seated in front of two booths with exactly the same items in each. The booths were lit by separate

DEVELOPING A CARBON FOOTPRINT MODEL FOR HOUSING

Rosie Ellis, Kevin White and Robert Flynn

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SUMMARY

This project developed two means of modelling carbon emissions from dwellings, both of which are capable of producing results at a very fine level. One method uses data from the national census in combination with national survey data to estimate emissions, while the other method uses data from local surveys. The models assume standard occupancy, and so reflect the status of the dwelling, not the behaviour of occupants. These models are potentially of great value to those seeking to reduce domestic emissions of carbon, as they identify areas with the greatest potential for carbon reduction by means of improvements to the dwelling.

BACKGROUND

The UK Government has indicated a continuing commitment to carbon reduction and approaches to reducing this will benefit from geographical information on carbon emissions.

The current mechanism for monitoring carbon emissions is a complex one, with data drawn from multiple sources. The most detailed geographical information comes from the UK greenhouse gas national inventory system^[1]. This provides figures at the local authority level which are a composite of several data sources.

The level of resolution at which these data are currently published is that of the local authority. These are sufficient for local authorities to compare themselves with one another, but not to indicate the distribution of emissions within a local authority.

In a bid to address this issue, this project seeks to help local authorities to supplement their knowledge of carbon emissions by means of a modelled estimate of the level of carbon emissions per dwelling at the local level. Such a model would be able to show the local authority where emissions were highest and where they were lowest. By combining these data with socio-demographic information and local knowledge, local authorities should be better able to formulate local carbon reduction strategies.

RESEARCH PROGRAMME

Two different approaches to this project were taken.

- *Stage 1* was to produce a top-down or national model which would estimate the distribution of carbon dioxide (CO₂) emissions within a local authority down to a local area level. This would provide local authorities who have no existing energy data with

an idea of which areas could be targeted for carbon reduction policies.

- *Stage 2* was to produce a bottom-up or local model based on existing local data. This would enable a local authority to use data which they have collected to derive an estimate of CO₂ emissions for each dwelling.

If the local authority has reliable energy data then being able to produce localised CO₂ emissions information is of huge benefit to the local authority. However, it is unusual for a local authority to have detailed data for all their stock.

The final stage, *Stage 3*, was to use the model created in *Stage 1* to 'fill in the gaps' in areas of the local authority for which there are insufficient data to produce an estimate for the *Stage 2* model.

Stage 1

The carbon variable modelled is based on total CO₂ emissions (tonnes/year) for a dwelling. This variable is derived from a combination of the standard assessment procedure (SAP)^[2] and BREDEM algorithms.

Predictor variables were established through discussion with BRE experts and the use of an application of SPSS[®] called AnswerTree[™] to assess which variables were potentially good predictors of CO₂ emissions. Stepwise multiple regression was then used to model CO₂ emissions.

The models for both the private sector and social rented stock were created using the CO₂ emissions variable from the English House Condition Survey (EHCS)^[3], as well as independent variables from commercially available small area datasets and from the census. The resulting models were then applied to a national dataset from which the final model outputs of

mean CO₂ emissions (tonnes per dwelling per year) at census output area (COA) level were produced.

Stage 2

A localised model was produced based on existing local data. For this project, access was given to data from a postal survey carried out by a local authority. This survey was issued to all households in the local authority and it achieved a 48% response rate.

The model created is based on SAP methodology which was modified to make use of local survey data. The CO₂ emissions estimate is derived as part of the SAP calculation. This resulted in a local model with CO₂ emissions estimates for 43% of all dwellings in the local authority.

Stage 3

The final stage used the national model created in Stage 1 to 'fill in the gaps' in areas of the local authority for which there were insufficient data to produce an estimate for the Stage 2 localised model.

The integration process begins with a database containing the address of each dwelling in the authority. The estimates from the local model were then applied to the database. This enabled identification of gaps in the local model.

A set of rules was developed to decide which set of modelled data should take precedence. This allowed the

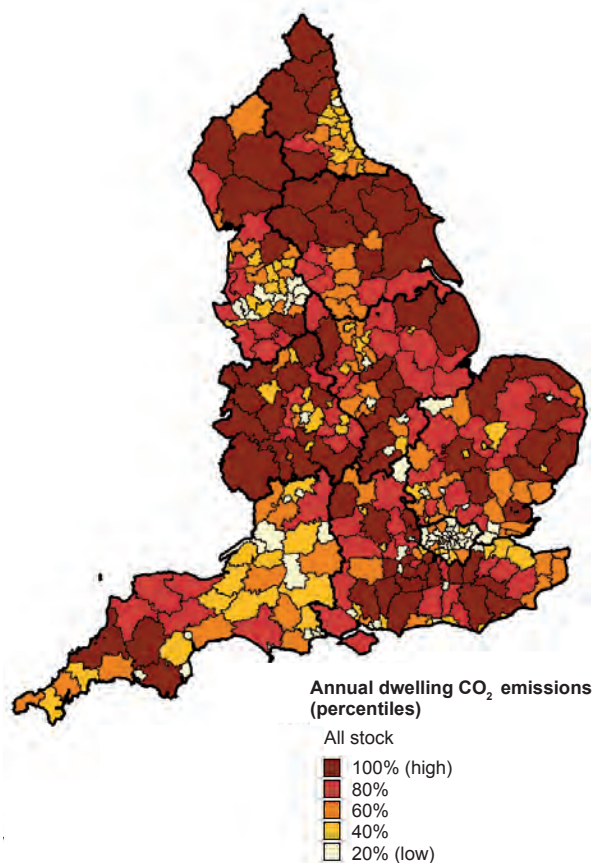


Figure 1: Distribution of mean CO₂ emissions for all the housing stock at local authority level

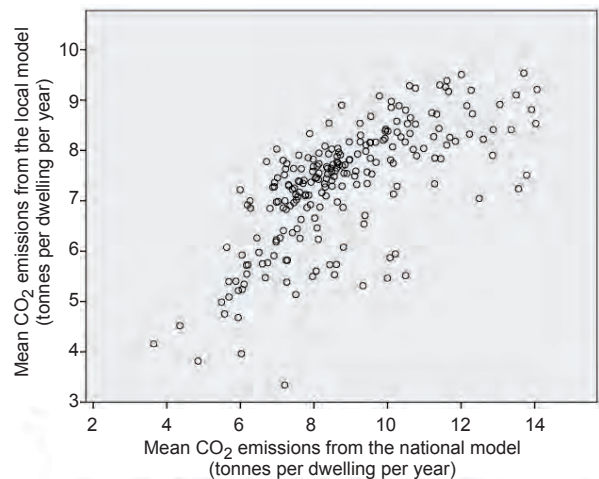


Figure 2: Scatterplot of the relationship between the (national) top-down and (local) bottom-up models

two models to be harmonised into a single data set which took full advantage of the partial data set sourced locally but used the national model to provide data where this was incomplete.

PROJECT OUTCOMES/CONCLUSIONS

- The national model was built as two separate models of the private and social rented stock which were combined to give average CO₂ emissions for the residential stock as a whole at COA level. These results can then be aggregated to ward and local authority level. Figure 1 shows the distribution of mean CO₂ emissions for all the stock at local authority level, providing a national map of carbon emissions.
- The local model produced in Stage 2 was used as a comparison and a correlation co-efficient of 0.7 was found between the two models. A scatter plot of the relationship is shown in Figure 2. The strong relationship gives confidence that the national model will be a good predictor of CO₂ emissions where no alternative data sources exist.
- The approach taken to combining the two data sets provides a template for local authorities who are trying to combine both national and local data sources.

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ANALYSIS OF DISPLAY ENERGY CERTIFICATE DATA FOR PUBLIC BUILDINGS

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SUMMARY

Historically, details of the actual energy performance of buildings have been hard to obtain.

In August 2009, the BBC published information from the Department for Communities and Local Government with details of Display Energy Certificates (DECs) for more than 28,000 public buildings*. For the first time, it became possible to analyse data for large numbers of buildings and compare their energy performances.

The research team undertook a preliminary analysis of the raw summary DEC data. This was tested for broad trends and distributions, and comparisons were made with data from other sources where this was available and a correlation with DEC data could be established.

BACKGROUND

Display Energy Certificates (DECs) became mandatory for many public buildings on 1 October 2008. A DEC is a record of the building's actual metered energy performance in use over a 12-month accounting period containing:

- an operational rating (OR) expressed as a numerical indicator and A–G banding
- a comparison of ORs over the last 3 years
- main heating fuel
- total useful floor area
- breakdown of heating versus electrical energy use in kWh/m²/year
- EPC asset rating if available

- an accompanying Advisory Report containing recommendations for improving the energy efficiency of the building.

RESEARCH PROGRAMME

A range of statistical analyses were undertaken on DEC ORs and bands across all sectors (Figures 1 and 2 and Table 1) and within sectors (Figure 3).

PROJECT OUTCOMES/CONCLUSIONS

There are gaps in the DEC data, relating both to the use of default ratings (where incomplete energy consumption data was available to the assessor) and obvious inconsistencies or data errors. Based on the number of default values and the number of buildings which receive an operational rating of 0 or >450, 11% of DECs could be considered incorrect or provisional.

* http://www.bbc.co.uk/blogs/opensecrets/2009/08/comparing_the_energy_efficiency_of_public_buildings.html. Accessed, May 2011

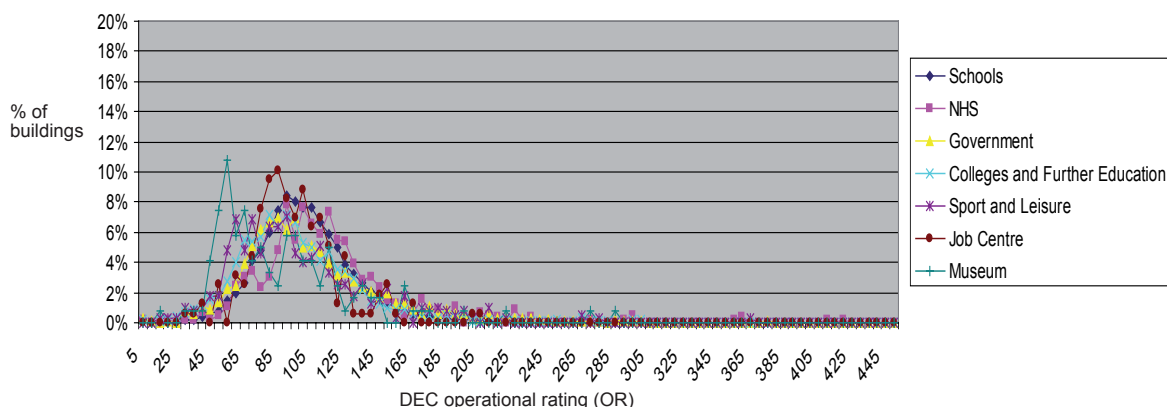


Figure 1: Percentage distribution of operational ratings for all sectors (excluding default ORs of 200)

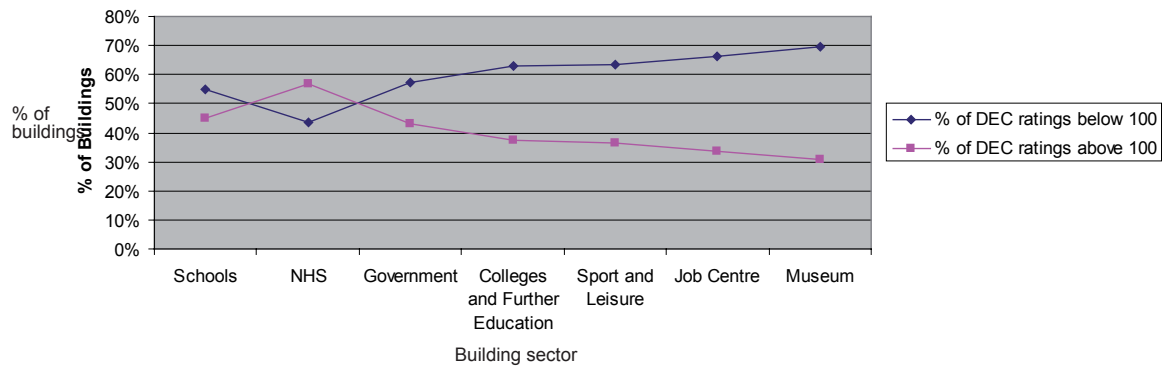


Figure 2: Percentage of DEC ratings that fall above and below the OR of 100

Table 1: Percentage distribution of DEC ratings across public sector building types

Building rating band	NHS	Schools	Government	Colleges and Further Education	Sport and Leisure	Job centres	Museums
A	0	0	1	1	1	0	1
B	2	2	5	6	6	5	14
C	12	15	20	23	28	18	33
D	29	37	32	33	28	44	21
E	31	29	20	21	18	24	15
F	14	11	11	9	9	6	7
G	12	5	12	8	9	3	8

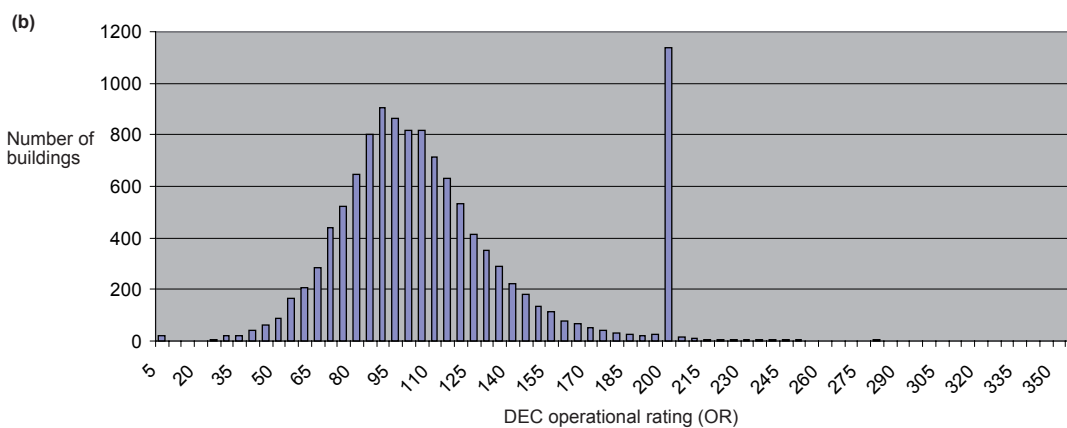
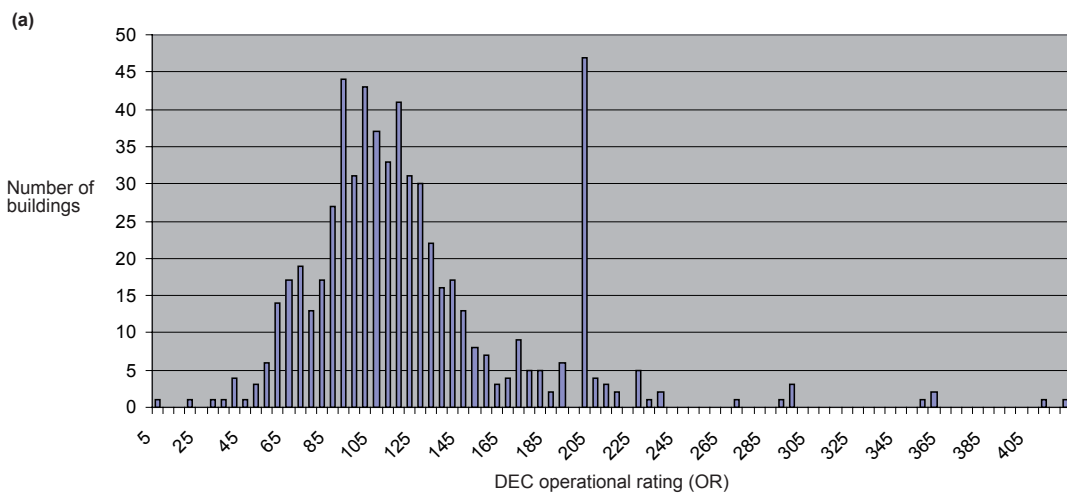


Figure 3: Histograms showing the distribution of operational ratings in (a) NHS buildings, (b) school buildings

Most public building sectors show relatively normal distributions around band D, which is the typical rating for a benchmark building; this could be taken as a validation of the benchmark and methodology. For some sectors (job centres, sport and leisure, colleges and universities), the peak occurs away from the benchmark value of 100, suggesting that the benchmarks may need to be reviewed.

The Department for Communities and Local Government (DCLG) DEC dataset on which this study is based contained records of 11,860 schools, some 56% of the 21,326 UK schools and related institutions. Less than 50% of the (admittedly small) sample of schools interviewed could confirm that a DEC was on display. There is no capital funding allocated for the uptake of Advisory Report recommendations; it seems likely therefore that only the low-cost measures will be implemented.

Comparisons of historical energy use for a small sample of schools show an overall rise in energy use, most significantly in electricity consumption, believed to be a result of more intensive use of school assets (out-of-hours learning and community use of facilities) and greater use of information and communication technologies to deliver education. A similar situation is believed to apply to the NHS, though comparisons have not been undertaken in this study.

DECs are likely to become more important in the future as they are rolled out (on a voluntary or mandatory basis) to encompass other non-domestic buildings. As DECs are prepared for second and subsequent years, they will become an increasingly important evidence-base for demonstrating low-carbon performance and management improvements in non-domestic buildings, but DEC data remains relatively inaccessible and hard to correlate with other datasets. If the DCLG dataset is to have wider application, it will be necessary to ensure that data quality is improved to ensure that the dataset is representative of the true DEC ratings.

There is an opportunity for BRE and other organisations to maintain a rolling analysis of key measures and trends in the DEC data and to work with government departments to correlate DECs with more detailed building-level information to evaluate and inform capital and operational programmes for energy and carbon reduction.

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PERFORMANCE OF PHOTOVOLTAIC SYSTEMS IN NON-DOMESTIC BUILDINGS

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SUMMARY

This project produced a report for use as a briefing paper giving information on design and operational factors affecting the performance of photovoltaic systems in non-domestic buildings. The report may be used to inform system design decisions from the earliest conceptual stages of projects, thereby increasing the chances of a successful outcome. It references monitored data from real buildings and from recent research, thereby utilising lessons learnt to inform its audience. It focuses on commercial systems but also draws on experiences within the domestic sector where relevant.

BACKGROUND

Photovoltaic (PV) cells produce electrical energy from sunlight by use of an interaction between light radiation and specialist semiconductor materials. In simplified terms, individual photons collide with individual electrons orbiting semiconductor atoms causing the electrons to be liberated from their orbits.

The semiconductor layers are arranged in such a way as to collect the free electron charges at an electrode, thereby creating a potential difference, or voltage, between it and a positive electrode. This voltage can then be used to drive the electrons around an electrical circuit. On a day-to-day level, we recognise such a flow of electrons as electrical current, available at the flick of a switch, and able to do useful work such as power the electrical devices in our houses. Once the electricity from PV systems has been appropriately conditioned, it is effectively indistinguishable from ordinary mains electricity.

In recent times, there has been an explosion of interest in PV systems because of their apparent ability to help mitigate some of the effects of climate change by reducing dependence on fossil fuels, and to contribute to the security of electricity supply by making the UK less dependent on imported fuels.

Most forms of renewable energy have these attributes, but PV has some special advantages:

- silent operation
- no moving parts (leading to very low maintenance)
- relatively simple to install
- an energy payback time of much less than the product lifetime.

Balanced against these advantages is:

- the high capital cost of design, procurement and installation, the specialist materials involved being the major cost.

PV systems can be incorporated into buildings in several ways:

- roof-based systems: retrofit or built-in
- façade systems: designed-in or replacement
- atria or skylights
- semi-transparent windows
- sunshades and sunscreens.

The modularity and scalability of PV systems makes them a popular choice when selecting renewable energy technology for use in the built environment and some of the design factors and options are explored in the report.

PROJECT OUTCOMES/CONCLUSIONS

PV materials

The performance of any PV system is dependent on its smallest component, the PV cell, which can be made from a wide range of materials, each having different properties and light-electricity conversion efficiencies (Figure 1).

Most commercially available PV cells are made from silicon-based materials. However, during the next few years we can expect new generations of thin film materials to become more common, largely due to their potential for lower manufacturing costs and lower embodied energy.

this, due to the much smaller quantities of active material used and more efficient, continuous manufacturing processes.

With almost zero maintenance and relatively rapid repayment of embodied energy through electricity generation, PV systems are rapidly gaining popularity, despite their historically high capital cost.

If we assume a conservative lifetime of 25 years for silicon-based systems (many manufacturers will warrantee performance levels over this period), PV systems will generate around five times as much energy as is consumed during their lifecycle (manufacture, installation, maintenance and decommissioning).

Using data from the PV Large-Scale Building Integrated Field Trial^[1], a typical cost of carbon saving would appear to be approximately £14,000 per tonne CO₂ saved per annum using PV technology. This is based on monitored data from existing silicon-based systems in the UK. The expected emergence of low cost thin film technologies into the main stream in the next few years should reduce this cost substantially.

PUBLICATIONS/RESEARCH OUTPUT

More information about the findings from this project will be given in a BRE Trust report provisionally entitled *Performance of photovoltaics in non-domestic buildings* which will be published by IHS BRE Press in 2011.

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BRE CENTRE OF EXCELLENCE IN ENERGY UTILISATION, UNIVERSITY OF STRATHCLYDE

John Counsell

Professor, Energy Systems Research Unit

The BRE Centre of Excellence in Energy Utilisation at the University of Strathclyde has been established as an integral part of the Energy Systems Research Unit (ESRU) which has over 30 years' experience in modelling, simulating and designing advanced energy systems for the built environment and renewable power generation. The centre, now in its 4th year, has 11 PhD students receiving part-funded scholarship funds from the BRE Trust.

In addition to the platform research of the PhD projects described in the papers that follow, the centre has built up a critical mass of knowledge exchange with the building services and building manufacturing industries. Example projects are:

- an Engineering and Physical Sciences Research Council (EPSRC) post-doctorate secondment working with BRE Scotland
- a Technology Strategy Board-funded project BIEN-RPG to develop innovative Green IT networks with Siemens SIS
- a partnership with Arup and India's IIT Bombay to research the feasibility of autonomous buildings, ie buildings that power themselves.

This year, the Centre has established a Knowledge Transfer Partnerships (KTP) programme to facilitate knowledge exchange of the research results with manufacturing industry, the first programme established being with Barr Ltd. The Centre has now filed patents in the automatic control of carbon emissions from appliances controlled via in-building networks. This will

lead to a potential spin-out company being formed in 2011 as a joint partnership between BRE Ventures and the University of Strathclyde.

The core platform of PhD students consists of projects grouped in the following key research themes in Energy Utilisation for the next decade. These are:

- Modelling and simulation tools for conceptual design of buildings and their energy systems and building regulation compliance
- Advanced control of energy systems (ACES) projects that aim to transfer leading-edge knowledge and control solutions from other fields such as aerospace and automotive systems into building controls.
- Digital energy networks (DENs) projects that explore full integration, smart grids, building-integrated renewable power sources and intelligent appliance networks with energy storage for energy demand reduction and electricity load management.

The projects in these areas draw on the core research science and software tools of the ESRU Group of which the BRE Centre is an integral part. The papers that follow provide an overview of final-year and second-year PhD projects.

For further information on any of the projects that follow, contact Professor John Counsell, Tel: 0141 548 3986, Email: john.counsell@strath.co.uk

RAPID ASSESSMENT TOOLS AND METHODOLOGIES FOR MODELLING OF EMERGING TECHNOLOGIES USING BRE'S STANDARD ASSESSMENT PROCEDURE (SAP)

Gavin Murphy

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SUMMARY

This project aims to develop methodologies and tools to assist in the process of introducing new technologies into the standard assessment procedure (SAP)^[1]. With the renewed sense of urgency to reduce carbon emissions in new and refurbished homes, it is vital that new technologies can be readily included in SAP without delay and be given a fair rating. Existing and new dynamic simulation of homes and their systems are being utilised to create a new framework to speed up SAP method approval for new technologies.

BACKGROUND

The drive towards low-carbon homes has seen dwellings increasingly utilise many different systems simultaneously, such as ventilation, heating and applications of renewable energy. The use of such systems simultaneously can be energy-intensive and increase the complexity of their control. Understanding the dynamics and sizing of these systems at the conceptual design stage will allow for better design. Assessing the dynamics of such systems in relation to energy consumption is an area where simplified methods such as the standard assessment procedure (SAP)^[1] are limited.

RESEARCH PROGRAMME

This project presents an ideal opportunity to bridge the gap which currently exists between the advanced approaches of dynamic simulation and those of semi-empirical and validated models such as BREDEM^[2].

The project describes a new simplified dynamic method of assessing the controllability of a building and its servicing systems, such as ventilation, heating and renewable systems. The fundamental difference in the approach taken in this dynamic model is the use of inverse dynamics. This dynamic method produces SAP-compliant results and attempts to indicate where advanced controllability of dwelling systems and a dynamic framework could supplement SAP (Figure 1).

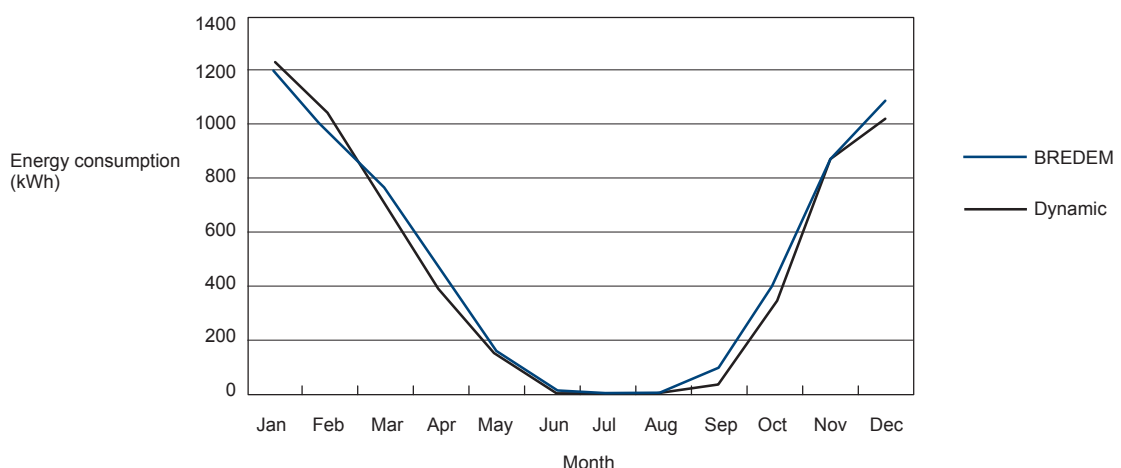


Figure 1: Monthly energy consumption

The resulting tool is named IDEAS (inverse dynamics energy assessment and simulation)

The knowledge for this method/tool has been transferred from design processes and methods used in the design of aircraft flight control systems to establish a modelling and design process for dwellings and their systems.

RESULTS

Initial studies have established how dynamic simulation tools such as PVSyst and TRNSYS can be used to create statistical based models for incorporation into the existing SAP format^[3,4]. Results suggest that this design approach could enhance the SAP methodology by the addition of advanced systems controllability and dynamic values. Additionally, this new approach could also assist building professionals in their decisions on which building design and services to use.

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ADVANCED NON-LINEAR CONTROL FOR AEROSPACE AND ENERGY SYSTEMS

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SUMMARY

This project has focussed on the use of non-linear controller design method Variable Transient Response to supersede traditional controller designs such as PID in building systems. It is a well-known fact that the higher the responsiveness of a system, then the more energy-efficient the system is. This is clearly demonstrated in the BREDEM calculation for energy consumption of heating systems in the home. The difficulty is that the responsiveness of a system in a highly insulated building is limited by the stability constraints of the control system. VTR enables the maximum response without stability concerns.

BACKGROUND

Building systems involve control problems which are highly complex and non-linear. The control system is often required to accurately track multiple, coupled variables (eg internal air temperature, relative humidity, CO₂ and luminescence) in the presence of many disturbances, and with actuator systems which have severe power limitations. If the control system is not designed to meet these challenges, performance of the system can be reduced resulting in undesirable behaviour, such as large temperature overshoots and excessive energy usage.

This project aims to improve the performance of a building's control systems by utilising controller design methods originally developed for high performance

flight control systems. Improving the control system can bring about benefits in energy efficiency and quality of performance through far more accurate control. It provides a knowledge exchange activity to apply these techniques to Building Energy Management Systems (BEMS).

RESEARCH PROGRAMME

The novel non-linear controller design methods of variable transient response (VTR) and rate actuated inverse dynamics (RAID) have been developed. These methods use flight systems' state-of-the-art non-linear inverse dynamics (NDI) as a foundation. VTR dynamically alters the system's transient response characteristics, such as damping and natural frequency, resulting in a

more efficient response. The RAID design method unlike previous NDI designs commands a rate of change of the system's actuator input. This functionality allows actuator rate limits to be compensated for in the controller design to significantly improve system stability and reduce setpoint overshoot.

Case studies

The first case studies^[1, 2] were unmanned aircraft autopilot simulations and Figures 1–3 illustrate the enormous improvement gained in performance of the VTR and RAID systems versus other traditional and state-of-the-art autopilot designs.

Following these case studies, the practicality of the controller designs was demonstrated after they were

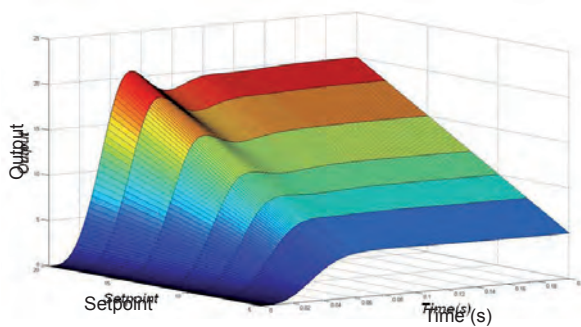


Figure 1: How variable transient response (VTR) works

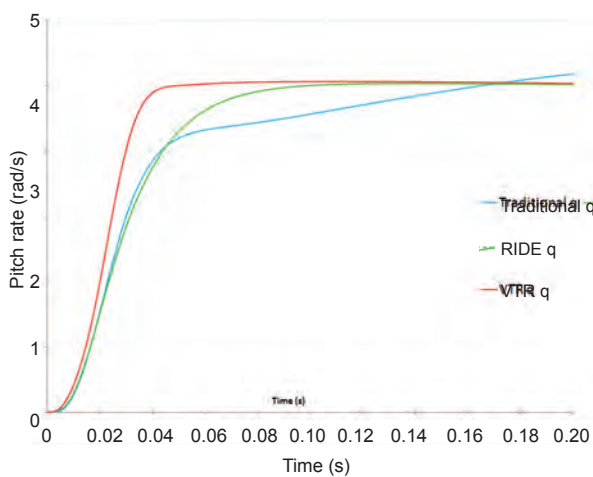


Figure 2: Examples of transient response for traditional, RIDE and VTR designs

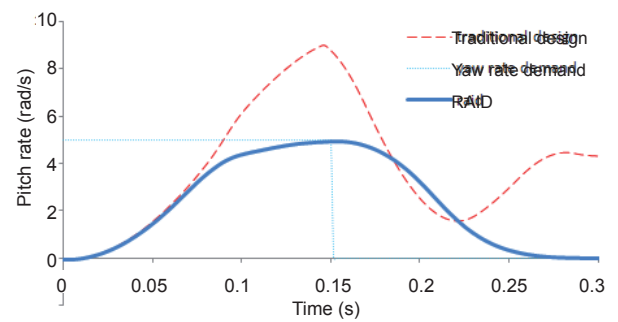


Figure 3: Simulated performance of the advanced RAID controller

successfully implemented in the control of an industrial plasma-coating process used in the manufacture of low-emissivity glass and photovoltaic panels.

NEXT STAGE

The technique is now being applied to temperature control systems for buildings designed with a climate-adaptive philosophy. The improved accuracy and response time is estimated to save up to 10% in energy consumption. This will both improve:

- the energy certification of the building and
- the thermal comfort of the occupants.

Thermal comfort has proved to be problematic in this type of building when employing traditional control methods such as a proportional–integral–derivative (PID) control.

REFERENCES AND RESEARCH OUTPUT

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CONTROLLABILITY OF BUILDINGS

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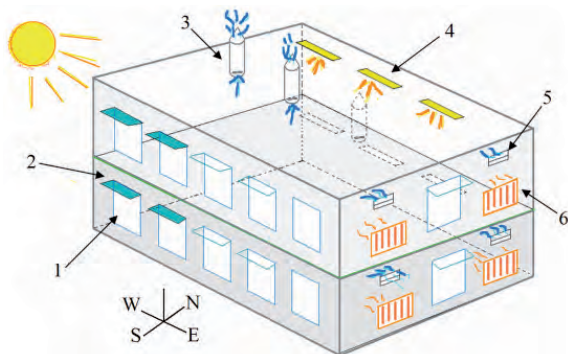
SUMMARY

This project presents a methodology for assessing the controllability of a building and its building services (eg heating, lighting and ventilation) applying processes used in the design of aircraft flight control systems. The project has established methods and simple tools that can be used by architects in the early stages of conceptual design, for example to predict whether the building will be easy or difficult to control. The tool is also useful in assisting control engineers in the design of more advanced control algorithms and strategies.

BACKGROUND

This project has developed a mathematical science to allow architects and building service engineers to assess the controllability of a building and its servicing systems. The science can be used to provide advice for building designers in the early design stage of conceptual design who are considering to use automatic controls for temperature, light and air quality.

This science is founded on a relatively simple dynamic representation of the building based on the schematic shown in Figure 1. This model, unlike complex and detailed models of buildings and their systems, is described by mathematical equations rather than computer-based simulations. The equations allow advanced control theory to be applied to the building control problems.



- 1 = Window
- 2 = Solar shading
- 3 = Passive stack ventilation
- 4 = Lighting
- 5 = Air vents
- 6 = Heater

Figure 1: Simple schematic drawing that can be used as a basis to model a building

RESEARCH PROGRAMME

The project has established that how easy or difficult it is to control the response of a building to changes in temperature, lighting level and air quality is determined by:

- *Stability*: Can the control system guarantee that the desired temperature, lighting and air quality can be held at a constant level?
- *Trackability*: Can it track a specified set point level?
- *Reachability*: Can it reach that set point?

In automatic control systems, a set point is used to decide what level of temperature, lighting and air quality is required by the occupants at a certain time of day, week and year. The accuracy to which this set point can be achieved is compromised by these three properties of controllability. Thus, it is vital to ensure in design of the building and its systems that the conditions to allow guaranteed stability, tracking and reachability can be easily achieved. Sadly, this is rarely the case and as a result occupants often interfere with building energy management systems and thermostats or even open windows to try to achieve the set points they desire.

Methodology

The research was carried out to assess controllability in three case studies described below.

Fast heating systems (eg electric fan heater)

A multi-input, multi-output system was chosen to simultaneously control temperature and humidity set points. It was found that with fast-acting heating and ventilation systems there was coupling of temperature and humidity control which can lead to instability. In summer months, this coupling causes little instability (ie little or no oscillations about a set point level) as temperature difference between incoming air and the

building temperature is small. However, in winter months the coupling is strong due to a large difference between inside and outside temperatures which leads to instability (ie large oscillations about the set point value or even complete divergence from it). Both control systems were found to be able to reach their required set points as long as the derived tracking criterion was satisfied. This criterion was derived for both summer and winter conditions.

Slow heating systems (eg under-floor heating)

In this case study, controllability was assessed for a system with simultaneous control of temperature, CO₂ and lighting with under-floor heating, mechanical ventilation and automatic lighting. It was found that due to thermal inertia of the floor the under-floor heating was slow to respond and thus overall controllability of the whole system was found to be difficult. The analysis was published in SIMPAT journal^[1].

Fast-response heating systems (eg radiators)

In this temperature control case study, fast-response radiators were used with automatic control of

temperature through a thermostat. In practice, most temperature control systems use a single-input, single-output system, ie only control one temperature for one control input on a radiator (eg a thermostatic radiator valve).

The controllability of air temperature and comfort temperature were compared. It was found that for air temperature control internal and external thermal mass in the buildings had no effect on the system's stability. However, for comfort temperature control internal and external thermal mass were important. In comfort temperature control the thermal mass determines the energy consumption and accuracy of perfect control. It was also found that internal and external thermal mass have a small impact on reachability of the temperature control system in both cases.

REFERENCE AND RESEARCH OUTPUT

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DC POWER DISTRIBUTION IN FUTURE LOW-IMPACT BUILDINGS

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SUMMARY

This project, jointly supported by Arup and the BRE Trust, is investigating the feasibility and standards associated with developing buildings which utilise DC power distribution infrastructure within the building. The DC power infrastructure has potential to reduce energy loss in buildings' power distribution by removing inefficient AC to DC transformers and allowing easier integration with building-integrated renewable power sources. This can bring about huge savings in the capital costs and installation of electric power distribution in buildings. This holistic study using case studies and sensitivity analysis to building design, climate and choice of façades will investigate the potential impact of using a novel DC power infrastructure on the energy efficiency of the buildings and their systems as a whole across global regions.

RESEARCH PROGRAMME

Methodology

The philosophy for low-impact buildings is seen in Figure 1. The first step is in understanding the changing requirements of the office with a focus on information and communications technology (ICT) and lighting trends. This information will be fed into a simulation model of the office place which is used to configure the direct current (DC) distribution architecture and quantify the opportunity for the building to operate independently from the grid.

The trends

Driven by Generation Y, the trends in ICT are towards increased mobility, virtualisation and cloud computing. The impacts on the infrastructural requirements of the office are significant:

- devices will become smaller, more mobile and pervasive
- fixed desktops will use thin clients rather than PCs
- wireless technology will be ubiquitous.

In lighting, there are equally significant changes as LEDs are emerging as a dominant force in design. LEDs and

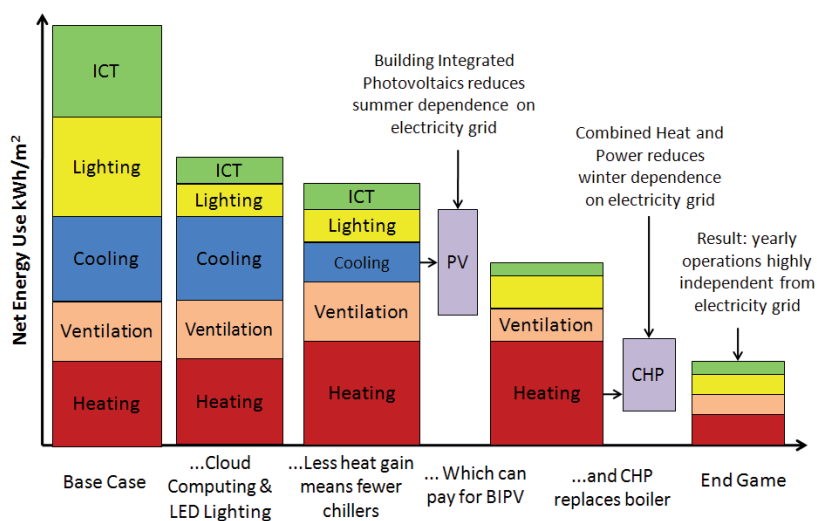


Figure 1: Project philosophy

OLEDs will offer an unparalleled flexibility in the way we light buildings, where the only limit is imagination.

In renewable power systems, thin film PV technology provides an exciting opportunity for the cost-effective manufacture of PV, and a wide range of building integration possibilities, such as in windows and on tablet PCs.

Impact on design

These trends suggest that a re-think in the way power is distributed in a building is necessary. While 230 V alternating current was an optimal solution at the end of the 19th century for transmitting power to metal-filament light bulbs, the requirements of the modern office are now completely different. Digital ICT, LED lighting, photovoltaics, heating, ventilation and air-conditioning (variable speed drives), and batteries all require a DC power supply to operate. There are indications that the industry is evolving with a wide variety of standards in development. The Institute of Electrical and Electronics Engineers (IEEE) 48 V DC combined power and data standard for ICT, EMerge Alliance's 24 V DC busbar standard for lighting and the Electric Power and Research Institute (EPRI) 380 V DC standard for data centres.

Case study

Using ESRU's thermal simulation software, ESPr, the impact of these digital building trends will be analysed. The simulations will be carried out in a variety of climates to build an international picture for the opportunity for DC buildings (Figure 2).

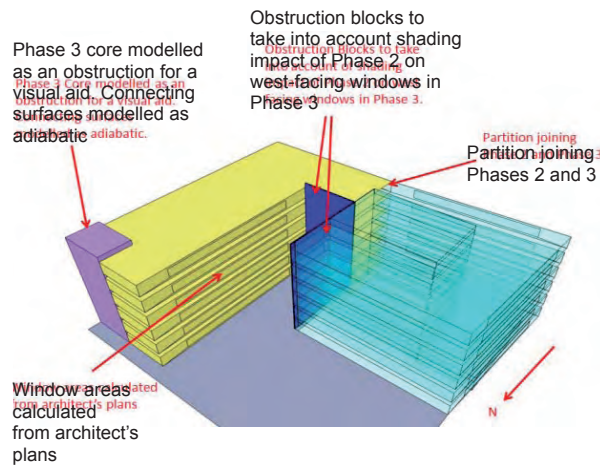


Figure 2: ESPr simulation model parameters and components

DEVELOPMENT OF A ROBUST ADAPTIVE CONTROLLER DESIGN METHODOLOGY FOR BUILDING ENERGY MANAGEMENT SYSTEMS (BEMS)

Obadah Zaher

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SUMMARY

This project aims to bridge the gap between high-performance control systems and model predictive controls through the development of a novel method which incorporates the benefits of both control strategies. This method can then be used for the development of high-performance building controllers.

BACKGROUND

The dynamic and uncertain nature of buildings means that designing an effective building energy management system (BEMS) is by no means a trivial task. The control systems currently in use in the buildings industry, however, tend to be basic in their design and hence are often incapable of effectively controlling the building's systems under varying conditions. This leads to poor energy management and consequently high carbon emissions as well as poor thermal comfort for occupants. Hence, there is a need to develop advanced building control systems which can overcome these issues.

Advanced control systems, typically used in the aerospace and automotive industries, have robust designs which means that they can provide high-performance control under uncertain or even adverse conditions. These control systems, however, require full knowledge of the system's physics and therefore cannot be effectively applied to buildings due to certain unknown factors (eg sensor time delays). A control strategy which uses black box system identification techniques for the control of unknown systems is known as model predictive control (MPC). However, controllers developed using this method commonly have poor robustness properties and hence may result in poor performance if used outwith the operating range for which they were designed.

RESEARCH PROGRAMME Methodology

A novel controller design methodology has been developed using advanced non-linear inverse dynamics methods used in the aerospace industry as a robust foundation for the controller design method. This robust foundation is augmented by a state-of-the-art adaptive



control technique based on a highly advanced and tailored evolutionary optimisation method stemming from the novel autotuning method developed for the robust inverse dynamics estimation (RIDE) controller design^[1]. The method identifies the system's input-output relationship while continually altering the control system's transient response characteristics, shaping the system's response for optimum performance. Therefore, in a building control system, factors such as sensor placement,

which have a severe effect on the performance of traditional controller designs, are no longer problematic as this adaptive control algorithm should account for the system's dynamics including the sensor time delay.

Case study

Initial tests on a non-linear missile pitch rate autopilot have shown promising results. The input–output relationship between the missile's control surface and pitch rate was successfully identified and the same high-performance control was achieved as when using the fully modelled input–output relation obtained from the state space missile model.

Future work

The controller design method is now being applied for building temperature control.

This method should significantly reduce the difficulty of developing high performance BEMS and resolve many of the aforementioned issues whilst eliminating the need for constant re-tuning of the building's control system which is both costly and time consuming.

REFERENCE AND RESEARCH OUTPUT

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LOW-POWERED DC ETHERNET NETWORKS FOR LED LIGHTING IN BUILDINGS

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SUMMARY

This project aims to power white LEDs with the Institute of Electrical and Electronics Engineers' standard 'power over ethernet' (PoE) direct current-powered cabling to create a low-cost, low-power and advanced controlled network.

BACKGROUND

Demand reduction is becoming recognised as the most credible solution to reducing global carbon emissions from buildings. At present, buildings account for approximately 40% of the UK's carbon emissions and are a key target for carbon reduction through policy, regulation, certification, new technologies and innovation.

Lighting in buildings accounts for approximately 33% of the electricity consumption and has already been targeted by low-energy compact fluorescent (CFL) light bulbs. CFLs are slow to respond and consequently use more energy than the highly responsive technology of white LEDs (WLEDs).

At present, WLEDs still require AC 240 V mains power, which results in poor reliability and an unnecessarily expensive solution. The aim of this project is to power WLEDs with IEEE standard power over ethernet (PoE) DC-

powered cabling to bring about a low-cost, low-power and advanced controlled network.

This network will have the advantage of safe voltage levels of less than 50 V so wiring will not require a qualified electrician to safely install or retrofit low-energy and highly controllable lighting networks.

RESEARCH PROGRAMME

As an initial study into the feasibility of the project, a small-scale LED lighting network will be incorporated into the BIEN-RPG project currently being built by the University of Strathclyde with funding from the Technology Strategy Board.

The lighting system will be powered via an array of photovoltaic (PV) panels with backup supply from the national grid. A schematic of the project is shown in Figure 1. Once the performance of the small-scale system

has been ascertained using ESL and MATLAB, dynamic models will be developed to simulate the performance and control of a large-scale implementation.

From this, control algorithms and new lighting configurations will be designed and developed for real-

life practical application of the LED lighting system in buildings. This will lead to a fully automated LED lighting network with light level tuning, occupancy sensing and daylight harvesting, all fully powered from renewable energy sources.

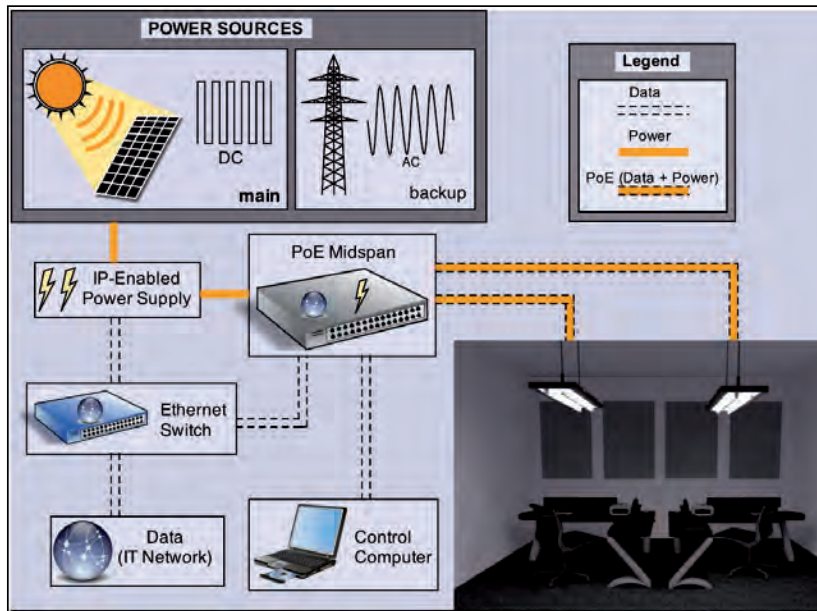


Figure 1: Schematic of the BIEN-RPG powered LED lighting network

FIRE AND SECURITY



SMOKE DETECTION IN HIGH CEILING SPACES

Raman Chagger

Fire and Security Group, BRE Global

SUMMARY

The capabilities of smoke detector technologies to detect small fires in high ceiling spaces are not fully understood. The project objective was to research, understand and provide guidance as to the capabilities and limitations of different detection technologies to detect fires in high ceiling spaces. As well as computational fluid dynamic simulations, fire tests were performed in a 43.5 m high hangar which confirmed that both aspirating smoke detectors and optical beam smoke detectors are capable of detecting smoke in high ceiling spaces, although for both technologies suitable sensitivity levels are required to produce an acceptable response.

BACKGROUND

As part of a project co-funded by the BRE Trust, the Fire Industry Association and a task group of aspirating smoke detector (ASD) manufacturers, research work was conducted into the detection of fires in high ceiling spaces. The current limitations of maximum ceiling heights and detection capabilities of different technologies are not fully understood. Therefore, the project objective was to research, understand and provide guidance as to the capabilities and limitations of different detection technologies to detect fires in high ceiling spaces. This research work was conducted in three stages.

- The first stage was to collate and review available theoretical and experimental evidence behind the current prescriptive codes of practice for smoke detection in high ceiling applications.
- The second stage was to conduct computational fluid dynamic (CFD) fire modelling to assist the identification of the limitations in ceiling heights and detector capabilities (Figure 1).
- The third stage was to conduct an appropriate set of real-life smoke tests to obtain data required to verify the limitations identified and to provide new experimental evidence to fulfil the project objective (Figure 2).

RESEARCH PROGRAMME

CFD modelling was carried out using the BRE CFD model 'JASMINE' and the 'Fire Dynamics Simulator' (FDS) code. The results from these suggest that the smoke levels required to produce an alarm condition for an optical beam smoke detector (OBSD) and ASD for small fires were lower when modelled in JASMINE than those modelled in FDS. For larger fires the predictions of the smoke density at the ceiling level were a lot more comparable. The differences observed may be due to the fact that both programs are operating at the limit of their accuracy due to a combination of a small fire size and the

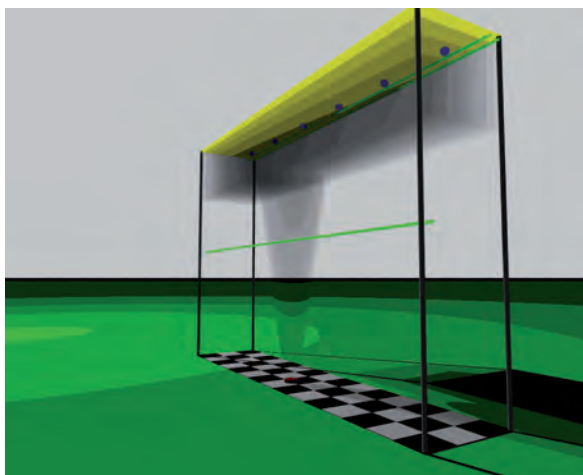


Figure 1: CFD configuration showing the modelled large open space and locations of the beam paths (green) and aspirator sampling points (blue)

large volumes which results in very low concentrations of smoke at the ceiling level. It was also very difficult to model precisely the obscuration caused by the various sizes of smoke particles.

The results from both CFD models suggest that the modelling predictions are in agreement with what is logical, that is small fires are detected at ceiling level and larger fire sizes produce more smoke at the ceiling level. The results also demonstrated that temperature gradients and cross-flows in the space lead to lower concentrations of smoke at the ceiling level.

Five different test fires were used in this research work to produce a broad range of smoke types with different profiles and characteristics. The results confirmed that the smoke from relatively small fires can extend 43.5 m vertically into high ceiling spaces. Seven OBSDs were used (four in a layer 16.5 m from the ground and three



Figure 2: Smoke plume from a potassium lactose test fire in a 43.5 m high hangar

just below the ceiling) and three ASDs were used (all located just below the ceiling). The three different ASD configurations effectively gave area, line and point integration. All detectors used during the fire tests were approved by the Loss Prevention Certification Board (LPCB) to the relevant EN 54 standard.

The fire tests revealed that the intermediate OBSDs (16.5 m from the floor) picked up smoke quickest for large volumes of smoke. Recommendations were made for OBSDs at ceiling level and it was advised that they are not set to be less sensitive than 35% and, where false alarms are less likely, that the sensitivity level of both the intermediate and ceiling level beams should be set at 25%.

For the ASD, it was observed that, generally, a Class C system with many sampling holes arranged over an area will reliably detect relatively smoky fires but increased sensitivity to Class B would make them more dependable.

PROJECT OUTCOMES/CONCLUSIONS

The results of the fire tests show that both ASD and OBSD systems are capable of detecting smoke in high ceiling spaces, although for both technologies suitable sensitivity levels are required to produce an acceptable response. The results also show the benefits of using integrative type smoke detection for detecting smoke in high ceiling spaces.

PUBLICATIONS/RESEARCH OUTPUT

The outcomes from the project will be explained in more detail in a BRE Information Paper *Smoke detection in high ceiling spaces* which will be published by IHS BRE Press in 2011.

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FIRE PERFORMANCE OF LIGHT STEEL-FRAMED BUILDINGS

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SUMMARY

The project summarises the results of a literature review of existing research information and industry guidance on the performance of light steel frame structures in fire. Gaps in knowledge have been identified. The most significant area for further research and development is in understanding the interaction between structural members at the fire limit state to prevent premature collapse and to ensure that the anticipated performance derived from standard fire testing is not compromised by the 'weakest link' in terms of system performance.

BACKGROUND

Steel is a traditional construction material and has been used for many years to build a wide range of different structures including large framed offices, commercial and retail buildings. Such buildings are normally designed and constructed using hot rolled steel sections where the thickness of the section ranges from approximately 4 mm up to around 80 mm. Traditionally, steel-framed buildings have not had a big market share in such areas as residential accommodation, hotels and student accommodation. Light gauge steel-framed modular and panellised systems have made significant inroads in recent years into such markets. The development of many light gauge steel systems has been driven by the need to:

- achieve greater efficiencies within the construction industry
- reduce energy consumption and waste
- improve acoustic and thermal performance.

In terms of performance in fire, all buildings must demonstrate compliance with the statutory requirements of national building regulations. This is generally achieved through a reliance on results from standard fire tests. However, the standard means of test and assessment does not provide information on some aspects of system behaviour which may be particularly significant for light steel-framed buildings. The purpose of this review is to highlight areas where designers and manufacturers may need to look beyond a simple reliance on standard fire test data to consider issues of detailing which may be critical to the performance of the building system in the event of a real fire.

RESEARCH PROGRAMME

The project provided a comprehensive review of both academic literature and industry guidance in relation to the performance of light steel-framed structures in fire.

Figure 1 shows the relationship between temperature and strength for cold-formed sections from a range of different sources and for a variety of different strain levels and section thicknesses. The graph also provides a comparison with typical values used for hot-rolled steel (see graph line for BS EN 1993-1-2). What is clear is that the reduction in strength with increasing temperature is more pronounced for cold-formed steel.

A study of available research data from both bench and large-scale tests has shown that light-gauge steel structures may be prone to complex modes of failure in a fire situation. Failure is typically due to a combination of flexural and distortional buckling. The susceptibility to localised distortional buckling is more pronounced where service holes are introduced into structural members. Large-scale fire tests have demonstrated the potential for modes of failure to be mobilised which cannot be predicted from the results of standard fire tests.

Light-gauge steel structures, in common with light timber construction, rely to a large extent on plasterboard linings to achieve the specified fire resistance performance. Once the integrity of the linings has been compromised either due to excessive deformation of the structure or localised failure of the fixings then load-bearing failure can be very rapid. The large-scale tests have shown that it is necessary to consider not just element behaviour in fire but also system behaviour. Connections in light-gauge steel are generally formed from self-drill, self-tapping screws, spot welds or rivets. Such methods of fixing may not have the strength or ductility required to accommodate the large displacements which typically occur during a fire.

Industry guidance is available covering a range of potential design solutions to achieve specified periods of fire resistance. The most important document in this regard is published by the Steel Construction Institute⁽¹⁾ and provides tabulated values for planar protection to

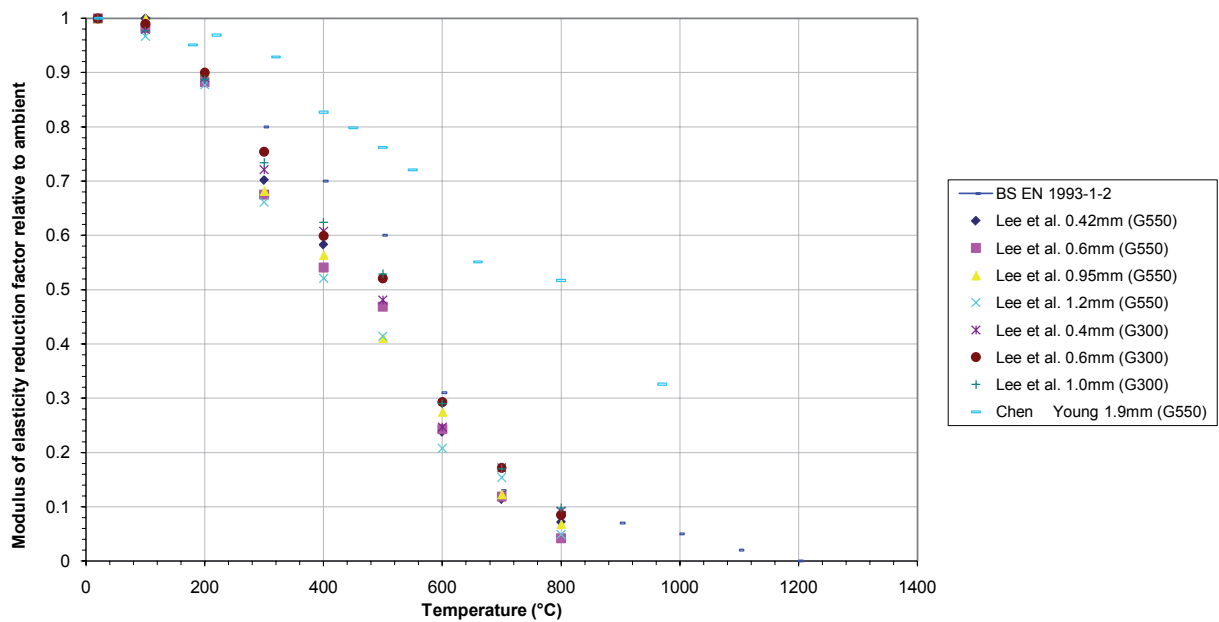


Figure 1: Strength reduction as a function of temperature for light and rolled steels
G = stress grade

floors and walls using gypsum plasterboard and typical values of thickness of sprayed and board protection for specific section factors. The critical temperature concept which relates performance in fire to the load applied at the time of the fire has been modified to provide limiting temperatures specific to cold-formed sections. This information is summarised in Table 1. SCI publication P129^[1] also provides detailed guidance on best practice for installation of boards to light-gauge steel. Further information is available from plasterboard manufacturers.

Table 1: Limiting temperatures (°C) for beams and columns using cold formed steel sections

Member type	Load ratio at the fire limit state				
	0.7	0.6	0.5	0.4	0.3
Beams supporting concrete slabs	530	555	600	640	670
Beams supporting timber floors	450	485	530	575	625
Columns in walls	445	480	520	560	605
Slender columns	400	450	490	540	590
Other elements, studs and ties	400	450	490	540	590

CONCLUSIONS

The project has identified knowledge gaps in relation to the performance of light steel-framed structures in fire based on a comprehensive review of existing research and industry guidance. The most significant area for further research and development is in understanding the interaction between structural members at the fire limit state to prevent premature collapse and to ensure that the anticipated performance derived from standard fire testing can be achieved.

RESEARCH OUTPUT

More information about the findings of this research project will be given in a BRE Information Paper which will be published by IHS BRE Press in 2011.

REFERENCE

[1] Lawson RM. Building design using cold formed steel sections: fire protection. P129. Ascot, The Steel Construction Institute (SCI), 1993

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REALISTIC SMOKE VISUALISATION FROM COMPUTER FIRE SIMULATIONS

Richard Chitty

Fire Safety Engineering, BRE Global

SUMMARY

One of the design criteria for a smoke control system in a building is to keep escape routes (and possibly access routes for firefighters) free from smoke during a fire. To demonstrate that a system meets the requirements for visibility, computer simulations may be performed for various design fires to predict the density and location of smoke in a building. This project has attempted to create photo-realistic images of smoke in buildings using freely available ray tracing software (POV-Ray⁽¹⁾), from the predictions of various fire models using smoke property data derived from test methods such as the cone calorimeter.

BACKGROUND

Conventionally, visibility data from computer fire simulations are displayed using contour maps (Figure 1), but these cannot be easily interpreted to determine how transparent or obscure smoke in a region of a building may be when viewed from different locations. Iso-surface can show the edge of a 'cloud' of smoke but does not indicate the attenuation of light along a line of sight through it. The lighting conditions in the building further complicate the issue; if the light sources are in the smoke layer then the intensity is attenuated as it passes through the smoke; if the source is outside the smoke, scattering will also influence visibility.

RESEARCH PROGRAMME

Simple design calculations and zone models assume that the smoke in a building accumulates in a homogenous

layer in a similar way to an inverted bath tub. A more detailed calculation method uses computational fluid dynamics (CFD). This approach divides the space into a large number of small volumes (cells) and solves equations for the conservation of mass, momentum, energy and species.

Zone models usually represent a fire as a heat source occupying a specified volume with combustion products being created in proportion to the burning rate of the fuel. This approach may also be used by CFD models.

However, a more realistic approach is to include a combustion model: the conversion of fuel to products is considered at every cell depending on the local concentrations, temperature and mixing rates. Using a combustion model creates an additional computational load but provides greater generality as the location of the flaming region does not have to be assumed a priori and the production rate of 'smoke' can be related to the combustion conditions.

For the simpler zone models, estimations of visibility through smoke are based on calculating the distance into the smoke for the attenuation light to fall to a specified value. For CFD simulations, the predictions of smoke concentration are related to position by the CFD computational mesh. Some programs including JASMINE⁽²⁾ and FDS⁽³⁾ use a Cartesian mesh where it is easy to extract data values along a 'line of sight' that is aligned with the coordinate axis. Other CFD programs that use non-structured grids, such as ANSYS-CFX⁽⁴⁾, provide post-processing tools to extract data along an arbitrary line.

Once a 'line' of data has been extracted the obscuration along the line can be found if the smoke density in each cell and the path length through each cell is known (Figure 2). Ray tracing programs also use this approach to calculate attenuation along a light path

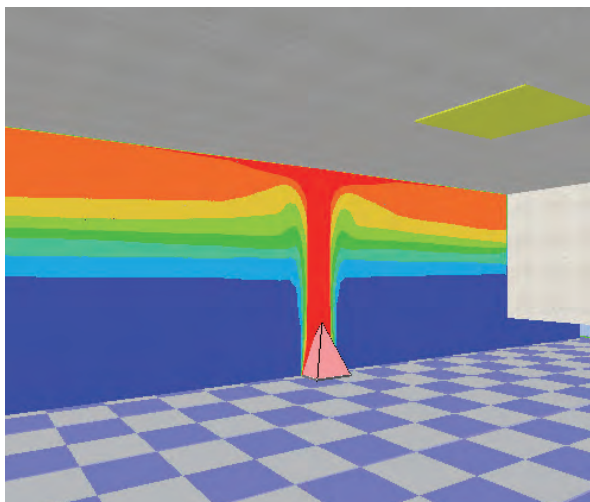


Figure 1: Contours show in smoke density

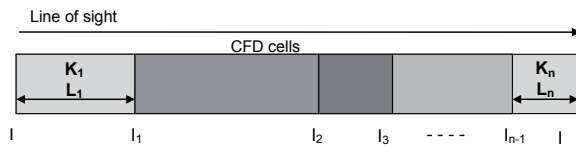


Figure 2: Attenuation of light through a line of CFD cells

and use that information to construct a photo-realistic image. Visualising smoke based on predictions by a CFD program, using the freely available ray-tracing software POV-Ray, has been achieved by creating a scene where each cell in the CFD mesh is represented by a transparent box. The transparency of the box is specified using the predicted extinction coefficient from the CFD simulation (Figure 3).

Light is also scattered by smoke particles and this can be included by ray tracing programs, however, measurements of smoke are typically limited to attenuation and data on scattering is sparse. This limits the ability to create an accurate, realistic image.

Figure 4a shows a room partly filled with a smoke layer, the attenuation of light by the smoke is based on homogenous properties calculated by a zone model. Figure 4b shows the same smoke layer, however in this case some (arbitrary) scattering of the light by the smoke has been included.

PROJECT OUTCOMES/CONCLUSIONS

Qualitative investigation of freely available software indicated that it could have a useful role to play in providing realistic images of smoke from both zone and CFD simulations of fires in buildings.

Using measured material properties and fire engineering calculations identified that, in addition to the commonly measured attenuation properties, scattering also needs to be considered to create a realistic image. The images are also dependent on assumptions made

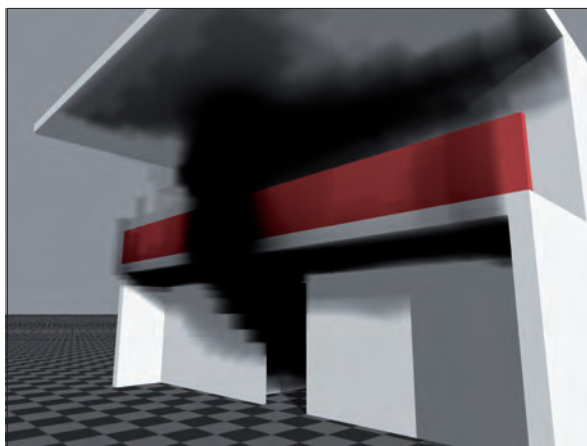


Figure 3: Ray-traced image of smoke based on CFD simulation data

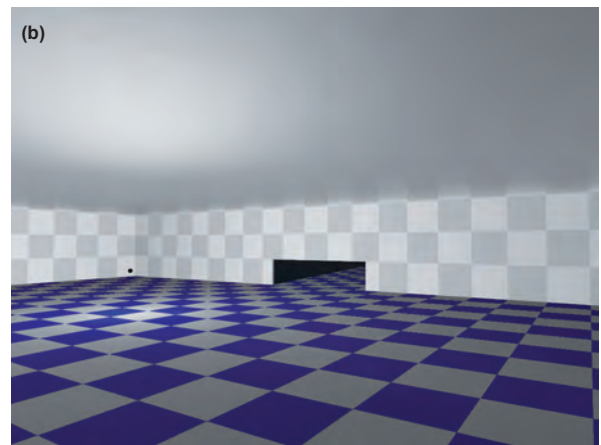
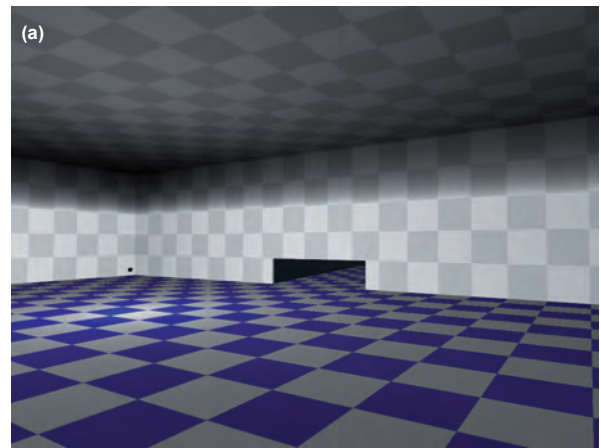


Figure 4: Visualisation of smoke from a zone model: (a) attenuation only, (b) scattering and attenuation

about lighting conditions. The method used to view CFD data is computationally expensive and needs to be optimised (especially if animated sequences are required).

PUBLICATIONS/RESEARCH OUTPUT

Chitty R. Realistic smoke visualisation from computer fire simulations. Poster paper, Interflam 2010. Proceedings of 12th Interflam Conference, 5–7 July 2010, University of Nottingham. London, Interscience Communications, 2010

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THE EVACUATION OF HIGHLY DEPENDENT PEOPLE FROM FIRES IN BUILDINGS

David Crowder and David Charters

Fire and Security Group, BRE Global

SUMMARY

To ensure safe and timely evacuation in the event of emergencies, people with responsibility for the design and management of buildings need to be capable of assessing the ability of a building's occupants to evacuate and whether there are any special requirements that need to be addressed. However, recent events such as the Rosepark Nursing Home fire and the World Trade Centre attack have highlighted the complexity of this issue. This project was therefore commissioned to investigate the evacuation of people across the range of the mobility spectrum, and to present guidance to assist those with relevant responsibility.

BACKGROUND

There is no simple way of knowing how long it will take a person whose mobility is impaired or who is highly dependent to evacuate or be evacuated from a building during a fire.

This uncertainty was illustrated during a fire in a hospital in Warrington in 2002, when a ward full of adult acute patients was evacuated by staff in less than four minutes, just before fire flash-over occurred. Historical data from evacuation exercises indicated that this should not have been possible. Equally, the Rosepark Nursing Home fire in Lanarkshire in 2004 demonstrated the challenge faced in many healthcare premises, as one of

the people who died would have required four people to evacuate her.

Even for notionally able-bodied people, the attack on the World Trade Centre, New York, in 2001 showed that over 1000 surviving occupants had a limitation that had an impact on their ability to evacuate, including recent surgery or injury, obesity, heart condition, asthma, advanced age and pregnancy.

The aim of this project, therefore, was to research the means of evacuation of people who are elderly, ill or children from buildings, residential care, healthcare and domestic premises.

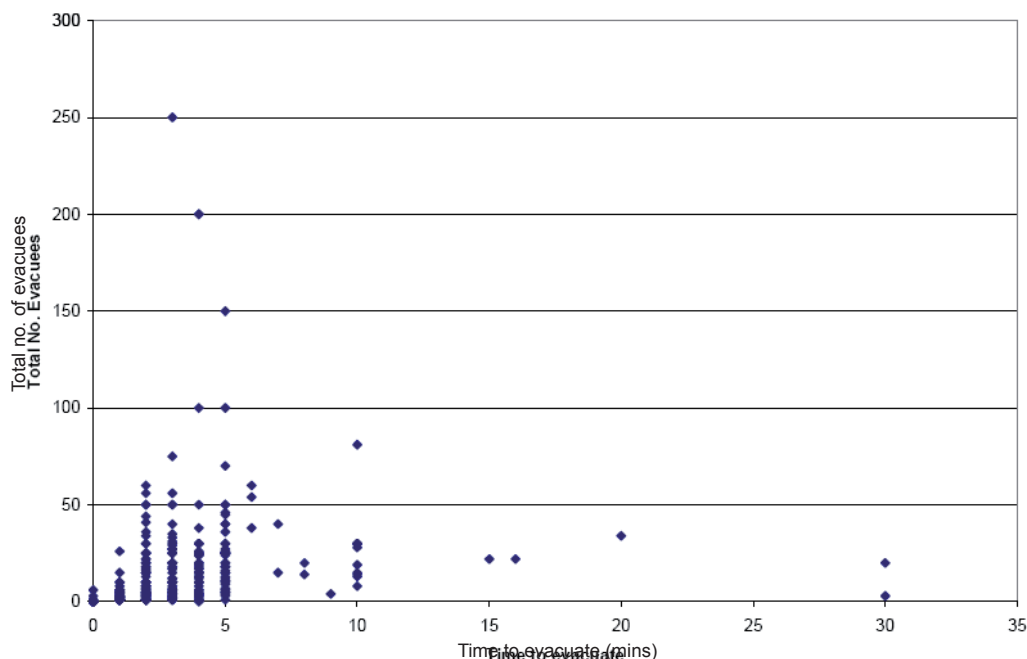


Figure 1: Number of evacuees against the time taken for evacuation

RESEARCH PROGRAMME

Time taken to evacuate

The project analysed detailed fire evacuation data from London Fire Brigade's 'Real fire database'. This data showed that most evacuations from healthcare premises involve less than 50 people and are complete in 5 minutes (Figure 1).

The data also showed that a small number of evacuations included a large number of people (up to 250 people) and were also completed within 5 minutes. Of most relevance were those evacuations of a small number of patients (less than 20) that took up to 30 minutes indicating a high degree of dependency. This data helped illustrate and quantify the overall evacuation time. However, the real world is insufficiently instrumented to provide the kind of detail required to develop a quantitative understanding sufficient for prediction.

The importance of evacuation drills

To provide a more detailed understanding of the processes involved in the evacuation of highly dependent

people, the project planned to record unannounced evacuation drills by healthcare providers (Figure 2).

Due to concerns over manual handling and infection control, however, it was discovered that few evacuation exercises were being undertaken. Detailed contributions by Janette Midda, Loughborough University, and Peter Aldridge, National Association of Hospital Fire Officers, demonstrated how concerns over manual handling and infection control were perhaps exaggerated and could be managed. This information should enable healthcare providers to undertake the evacuation exercises so crucial to the efficient evacuation of patients in an emergency. Indeed, one unannounced evacuation drill showed that trained staff were more than twice as efficient at evacuating patients as untrained staff.

The need for evacuation drills was also illustrated by the fatigue of two members of nursing staff evacuating a 50 kg dummy five consecutive times using ski pads and ski sheets (Figure 3). Evacuation drills are essential so that all involved have a realistic appreciation of what it entails and what is possible.

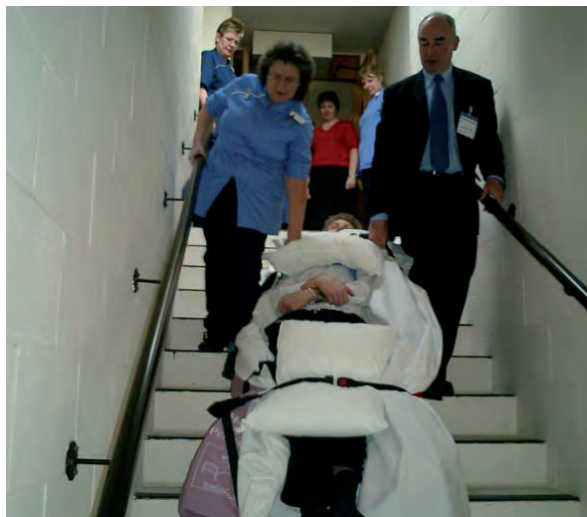


Figure 2: A 'patient' is evacuated down stairs during an evacuation drill

Practicability of evacuation in some cases

The research allowed estimates of the times needed for evacuation for a range of degrees of dependency. These estimates re-confirmed that progressive horizontal evacuation was still generally the most effective evacuation strategy for highly dependent occupants of healthcare premises. However, events like the Rosepark Nursing Home fire, the increase in the number of geriatric people and the dependency of many in hospital wards may indicate that for some people in some circumstances, the most effective approach to evacuation might be an explicit 'defend in place' strategy.

RESEARCH OUTPUT

More information about the findings of this research project will be given in a BRE Trust Report which will be published by IHS BRE Press in 2011.

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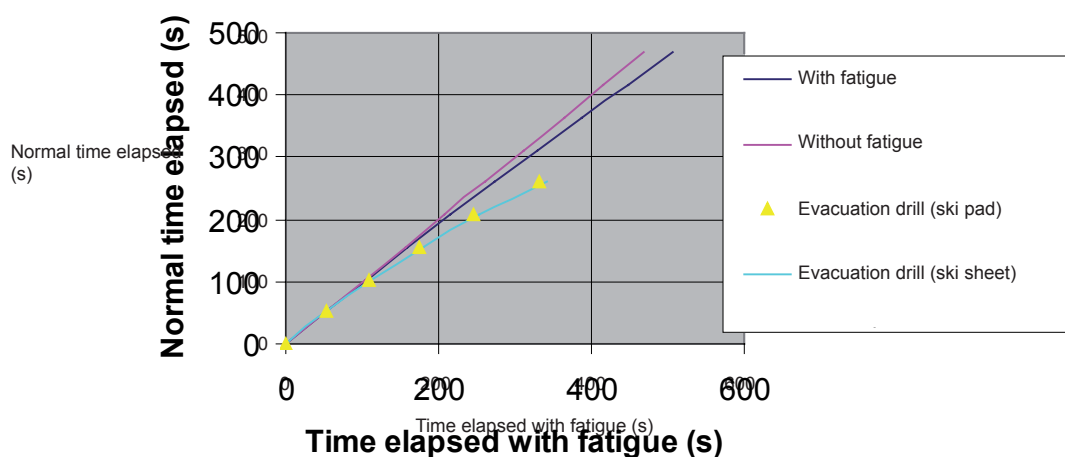


Figure 3: The effect of fatigue on members of nursing staff during evacuation

SECURITY GLAZING: Is it all that it's cracked up to be?

Richard Flint and Craig Devine

Fire and Security Group, BRE Global

SUMMARY

The aim of this project was to deliver guidance on specification of security glazing that provides resistance to forced entry by criminals consistent with that provided by the walls, windows, doors and other building elements in which glass is to be fitted.

BACKGROUND

This project was originally proposed at the time of a spate of burglaries in the West End of London which involved 'smash-and-grab' attacks of expensive goods such as jewellery and designer clothing from window displays involving breaking the windows and taking the goods. In one incident in early 2008, thieves managed to escape with over half a million pounds worth of jewellery from a jewellery store in Sloane Square. To the horror of the jeweller (and those that specified the glass used in the shop front) the assailants simply impacted the glazed shop front a number of times to puncture two holes large enough through which they removed a number of very expensive items of jewellery. All of this took less than a minute and was conducted in the middle of the day in a street with members of the public going about their business.

Those involved in insuring such businesses had reported that the frequency of such incidents is on the increase with many jewellers, specialist fashion retailers and other retailers selling high net worth goods being targeted, particularly in London and the South East.

Discussions held with representatives of police, insurance and other stakeholders interested in preventing such burglaries indicated there was a distinct lack of guidance that:

- advised specifiers on how to specify glass that would be effective in preventing such attacks
- provided an indication of what resistance to attack glazing would offer.

This project aims to fill this void.

RESEARCH PROGRAMME

The following work was conducted.

- UK crime statistics were reviewed to identify whether burglars were targeting glass when attempting to gain entry to a property or protected area within a property.
- Publicly available guidance on building security was reviewed to determine whether:

- there were any trends in relation to the glazing materials they specified
- glazing was recommended on the basis of physical attributes (eg type and thickness) or performance
- there was any correlation between the performance of the glazing recommended and the performance of the building elements (eg doors and windows) in which the glazing would be fitted.
- A test programme was conducted on common glazing materials. This was to determine:
 - whether the glazing's performance correlated with that of the building element(s) in which it may be fitted.
 - the glazing's resistance to forced entry.

The UK crime statistics reviewed as part of the project, together with the responses received from police, insurers and property owners, suggested methods of entry involving breaking glass (18–29% of burglaries) were second only to methods involving forcing opening elements such as window sashes and door leaves (37–56%). It was therefore considered to be understandable that the majority of the 76 publicly available guides to preventing domestic burglary recommended strengthening the frames and locks on opening elements such as doors and windows (91% of domestic guidance). Only 32 documents (42%) suggested what glazing should be used.

The situation relating to security of commercial properties, such as offices and shops, and schools, mirrored the domestic situation. That is, only 42% of publicly available guidance about securing commercial properties suggested what glazing should be used to reduce the risk of burglary. Furthermore, the limited guidance on glazing that was found during the review was inconsistent. Different documents suggested different solutions, including the following:

- double glazing
- wired glass
- toughened glass

Table 1: Summary of specimens tested

Type	Description
Fire (Intumescent)	11.4 mm laminated fire glass
	15 mm laminated fire glass
	23 mm laminated fire glass
Fire (Wired)	6 mm wired glass
Float	10 mm float glass
Toughened	4 mm toughened
	6 mm toughened
	10 mm toughened
Polycarbonate (single ply)	6 mm polycarbonate
	8 mm polycarbonate
	10 mm polycarbonate
Laminated (glass/pvb and glass/PUR)	6.4 mm glass/pvb laminate
	6.8 mm glass/pvb laminate
	7.4 mm glass/pvb laminate
	7.5 mm glass/pvb laminate
	10 mm toughened glass/PUR laminate
	11.4 mm glass/pvb laminate (5 ply)
Laminated (glass/polycarbonate)	10 mm glass/polycarbonate laminate
	12 mm glass/polycarbonate laminate
	16 mm glass/polycarbonate laminate
	18 mm glass/polycarbonate laminate
	28 mm glass/polycarbonate laminate
	46 mm glass/polycarbonate laminate

pvb = polyvinyl butyral; PUR = polyurethane.

- laminated glass (in particular 6.4 mm thick laminated glass for domestic and either 6.8 mm or 7.5 mm thick for schools and commercial premises)
- polycarbonate.

None of the domestic security guides indicated what performance the glazing should provide. Meanwhile, only four of the commercial security guides suggested what performance specifiers should look for, ie BS EN 356^[1] and BS 5544^[2].

None of the guidance documents mentioned the following important issues:

- the need to ensure that the glass used offered equivalent resistance to attack to that provided by the product (eg doorset or window frame) in which it was to be mounted or
- methods by which the compatibility of the glass and frame could be verified.

This was despite the findings of a 1994 study by Pascoe & Harrington-Lynn^[3] who concluded that: *'increased security can only be provided by an appropriate combination of glass type and frame material'*.

Furthermore, despite their findings, only one of the standards for the security performance of glazed elements (LPS 1175^[4]) required the glazing used in doors and windows to provide equivalent resistance to attack irrespective of the level of security provided. Other standards, such as prEN1627^[5], only required glazing used in products of higher grades to provide resistance to the same range of attack methods. Meanwhile, standards,

such as BS 7950: 1997^[6], merely mentioned the need to use particular generic types of glass (eg laminated).

The tools and impact equipment used to conduct the test programme on the glazing materials listed in Table 1 are shown in Figures 1–4 and were those specified in the following standards commonly used to determine the security performance of doors, windows and other building components containing glazing:

- BS 7950: 1997^[6]
- ENV 1627: 1999^[7]
- LPS 1175: Issue 6^[4]
- PAS 24: 2007^[8].

The test programme confirmed the following.

- As the thickness of a generic type of glazing material was increased, its resistance to forced entry, soft body and hard body impact generally increased. However, there were instances where this was not the case. For example, 7.4 mm thick glass/pvb laminated glass performed significantly worse than 6.4 mm and 6.8 mm glass/pvb laminates, while 8 mm polycarbonate performed worse than 6 mm thick polycarbonate during certain attacks. One possible explanation for these differences is the effect the stiffness of the glazing element has on the material's resistance to particular types of attack. However, further research would need to be conducted to prove whether this hypothesis was correct and, if it was, at what thicknesses do these effects bottom out.
- The most significant improvement to manual attack was achieved by incorporating polycarbonate. Unlike PVB and PUR interlayers, which could be cut relatively easily with a knife once the glass layers had been broken, polycarbonate offered significantly greater resistance to such methods. It was therefore generally necessary to use drills to penetrate the polycarbonate before chiselling the polycarbonate or, in the case of much thicker layers or laminates, to use battery-powered cutting tools such as jigsaws and reciprocating saws to cut the polycarbonate layers.



Figure 1: Glazing and infill removal test tools specified in BS 7950^[6] and PAS 24^[8]



Figure 2: Leather spheroconical bag used to conduct soft body impact tests

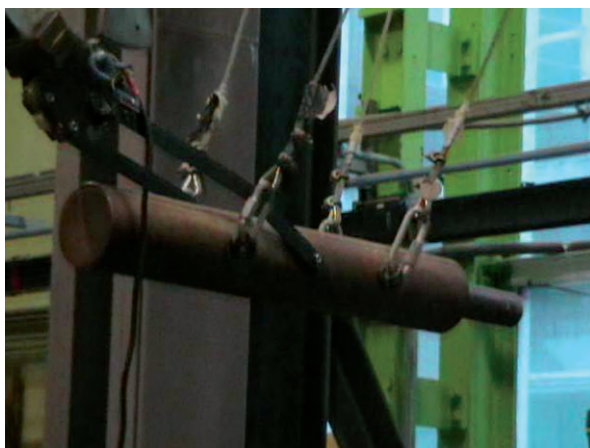


Figure 3: Impactor used to conduct hard body impact tests



Figure 4: Hole formed in top corner of wired glass sample as a result of the first hard body impact

PROJECT OUTCOMES/CONCLUSIONS

The research demonstrated that the glazing materials recommended within BS 7950^[6], ENV 1627^[7] and PAS 24^[8] do not necessarily offer resistance to manual attack commensurate with those that the standards required of other aspects of the building elements such as windows and doors.

The tests also demonstrated that using laminated glazing of the 6.4 mm and 6.8 mm thicknesses recommended by *Secured by Design* in the 2009 edition of their 'New homes' document^[9], would leave windows and doors meeting the requirements of BS 7950 and PAS 24 vulnerable to forced entry using the same tools that are used to evaluate the resistance provided by other aspects of those products when tested to BS 7950 and PAS 24.

Many of the glazing materials tested were also found to be vulnerable to penetration using the hard body impact tests described within PAS 24 as well as the soft body impact tests defined within BS 7950, PAS 24 and ENV 1627.

On the other hand, LPS 1175 did not include any hard body or soft body impact requirements but did treat the glazing as an inherent part of the product being rated and therefore required the glazing fitted to a product to offer compatible resistance to manual attack. Because of this and the relatively poor performance exhibited by the glazing permitted within BS 7950, PAS 24 and ENV 1627, it was found that the glazing used in products classified to LPS 1175 offered substantially higher resistance to manual attack. However, that glazing was also significantly more costly. This may act as a barrier to it being adopted by a greater number of manufacturers and specifiers, especially within a period of economic downturn such as that being experienced at the time this project was conducted.

RESEARCH OUTPUT

More information about the findings of this research project will be given in a BRE Trust Report, *Security glazing: Is it all that it's cracked up to be?*, which will be published by IHS BRE Press in late 2011. It will not only contain a summary of the research findings in relation to the manual attack resistance provided by glazing, it will also touch on other performance attributes such as blast and ballistics, fire resistance, insulation and safety. A summary of the glazing materials found to offer resistance to attack commensurate with that required of other aspects of the building elements in which they may be used will also be provided.

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- [4] BRE Global. LPS 1175: Issue 6 Requirements and testing procedures for the LPCB approval and listing of intruder resistant building components, strongpoints, security enclosures and free-standing barriers. Watford, BRE Global, 2007. Available at www.redbooklive.com
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- [7] BSI. ENV 1627: 1999 Windows, doors, shutters. Burglar resistance. Requirements and classification
- [8] BSI. PAS 24: 2007 + A1: 2009 Enhanced security performance requirements for door assemblies. Part 1: Single and double leaf, hinged external door assemblies to dwelling
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BRE CENTRE OF EXCELLENCE IN FIRE SAFETY ENGINEERING, UNIVERSITY OF EDINBURGH

José Torero

BRE Trust/RAEng Professor of Fire Safety Engineering

2010 was an extremely busy, successful year for the BRE Centre of Excellence in Fire Safety Engineering. Numerous research projects have commenced following successful applications for funding.

One of many highlights is an EC FP7 funded project entitled *AircraftFIRE* which began in early 2011. The Centre's role in this project is to use the concept of fire signatures to develop robust pre-flaming fire detection systems for aircraft. This is a 3-year project with some 13 partners in academia and industry from all over Europe.

The Centre is receiving funding over 3 years from the Scottish Government to assess the current state-of-the-art of tall building design for fire.

The insurance company AXA is funding a project that looks at improving assessment of risk of forest fire outbreak through the introduction of fire science to current prediction tools.

The Centre graduated a total of eight PhD students, of which four were sponsored by BRE Trust:

- Cecilia Abecassis Empis for 'Analysis of the compartment fire parameters influencing the heat flux incident on the structural façade'
- Wolfram Jahn for 'Inverse modelling to forecast enclosure fire dynamics'
- Angus Law for 'The assessment and response of concrete structures subject to fire'
- Sung-Han Koo for 'Forecasting fire development with sensor-linked simulation'.

A further seven students have since begun research PhDs.

This year also saw the start of the International Master of Science in Fire Safety Engineering, a two-year MSc course hosted by the Universities of Edinburgh, Lund and Ghent.

The Centre's Director, Professor José Torero, was elected to Fellow of the Royal Academy of Engineering in July. This award was accepted with a speech entitled, 'The twin towers: 10 years – 10 lessons on sustainable

infrastructure'*. Professor Torero was also the recipient of the 2010 Tom Dalyell Medal for Excellence in Engaging the Public with Science, accepted with a speech entitled, 'Fire: a story of fascination, familiarity, and fear'†.

Other individual awards were:

- The Lloyds Science of Risk Prize in the Technology Category was awarded to Dr Francesco Colella for his research paper entitled, 'A novel multiscale methodology for simulating tunnel ventilation flows during fires'
- The 2009 Hinshelwood Award from the Combustion Institute to Dr Guillermo Rein
- The 2010 David B Gratz Scholarship from the National Fire Protection Association to Jamie Stern-Gottfried
- The Lessells Travel Scholarship to Sam Grindrod from the Royal Society of Edinburgh.

2010 also saw a significant number of conferences and symposiums organised at the Centre. These included:

- The 2010 Ove Arup Foundation Lecture given by Professor Emeritus Peter Jones
- The 2010 IFE Rasbash Lecture on Fire and Structures given by Professor Roger Plank
- The Spring Meeting of the British Chapter of the Combustion Institute

The Centre also hosted its annual one-day conference, FireSEAT, this year focussing on, 'Fire safety engineering in the UK: the state-of-the-art'.

* <http://www.youtube.com/watch?v=cypIiVb5c8c>

† http://www.youtube.com/watch?v=cY0litLLRA&feature=player_embedded

*For further information on any of the projects that follow, contact Professor José Torero,
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ANALYSIS OF THE COMPARTMENT FIRE PARAMETERS INFLUENCING THE HEAT FLUX INCIDENT ON THE STRUCTURAL FAÇADE

Cecilia Abecassis Empis

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SUMMARY

A detailed analysis of the Law Model for determining thermal insult to external elements of structures has been conducted. The analysis determined that fire load is the parameter of pivotal influence; all other parameters having minor influence by comparison. The result is a simplified methodology with clear limits of applicability, based principally on the fire load with the contribution of other parameters grouped into error bars.

BACKGROUND

In recent years several high-profile building fires have highlighted shortcomings in the way we design for the complex interaction of structures and fire. These weaknesses appear to arise from a combination of gaps in knowledge of some of the more intricate aspects of compartment fire dynamics and from limitations in the engineering applications developed to date from hitherto established fundamentals. In particular, the One Meridian Plaza Fire, Philadelphia (1991), the Windsor Tower Fire, Madrid (2005) and the Lakanal House Fire, Camberwell (2009) have emphasised the need for further study in the field of post-flashover compartment fires and the often consequent external fires that emerge from the compartment openings.

External fire plumes impinge on the structural façade, causing added structural stress, and often result in external fire spread and secondary ignition in upper-level compartments. Hence, a better understanding of the effect by the internal compartment fire on the development of external flaming and the thermal insult of the plume to its surroundings is beneficial for structural engineers, fire protection engineers and emergency response personnel alike.

This research explores existing correlations, identifies their limitations and proposes a simplified methodology that links key parameters found to govern the internal post-flashover compartment fire to the heat flux potentially imposed on the exterior façade.

RESEARCH PROGRAMME

Existing correlations addressing the effect of compartment fires on the thermal insult to the external structure have largely been compiled by Margaret Law and are summarised in the form of a design guide for bare external structural steel^[1]. Formulated in the 1970s, these correlations are based on the combined findings of several different experimental tests devised to investigate component phenomena of compartment fires and external flaming, forming an analytical model which is mostly empirical in nature. The methodology is convoluted and has several inherent assumptions which give rise to various limits of applicability. However, it is currently still used in structural fire design, but best known as Annex B of both Eurocodes 1 and 3^[2,3].

As part of the present research, full-scale fire tests were conducted in situ, in a highly instrumented high-rise building, to provide high-resolution measurements of several internal compartment fire characteristics during a post-flashover fire in a modern, realistically furnished compartment (Figure 1). External high-resolution instrumentation in the main test also provided detailed measurements of the external flaming and distribution of heat flux incident on the façade.

The tests provide realistic benchmark scenario data for comparing physical measurements against the analytical Law Model, the difference in which allows for an evaluation of the assumptions used in the model, which have often been described as 'conservative' in nature from the perspective of structural design.

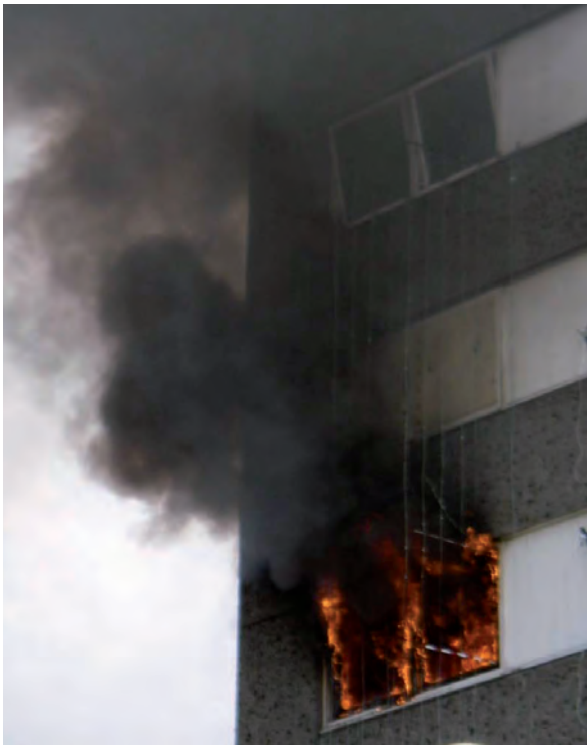


Figure 1: External flaming observed during Dalmarnock Fire Test One when the window broke post-flashover. A number of sensors were used to record external temperature and the distribution of heat flux incident on the façade above the window

A detailed sensitivity study of the main input parameters in the Law Model (based around the realistic benchmark scenario for reference) allows for the identification of parameters of pivotal influence on the resultant heat flux incident on the plane of the external façade.

RESULTS AND CONCLUSIONS

In-depth analysis of the Law Model and its underlying experimental basis reveals several limits in the applicability of the existing model. The thorough parameter sensitivity study identifies the fire load as the sole key parameter to have pivotal influence on the resultant heat flux to the external façade, where the contribution of other parameters (ie compartment dimensions, opening dimensions, etc.) is dwarfed by comparison. These findings show that the analytical model can be stripped of unnecessary complexity and a 'simplified' model is proposed with clear bounds of applicability. The proposed model describes the vertical distribution of heat flux incident on the façade above an opening in a single compartment fire and features only parameters of key importance, where the contribution from low-dependency parameters is grouped into relevant error bars. The model can be applied in the design of

several building components that fall in the plane of the façade, such as structural elements (perimeter columns, spandrel beams, etc.), cladding materials and window arrangements. Furthermore, its ease of implementation renders this simplified model more widely accessible to different parts of the fire engineering community.

FURTHER RESEARCH

The analysis of the Law Model also highlights further parameters that may be of potential importance in describing the external heat flux, that have not yet been addressed. A preliminary investigation conducted using computational fluid dynamics (CFD) tools shows that variation in some parameters that are not individually accounted for in the Law Model (ie fire load distribution, compartment geography, etc.) may influence the compartment fire conditions, the consequent external flaming and, in turn, the resultant external heat exposure. Therefore, it is recommended that further comprehensive experimental research be conducted into the potential influence of the additional parameters identified.

RESEARCH OUTPUT

Abecassis-Empis C & Torero JL. Analysis of the compartment fire parameters affecting the heat flux incident on the building façade: A simplified model with distinct bounds of applicability. Paper to be submitted to Fire Safety Journal

Cowlard A, Jahn W, Abecassis-Empis C, Rein G & Torero JL. Sensor assisted fire fighting. Fire Technology 2010: 46(3): 719–741

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INVERSE MODELLING TO FORECAST FIRE DYNAMICS

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SUMMARY

A methodology is proposed in which inverse modelling is used as a mechanism for providing accurate forecasts of fire scenarios using CFD models. Live data streams are assimilated to estimate critical parameters in the CFD model. The data streams are constantly adjusted through inverse modelling, accelerated by tangent model optimisation and corrected for inaccuracies introduced through the coarseness of the grid cells and the assumptions embedded in the model. This approach has been developed in the context of the FireGrid project.

BACKGROUND

Despite advances in the understanding of fire dynamics over the past decades and despite the advances in computational capacity, our ability to predict the behaviour of fires in general, and building fires in particular, remains limited. This project proposes and studies a method to use measurements of the real event to steer and accelerate fire simulations. This technology aims at providing forecasts of the fire development with a positive lead time, ie the forecast of future events is ready before those events take place.

RESEARCH PROGRAMME

A simplified fire spread model is implemented, and sensor data are assimilated into the model to estimate the parameters that characterise the spread model and thus recover information lost by approximations. The assimilation process is posed as an inverse problem, which is solved minimising a non-linear cost function that measures the distance between sensor data and the forward model. To accelerate the optimisation procedure, the 'tangent linear model' is implemented, ie the forward model is linearised around the initial guess of the governing parameters that are to be estimated, thus approximating the cost function by a quadratic function. The methodology was tested first with a simple two-zone forward model, and then with a coarse-grid computational fluid dynamics (CFD) fire model as forward model. Observations for the inverse modelling were generated using a fine-grid CFD simulation to illustrate the methodology. A test case with observations from a real scale fire test is presented.

RESULTS AND CONCLUSIONS

Two-zone model

The governing invariant parameters that are estimated in this approach are:

- spread rate
- entrainment coefficient
- gas transport time.

With this approach, the parameters could be estimated correctly and the temperature and the height of the hot layer were reproduced satisfactorily. Moreover, the heat release rate and growth rate were estimated correctly with a positive lead time of up to 30 s. The results showed that the simple mass and heat balances and plume correlation of the zone model were enough to satisfactorily forecast the main features of the fire, and that positive lead times are possible.

CFD forward model

The growth rate, fuel mass loss rate and other parameters of a fire were estimated by assimilating measurements from the fire into the model. This approach showed that with a field-type forward model it is possible to estimate the growth rates of several different spread rates simultaneously. A coarse-grid CFD model with short computation times was used to assimilate measurements and the approach showed that spatially resolved forecasts can be obtained in reasonable time, when combined with observations from the fire.

Real scale fire test

The assimilation of observations from a real scale fire test into a coarse-grid CFD model showed that the estimation of a fire growth parameter is possible in complicated scenarios in reasonable time, and that the resulting forecasts at localised level present good levels of accuracy (Figure 1).

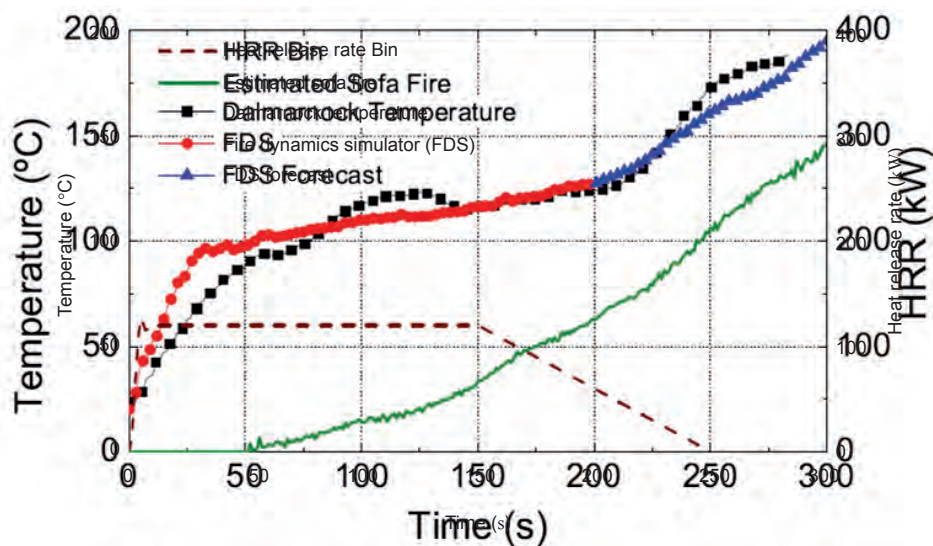


Figure 1: Forecast of fire development in Dalmarnock Test One

ONGOING RESEARCH

The proposed methodology is still subject to ongoing research:

- the limited capability of the forward model to represent the true fire should be addressed in more detail
- the additional information that has to be provided in order to run the simulations should be investigated.

When using a CFD-type forward model, additional to the detailed geometry, it is necessary to establish the location of the fire origin and the potential fuel load before starting the assimilation cycle. While the fire origin can be located easily (as a first approximation, the location of the highest temperature reading can be used), the fuel load is potentially very variable and it might be impractical to continually keep track of its exact distribution. It was, however, shown that for relatively small compartments the exact fuel distribution is not essential to producing an adequate forecast, and the fuel load could, for example, be established based on a statistical analysis of typical compartment layouts.

RESEARCH OUTPUT

Jahn W, Rein G & Torero JL. Forecasting fire growth using an inverse zone modelling approach. *Fire Safety Journal* (in press)

Note: This paper was short-listed within the Top 5 submissions for the 2010 Lloyd's Science of Risk Prize (Technology category)

Jahn W, Rein G & Torero JL. A posteriori modelling of the growth phase of Dalmarnock Fire Test One. *Building and Environment* (in press)

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FORECASTING FIRE DEVELOPMENT WITH SENSOR-LINKED SIMULATION

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SUMMARY

A sensor-linked modelling tool for live prediction of uncontrolled compartment fires, K-CRISP, has been developed to facilitate emergency response via novel system such as FireGrid. The modelling strategy is an extension of the Monte-Carlo fire model, CRISP, linking simulations to sensor inputs, thereby controlling the evolution of the parametric space in which new scenarios are generated, and thus representing 'learning' about the fire. The output of the model therefore tends to become a progressively closer representation of the real fire, thus enabling some degree of 'forecast' of evolving hazards.

BACKGROUND

In fire, any information about the actual condition within the building could be essential for a quick and safe response of both fire-fighters and occupants. While the emergency responders will rarely be aware of the actual conditions within a building, recent buildings are equipped with numbers of sensors which may potentially contain useful information about the fire. Integrating real-time sensor data with the output of fire simulation tools can provide an estimate of the possible future development of the fire, together with advance warning of extreme events such as flashover and structural failure.

RESEARCH PROGRAMME

A sensor-linked modelling tool for live prediction of uncontrolled compartment fires, K-CRISP, has therefore been developed. The modelling strategy is an extension of the Monte-Carlo fire model, CRISP, linking simulations to sensor input which controls the evolution of the parametric space in which new scenarios are generated, thereby representing real-time 'learning' about the fire. CRISP itself is based on a zone model representation of the fire, with linked capabilities for egress modelling and failure prediction for structural members, thus providing a major advantage over more detailed approaches in terms of flexibility and practicality, though with the conventional limitations of zone models. Large numbers of scenarios are required, but computational demands are mitigated to some extent by various procedures to limit the parameters which need to be varied. HPC (high performance computing) resources are exploited in 'urgent computing' mode.

A concept of randomizing input parameters for the model is suggested, using a simulation tool derived from a Monte-Carlo-based methodology. A randomised

approach is required so that the model will be capable of generating sufficiently diverse scenarios even without precisely defining their parameters. The model outputs will be continuously examined by comparison with sensor observations using statistical matching criteria. Different methods of establishing an appropriate feedback loop between the results assessment and the parametric space in which new fires are generated is suggested, with the aim of enabling some degree of 'forecast' for evolving hazards.

CRISP, a zone model with capabilities for risk and egress modelling, was chosen as the basic simulation tool and the capability of the model in reproducing the gas layer temperature of the Dalmarnock fire test (given knowledge of the approximate heat release rate in the fire) was first verified. The randomised aspects of the model were examined and a matching criterion was selected to characterise the difference between the model predictions and the measurements. A sensor-linked modelling tool for live prediction of uncontrolled compartment fires, K-CRISP, was then developed to facilitate emergency response.

The model was tested in 'real-time' using (pseudo) live sensor measurements obtained in the full-scale fire tests, the Dalmarnock Fire Test One and FireGrid D7.4 demonstrator.

RESULTS

K-CRISP performed simulations of the FireGrid D7.4 demonstrator case much faster than real time. Using only a few processors on the HPC resource, it was possible to produce more than 1000 scenarios per minute, to perform the update, and to come up with a new input parameter set every 30 s which was the sensor data update frequency. Thus, it ought to be feasible to model

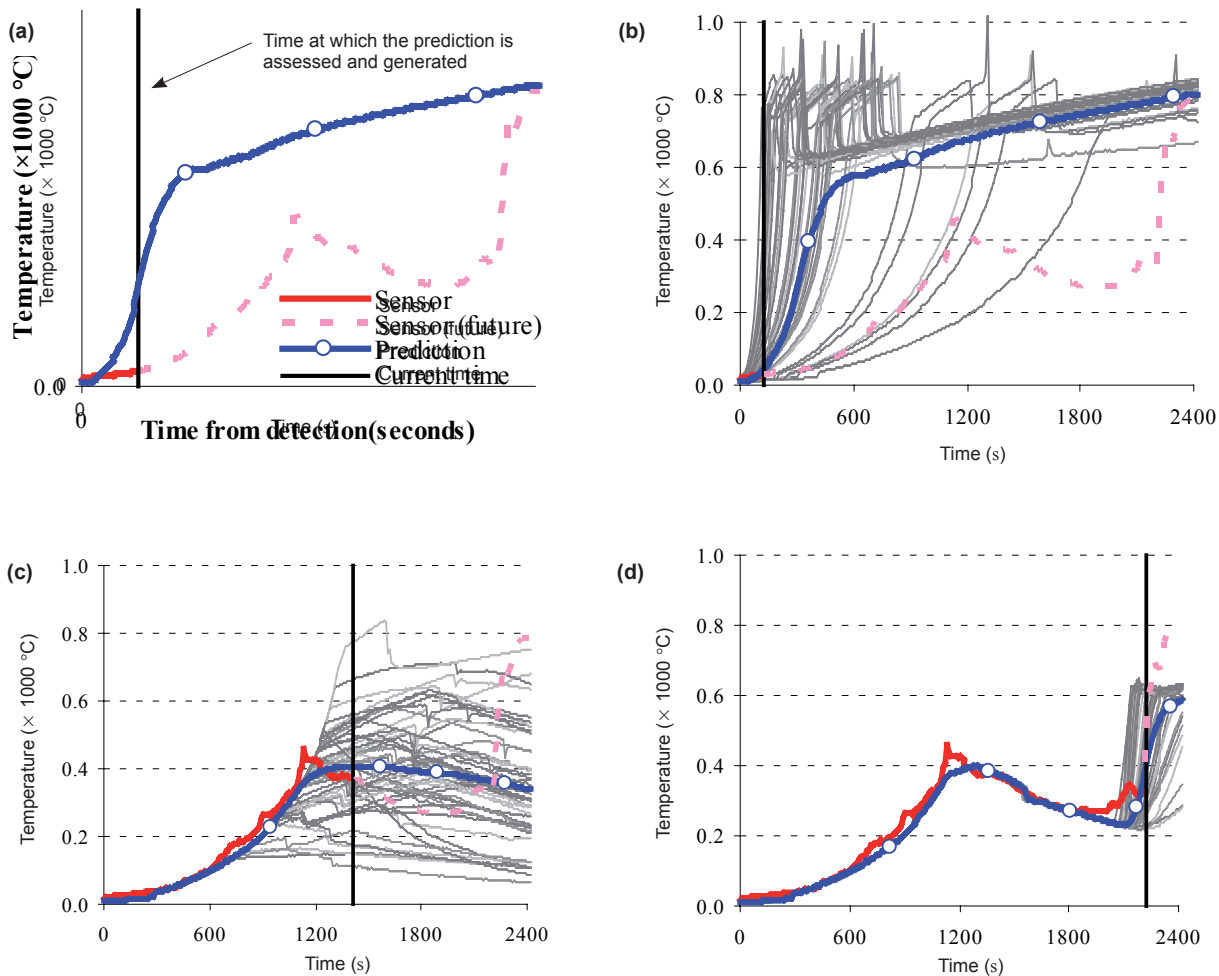


Figure 1: Comparison between sensor data (a) and K-CRISP predictions for full-scale demonstration test: (b) 120 s from detection, (c) 1410 s from detection, (d) 2220 s from detection

more complex scenarios, or longer duration runs, simply by calling on greater amounts of HPC resource, and also to increase the frequency of the updates as required.

Figure 1 compares the hot layer temperature of the sensor measurements and those of the K-CRISP prediction at three different timestamps. The sensor measurements are only 'known' up to the current instant in time, as indicated by the thick line, with the dotted portion showing the future trends. The sets of narrower light lines represent a random sample of 100 scenarios (predictions) selected from among those generated by K-CRISP in the most recent 30 s period. Finally, the evolution of the 'averaged prediction' is depicted by the thick line with symbols.

After several applications of the updating, it is apparent that the model has been steered in a way that the slope of the temperature rise becomes similar to the real fire. The first series of predictions show that there is a 'flashover' (when the temperature exceeds 500 °C) around 1300 s from detection; however, once the model had observed a continuous temperature decrease at around 1100 s, it had changed its fire phase and fixed parameters for

the growing phase, ie they could no longer be modified, while releasing those for the decay phase. In the experiment, the temperature continued to decrease until 2100 s from detection, as flashover began to develop. K-CRISP then changed its fire phase from non-growing to full-room at around 2200 s, shortly after the temperature had begun to rise significantly.

These results are a demonstration that it is possible to 'steer' a fire model in real time, though the generality of the conclusion needs further exploration.

RESEARCH OUTPUT

Two journal papers incorporating this work were published in the *Fire Safety Journal* and *Journal of Parallel and Distributed Computing* in 2010. Earlier, the results were presented at 9th IAFSS (International Association for Fire Safety Science) Symposium and the author was awarded the 2008 FORUM Student travel award for this conference. The work also received an award at the 3rd Hyundai Engineering Company technical award in Korea. The author's PhD thesis on this topic was accepted in September 2010.

SUSTAINABILITY



DEVELOPING A TOOL FOR DESIGNING GREENER SHOPFITTING DISPLAY EQUIPMENT: LIST (Low Impact Shopfitting Tool)

Katie Johnson*, Flavie Lowres*, Naomi Wells+ and Jane Anderson#

Building Technology Group, BRE*

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SUMMARY

An area within retail that has previously received little attention is that of the sustainability of loose shopfitting display equipment. This project developed an online tool LIST (Low Impact Shopfitting Tool) which aims to assist retailers, designers and manufacturers to evaluate and compare the environmental impacts of shopfitting display materials and equipment through their entire life-cycle, from the initial design stage to end-of-life disposal.

BACKGROUND

Sustainability has been defined as:

'meeting the needs of the present without compromising the ability of future generations to meet their own needs'.^[1]

The UK Government has set targets to reduce CO₂ levels by 80% by 2050 which is bringing about an increasing consciousness of the environmental impact of everyday activities. Many retailers are taking a lead by making improvements and encouraging sustainability in their business. However, a crucial area within retail that has yet to receive significant attention is the environmental performance of the loose shopfitting display equipment that is used to sell a variety of retail products (Figure 1) and is commonly updated by retailers every 3–5 years.

RESEARCH PROGRAMME

The Low Impact Shopfitting Tool (LIST) was developed by BRE, FITCH, Leggett & Platt Store Fixtures Europe and M&S to reduce the impact on the environment of retail display products. This project, funded by the BRE Trust and the partners, will enable retailers, designers and manufacturers to evaluate and compare the environmental impacts of shopfitting display materials and equipment from the initial design stage. LIST encourages designers to consider the environmental consequences of the product from the preliminary designs throughout the life-cycle of the shopfitting display equipment.

- It will highlight the importance of recycled materials, and make the issues surrounding packaging waste, transport and end-of-life clearer.



Figure 1: Examples of common shopfitting display equipment: (a) freestanding display that stands on its own and can be moved, (b) parasite display hanging from or attached to other displays, (c) shelf and counter display

- The tool will enable retailers to evaluate the overall sustainability credentials of their shopfitting display materials and products at the design stage, allowing improvement to be made before manufacturing has commenced, saving time and money.
- LIST has been designed to minimise the amount of work required by the users and, as a result, will not greatly increase the time spent in the design process.
- The expertise given by the partners reduces the need for specialist training within retail companies; users benefit from the partners' combined knowledge which is utilised and implemented within LIST.
- Use of the tool will raise awareness of the materials available to designers and manufacturers, and potentially indicate alternative materials with lower environmental impacts.

From the outset, it was clear that although each partner was an expert within their own field, this knowledge needed to be expanded across all aspects of the tool, life-cycle assessment (LCA) and the shopfitting equipment industry. The combined knowledge of four leading companies has led to the development of a tool designed to ensure that a sustainable solution to loose shopfitting display equipment design can be provided.

PROJECT OUTCOMES/CONCLUSIONS

LIST is web-based and gives global access. It is primarily aimed at shopfitting display equipment designers, manufacturers and retailers. Each user will be provided with a login and password to ensure the privacy of data entered. Users can create personal projects and keep a record of all designs entered in the tool. These designs can be kept for the user's future reference allowing comparison of the environmental performance of two or more shopfitting display equipment designs, providing users with a choice based on the level of environmental impact of the products.

While carbon is currently the buzz word in the market place in the context of sustainability, through their involvement in the project the partners have become increasingly aware that carbon is just one part of a much bigger issue. Hence, the 13 impact categories (see Box 1) as described in the BRE Global Environmental Profile Methodology^[2] are used. The results that LIST produces therefore provide a score in kg of CO₂ eq. per unit and in Ecopoints per unit.

A case study using an 8-box merchandiser was undertaken during the project. It compared the environmental performance of a first-generation design

in plastic and steel with a second-generation design in hessian (Figure 2). LIST is of great value to designers as it highlights which parts, or components, of a product have the highest environmental impact (Figure 3). Based on this analysis, designers can choose to use an alternative material. The results of two designs can be shown side by side, allowing a comparison of the environmental performances and highlighting which section of the product's life-cycle (eg raw material extraction or end-of-life disposal) generates the greatest impact (Figure 4).

Box 1: Environmental impact categories

- Climate change
- Water extraction
- Mineral resource extraction
- Stratospheric ozone depletion
- Human toxicity
- Ecotoxicity to freshwater
- Nuclear waste (higher level)
- Ecotoxicity to land
- Waste disposal
- Fossil fuel depletion
- Eutrophication
- Photochemical ozone creation
- Acidification



Figure 2: (a) First-generation design using plastic and steel, (b) second-generation design using plastic, steel and hessian

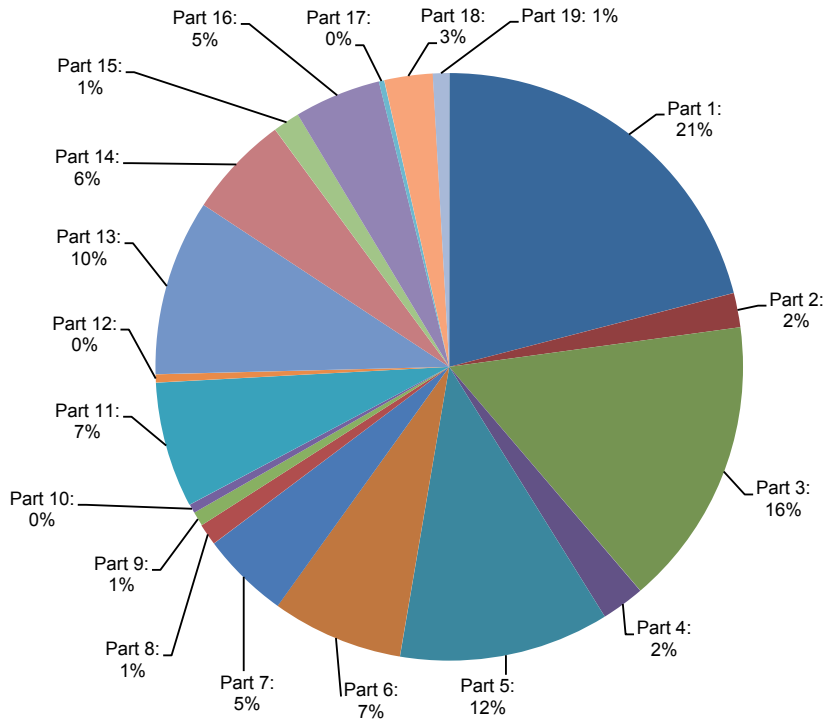


Figure 3: The percentage of environmental impact from each part of the first-generation design

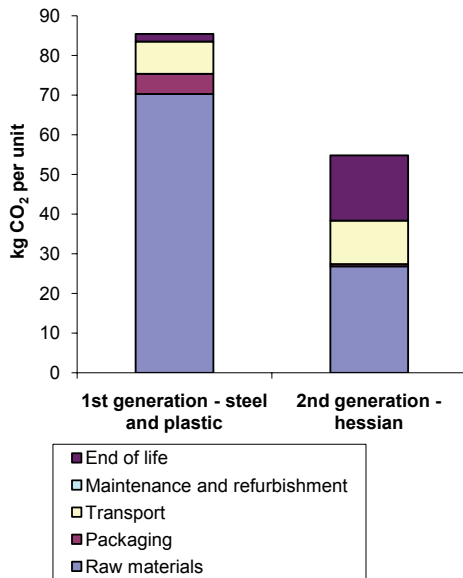


Figure 4: Amount of CO₂ (kg of CO₂) generated for the whole life-cycle of the two designs

PUBLICATIONS/RESEARCH OUTPUT

LIST will be available in March 2011; interested parties should contact Flavie Lowres, BRE, for further details (see contact details in box opposite).

More information about the findings of this research project are given in BRE Information Paper IP 1/11 *LIST (Low Impact Shopfitting Tool) for designing sustainable shopfitting display equipment*.



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- [2] For further information on LCA and the BRE Global Environmental Profile Methodology, see www.thegreenguide.org.uk

For further information, contact Flavie Lowres, Tel: 01923 664560, Email: lowresf@bre.co.uk

GREEN IT

Christopher Anastasi

Information Systems, BRE

SUMMARY

There is no doubt that the effects of climate change are influencing every facet of our daily lives. However, it has only recently become apparent that our growing reliance on Information Technology (IT) and allied systems are also adversely contributing to the change. Closely aligned to this is the built environment which predominantly provides the main container for these technologies.

The purpose of this project is to introduce the concepts aligned to making IT more sustainable, otherwise more commonly referred to as 'green IT'.

BACKGROUND

Use of the term 'green IT' often refers to attempts to reduce the environmental impact of computer operations. This can take the guise of numerous initiatives from hardware and software design to government regulation and corporate sponsored initiatives. Often, these activities are encompassed within a bespoke 'green IT policy' created by an organisation to help drive their green IT agenda. One of the earliest, most widely considered influencing examples of green IT was the 'energy star' programme launched by the US Environmental Protection Agency in 1992. Since then, a global 'green IT' economy has blossomed as it has become clear that simply designing a piece of hardware or software in isolation to run more efficiently is no longer the only course of action, if anything it could contribute adversely to the environment^[1,2].

A green IT policy outlines a strategy for reducing the environmental impact of the given IT infrastructure, by way of a series of commonly used tools. These include (but are not limited to):

- energy-efficient hardware
- responsible sourcing and disposal
- reviewing data centre design and cooling
- power management
- the practice of combining several servers into one (often referred to as virtualisation).

Figure 1 provides an example of an energy-efficient blade server array. Just one of these single-blade servers has replaced the whole bank of traditional servers featured in the inset.

RESEARCH PROGRAMME

The aim of this research was to examine the key issues affecting the green IT agenda. The methodology included a literature review of relevant regulations, tools and methodologies for reducing CO₂e and techniques for managing processes aligned to green IT. At present, it is



Figure 1: Example of an energy-efficient blade server array. One of these single-blade servers has replaced a bank of traditional servers (see inset, bottom right of photo)

seen as an unregulated part of building CO₂ emissions and therefore lacks accountability.

PROJECT OUTCOMES/CONCLUSIONS

Undoubtedly, any facet of IT advances quickly, and green IT is no exception. We are already witnessing a maturation of ideas and green IT tools commonly known to help lower the energy usage of information systems technology such as virtualization and energy-efficient hardware^[3].

Unfortunately, due to the lucrative nature of the IT industry, there is a vast presence of vendor marketing that can cloud long-term sustainability issues. These issues should ultimately seek to go beyond the current references to green IT, which inevitably involve the unsustainable and bloated perpetual IT life-cycle of yet more hardware, licensing, maintenance, software and training. Such examples include:

- promotion of LCD monitors over traditional CRT, without taking into account any embodied emissions associated with the whole process of the manufacture and distribution of an LCD screen
- promotion of mobile phones as a home/remote working tool to help limit the carbon impact of a conventional office commute/environment when in fact global mobile phone usage runs at a staggering 125 million tons of CO₂e a year^[4].

Moreover, green IT concepts must mature beyond merely being seen as a cost-cutting exercise (or a lowering of corporate carbon footprint), as by its very existence it should be logically recognised that IT can never truly be green^[5]. It is the processes by which organisations currently underpin IT that require revision such as:

- making network protocols run more efficiently^[6],
- preventing bloating of software (ie re-use of existing computer code to create 'recycled' software^[7],
- creating new ingenious methods for remotely backing up an organisation's data^[8]
- helping to finance more research into making WiFi networks function more effectively^[9].

Along with these independent, objective advances in green IT technology, we should be aware that ultimately it is we who need to be developed and to have our behaviour changed, not IT systems, if we do not wish to become a part of what has been termed the Icarus paradox*^[10].

A shared responsibility by both organisational leaders and their IT compatriots is required as ultimately IT is about people and the built environment in which it ultimately co-exists. When considering green IT, merely looking at data centres and IT architecture in isolation is only looking at one small part of the cog in what is a complex set of intertwined relationships (Figure 2). Further clarity and tools are required on how we measure the unregulated components of CO₂ which are created by IT infrastructures within this built environment.

RESEARCH OUTPUT

More information about the findings of this research project will be given in a BRE Information Paper which will be published by IHS BRE Press in 2011.

REFERENCES

- [1] University of Calgary. IT not so green. Article available at www.ucalgary.ca/news/utoday/feb24-09/ITnotgreen. Accessed on 31 January 2011
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* **The Icarus paradox** makes reference to the fabled character 'Icarus' in Greek mythology who over-confidently flew too close to the sun causing the wax on his artificial wings to melt. Similarly, advances in technology are a mirror of this unreserved over-confidence: effectively, an exaggerated over-reliance across the whole IT system value chain on resource-intensive technological assets and ideologies.

Figure 4

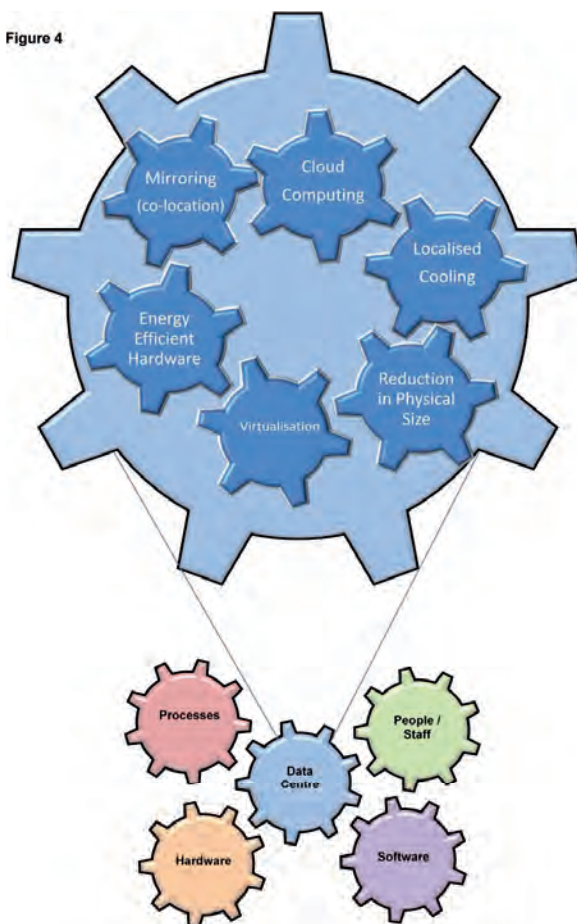


Figure 2: Green IT is a complex set of intertwined relationships

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BUILDING THE FUTURE

Martin Brocklesby

BRE Wales

SUMMARY

The Royal Society of Architects in Wales wish to create a certification scheme that their members can gain through a process called Environmental Professional Development (EPD) and that clients can ask for to ensure expertise in environmental matters when employing an architect. To this end, RSAW approached BRE Wales to assist with the project generally and, more specifically, to create a training programme covering a set syllabus that would enable candidates to pass an examination at the end of the programme.

BACKGROUND

With the increasing importance of environmental issues in construction, all those involved in the construction process should be fully informed of the issues. This is especially true for architects so the Royal Society for Architects in Wales (RSAW) wished to address this by setting up a certification scheme covering environmental issues. They asked for assistance from BRE Wales who sought funding from the BRE Trust to enable the provision of suitable training material. In addition to the involvement of BRE, RSAW approached the University of Wales Institute Cardiff (UWIC) to set and administer an exam covering the syllabus. RSAW planned to be responsible for administering the course and maintaining a register (or similar) of those who have gained the qualification.

RESEARCH PROGRAMME

The aim of this research project was to produce a modular training programme and to advise on a final exam.

The requirements for the scheme were that:

- the knowledge required to pass the exam should be at a level at which a well-informed architect who has kept up-to-date on environmental issues could pass without any supplementary training (the training element was therefore not to be mandatory)
- candidates should be able to undertake only the modules that they specifically as individuals required to pass the exam, rather than all the modules.

The concept is illustrated in Figure 1, where the bell curve represents the current level of 'environmental knowledge' of architects as a group and the red line represents the approximate level at which the exam would be pitched.

This is obviously an idealised and theoretical graph, since 'environmental knowledge' is not a simple single identifiable number and would in any case vary with different subjects within the syllabus. Additionally, the

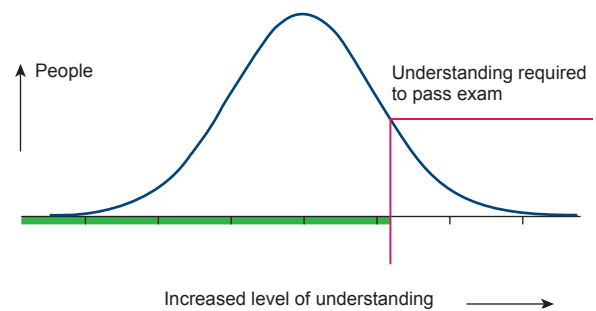


Figure 1: Idealised current understanding and pass mark

standard deviation of the bell curve is not known. The diagram also illustrates the issue of how to pitch the training materials; any given candidate might have a level of knowledge ranging from novice to expert. The modules would need to be designed to provide useful and comprehensible information to the full range of candidates. A candidate just to the left of the pass line might only need a small amount of teaching, while someone at the far right should already understand all the issues.

In addition to the requirements listed above, the coursework generated would have to mediate between other factors that are sometimes in direct conflict, for example quality and cost. There was a requirement to provide:

- a high quality package of training and examination that is perceived to have value:
 - within the architectural community (architects must want to gain the qualification)
 - by other construction professionals (ie the qualification must be perceived to have merit and gravitas and to be of value to potential clients)
- the cost and time requirement to undertake the coursework and exam should not be excessive (the

costs for candidates would comprise both direct costs [eg tuition fees, travel cost, etc.] and indirect costs [time not spent working on paid projects]).

BRE Wales would also be involved in assisting UWIC and RSAW with the development of the exam because the exam would need to cover all the areas that the coursework modules covered, otherwise there would be no incentive for candidates to undertake the training programme.

RESEARCH OUTPUT

The materials and exam have been developed and a full-scale trial was held during a 4-day training event in March and April 2010. The deployment of the training modules was broadly successful, although weaknesses in individual modules were noted.

The training material which has been developed covers environmental issues in the modules listed in Box 1.

The RSAW has requested the addition of BREEAM Accredited Professional certification to secure their ongoing support.

PROJECT OUTCOMES/CONCLUSIONS

The project was successful in that the required training materials have been developed and delivered. It is hoped that the programme will eventually be adopted by RSAW.

*For further information, contact Martin Brocklesby,
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Box 1: Modules in the training programme

- Production of energy
- Renewable energy
- Life-cycle assessment
- The basic principles of a low-impact design
- Environmental and building physics
- Zero carbon
- Carbon offsetting
- Passive house and Passiv Haus
- Modern methods of construction and collaborative working
- Water and sewage
- On-site issues and waste issues
- In-use and post-occupancy evaluation
- Refurbishment of buildings
- Very low-impact design, eg straw bale, earth wall, etc.
- Planning issues/TAN22/MIPPS
- Accreditation schemes:
 - BREEAM
 - CSH
- Accreditation tools:
 - SAP
 - The Green Guide

BRE CENTRE OF EXCELLENCE IN 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 in improving interactions between people and the built environment. The aim is to develop a better understanding of how people perceive, experience and operate the built environment and relevant technologies so that we can develop design tools and create a built environment that enhances people's lives and simultaneously reduces our impact on natural systems. Research carried out in SuDoBE recognises the need for a holistic approach to sustainable design, embracing social and economic aspects of sustainability as well as environmental concerns. The underlying premise is that if we are to reduce carbon dioxide emissions and reliance on energy consumption then it will require imagination to develop solutions that will persuade people to abandon the 'business as usual' attitude.

During the past year, the Centre has built on its previous funding successes by developing a portfolio of inter-related research projects. Many of the current projects involve monitoring energy consumption and environmental conditions, recognising the need to understand what happens in real buildings rather than relying solely on desk-based studies.

ENVIRONMENTAL AND ENERGY MONITORING

As part of the EPSRC/E.ON-funded project, *Carbon, control and comfort: user-centred control systems for comfort, carbon saving and energy management*, researchers in the Centre have been monitoring the environmental conditions and energy consumption in nine dwellings in the Merthyr Tydfil and Pontypool areas. The aim of this work is to establish how people create and maintain conditions they deem to be comfortable and to investigate the consequences of this on energy use. The hypothesis is that people will often seek thermal conditions that depart significantly from the received wisdom on thermal comfort. If we are to make progress on reducing carbon emissions resulting from heating in

homes, we need to understand the perceptions of those who live in those homes and determine their energy use.

Early results for this work are summarised in Figure 1 and show that there is a significant variation across the dwellings during the heating season and that there is a clear rise in temperatures in living rooms in December (Figure 1a), just as the external air temperature is decreasing. There is an even greater variation in the average bedroom temperatures as shown in Figure 1b.

COMFORT SURVEYS

In parallel with the environmental and energy monitoring, the researchers in Cardiff have been conducting comfort surveys using a novel method for linking reported comfort perceptions to the measured physical data. Part of the information sheet used in these telephone surveys is shown in Figure 2.

In the next phase of this research, the project team will introduce a series of designed interventions to see if these alter the occupants' energy and environmental behaviour.

SUSTAINABLE REFURBISHMENT OF BUILDING FAÇADES AND EXTERNAL WALLS

Monitoring is central to another current project funded under the European Framework Programme 7 (FP7). *Sustainable refurbishment of building façades and external walls* (SUSREF) is investigating strategies for refurbishing external walls and façades to improve their energy performance and sustainability. The main role for SuDoBE is to model, monitor and analyse the hygrothermal behaviour of thick stone walls in the extreme climate of North West Wales, which experiences high driving rain indices. Many such buildings require a sensitive approach to refurbishment to avoid upsetting the delicate distribution of heat and moisture that protects the construction from biodegradation and frost damage. Many are listed buildings and therefore not amenable to 'standard' solutions.

Refurbishment poses greater challenges for buildings on the western fringe of Europe where they are exposed to the persistent moisture-laden winds off the Atlantic Ocean. The research will involve intensive physical monitoring of existing properties before and after different

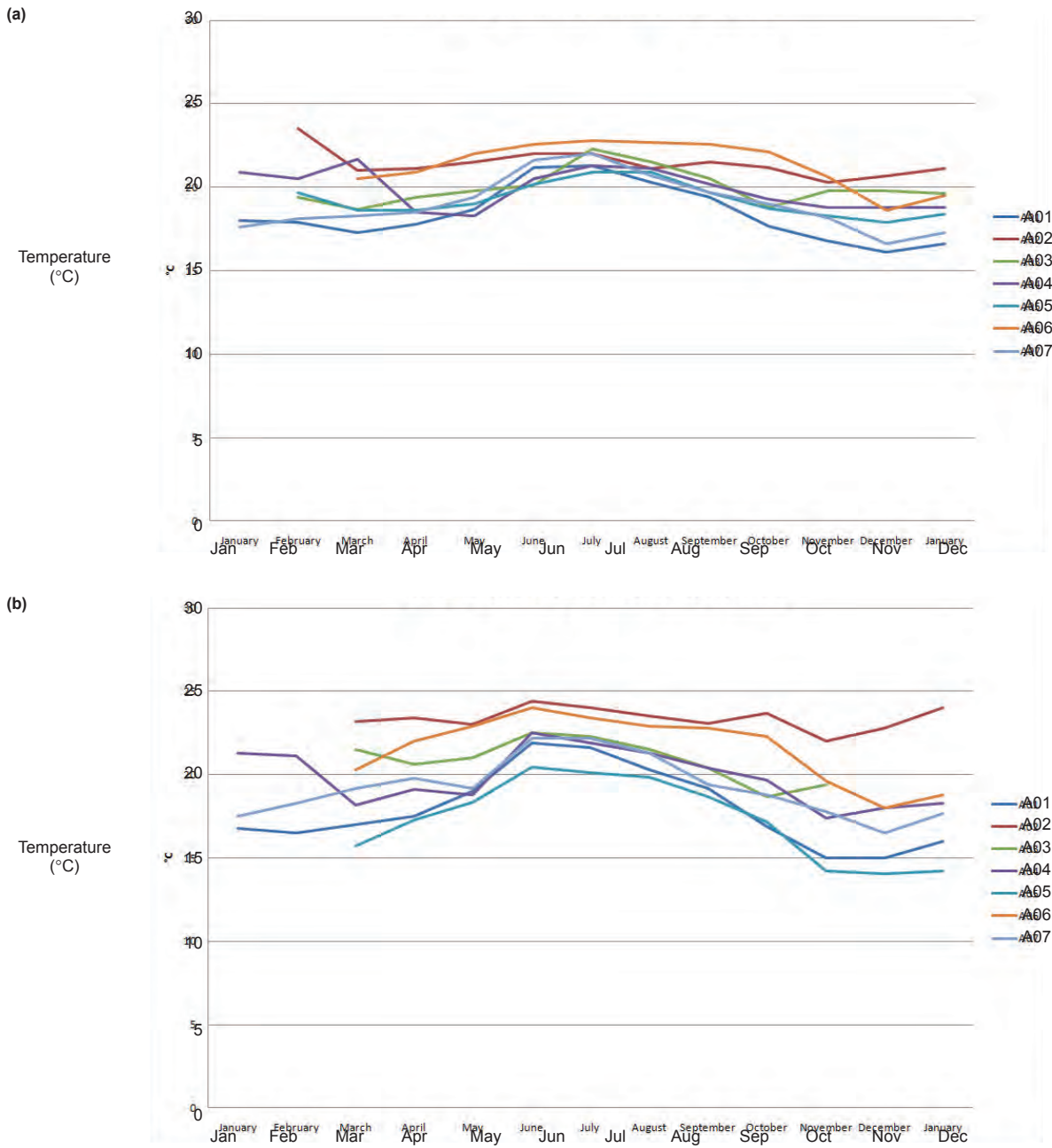


Figure 1: Average monthly temperatures in seven dwellings in Merthyr Tydfil area: (a) living rooms, (b) bedrooms

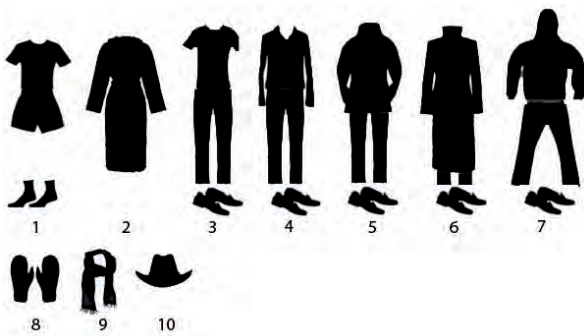


Figure 2: Graphic representations of different clothing levels depicted on the information sheet given to occupants for use during the telephone comfort surveys. The clothing insulation values (clo) increase as the numbers ascend.



Figure 3: Setting up the hygrothermal monitoring of a thick stone wall in North Wales

treatments are applied. The treatments will include both breathable and non-breathable constructions. Figure 3 shows the current monitoring equipment being tested in the Moelyci Environmental Centre. The UK team on this project includes BRE Wales and Sustainable Gwynedd Gynladwy.

RETROFIT FOR THE FUTURE

The Centre has been successful in securing funding from the Technology Strategy Board's (TSB) competition: *Retrofit for the future*. Researchers in the Centre have been working alongside other colleagues in the Welsh School of Architecture on the retrofit of an end-of-terrace property in Newport. The refurbishment has been completed and the Centre has been involved in gathering the householders' views on the new environmental conditions, energy consumption and the process of retrofitting, as well as the views of different members of the research and retrofit teams.

BUILDING PERFORMANCE EVALUATION

More recently, the Centre has been successful in securing funding from the TSB's competition: *Building performance evaluation* and has been contracted to assess the performance of two Passivhaus designs in Wales under this programme (Figure 4). The monitoring includes physical measurement, such as co-heating and disaggregated energy consumption monitoring, as well as post-occupancy evaluation. The project began with a design review. The Centre's main interest in this work is that it will allow us to examine the performance of this new standard for low-energy buildings and develop suitable monitoring protocols for this type of building.



Figure 4: One of two Passivhaus designs being monitored under the TSB *Building performance evaluation* programme

LOW-CARBON BUILT ENVIRONMENT PROJECT

The development of monitoring strategies and protocols is the subject of a further funded programme, which is part of the *Low-carbon built environment (LCBE) project* funded by the Low Carbon Research Institute (LCRI) based in the Welsh School of Architecture. The aim of this research is to take a broad view of performance evaluation to inform the development of new monitoring methods and tools. This is particularly relevant at a time when there are many new 'low-carbon' products being launched. It is important to know how to assess the performance of these in practice if we are to achieve the necessary carbon emissions reductions and develop the best components in the UK. The research will address issues of building performance in design, construction and operation (Figure 5).

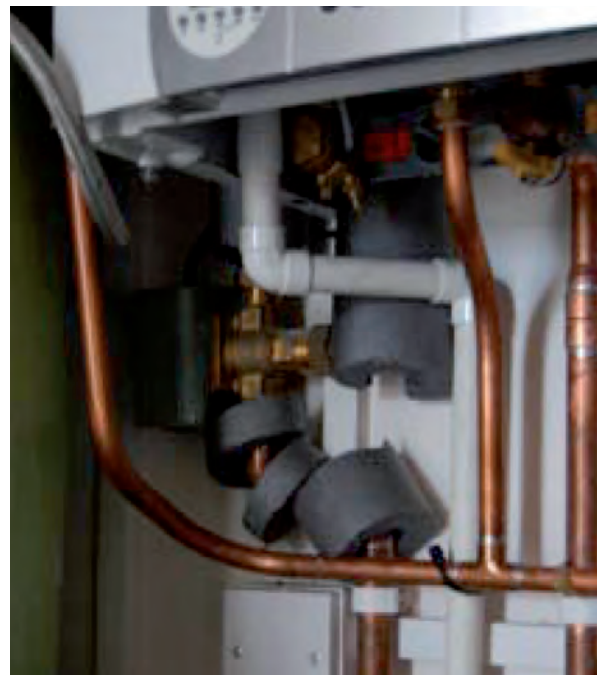


Figure 5: New technologies require new skills and understanding. The success of low-carbon designs may rest on attention to critical details such as the proper lagging of pipes

ENERGY CONSUMPTION AND BEHAVIOUR IN THE ELDERLY

As reported last year, the Centre submitted an application along with universities in Manchester, Lancaster and Exeter to investigate the relationships between energy consumption and behaviour among older people. This funding application to EPSRC and EDF has been successful and the project, *Conditioning demand: older people, diversity and thermal experience*, started in January 2011. The research will examine the diversity of behaviour in the pursuit of different thermal experiences among older people with particular reference to emerging low-carbon heating technologies, such as heat pumps.

LOW-CARBON INITIATIVES ON AN URBAN SCALE

The Centre is also involved in another successful proposal to EPSRC, funded under the Sustainable Urban Environments programme. This new project is investigating transition processes leading towards low-carbon scenarios on an urban scale. The Centre is investigating the logistics involved in retrofitting an entire town or city in partnership with BRE Wales, using Wales's first low-carbon town, Aberdare, as a case study.

BRE TRUST FUNDED PhD PROJECTS

The School of Architecture has three active studentships from the BRE Trust:

- Understanding the impact of occupant behaviour on energy consumption within existing homes
Shiyu Jiang

- Learning from low-carbon design: designing and constructing buildings to emerging standards
Gabriela Zapata
- Developing effective strategies for design interventions to improve sustainability in existing urban communities
Kate Knowles

In all cases, these connect with projects that are either underway or about to begin in collaboration with BRE. The research, therefore, should benefit from, and contribute to, a synergy that will strengthen ties between the Centre and BRE. They further define the central theme of SuDoBE research which aims to address the interface between people and built environment technologies.

CONTROLLABILITY OF LOW-ENERGY BUILDINGS

The Centre is working with the BRE University Centres of Excellence in Bath and Strathclyde to develop a new research proposal on the controllability of low-energy buildings. We expect to submit this for funding later this year.

*For further information on any of these projects or the article to follow, contact Professor Christopher Tweed,
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DESIGN



FLOOD-RESILIENT PLANNING AND BUILDING

Stephen L Garvin

BRE Scotland

SUMMARY

This training programme addresses the main issues for flood-resilient planning and building in the UK. The two-day course has been especially structured and developed to guide delegates through legislation, planning requirements, building standards, new build issues and repair of existing buildings to increase resilience. The course includes interactive presentation sessions and group working through set exercises. At the end of the course, delegates will:

- be able to identify the key issues
- understand planning and building standards requirements for flood resilience
- be able to articulate the main issues regarding new buildings and existing buildings
- have awareness of emerging issues.

The course is of interest to a range of professionals in the construction industry and the flood management field.

BACKGROUND

The Pitt Report (June 2008)^[1] highlighted the lessons learned from the floods in summer 2007 and the need to develop guidance and build capacity in the stakeholders involved. For example, Pitt recommended that building regulations be developed for new and existing buildings relevant to flood resilience.

The planning legislative framework under which various UK agencies involved in urban flood-risk management operates is complex. Separate pieces of legislation govern the activities of the environment agencies, sewage undertakers, planners and the construction industry responsible for resilience measures. Development control and planning policy are fundamental to flood risk management and the UK Government has sought to strengthen planning guidance on flood risk in Planning Policy Statement 25 (PPS25)^[2] for England & Wales and Scottish Planning Policy 7^[3] for Scotland and its accompanying good practice guide. PPS25 promotes a strategic approach, ensuring that flood risk is considered at all stages of the planning process and strengthening the importance of flood risk assessments in supporting that analysis.

Historically, flood-risk management has mainly concentrated on river and coastal flooding. Pluvial flooding is primarily the result of run-off exceeding the drainage capacity during short, intense periods of heavy rainfall, typically summer thunderstorms. Over the years, flooding and flood-risk management are becoming increasingly important issues. The impacts of severe events will be felt by an increasing number of the



Figure 1: Flood-resilient floating homes in The Netherlands

population and therefore the cost of associated damage increases dramatically.

At the centre of any flood risk strategy is the fact that flooding, as a natural event, cannot always be predicted or prevented. The effects of climate change may make the occurrence of extreme weather events and sea level rise more likely, however it is difficult to give any guarantee that the impact of flooding will be managed and minimised effectively. This has led to the development of flood-risk management strategies that have been developed in both the UK and beyond.

RESEARCH PROGRAMME

BRE undertook a research and development project under the BRE Trust's research programme on flood-resilient planning and building. The aim of this project was to use the results of recent research to develop state-of-the-art training for decision-makers and practitioners, particularly those in the planning, construction and environmental regulation areas.

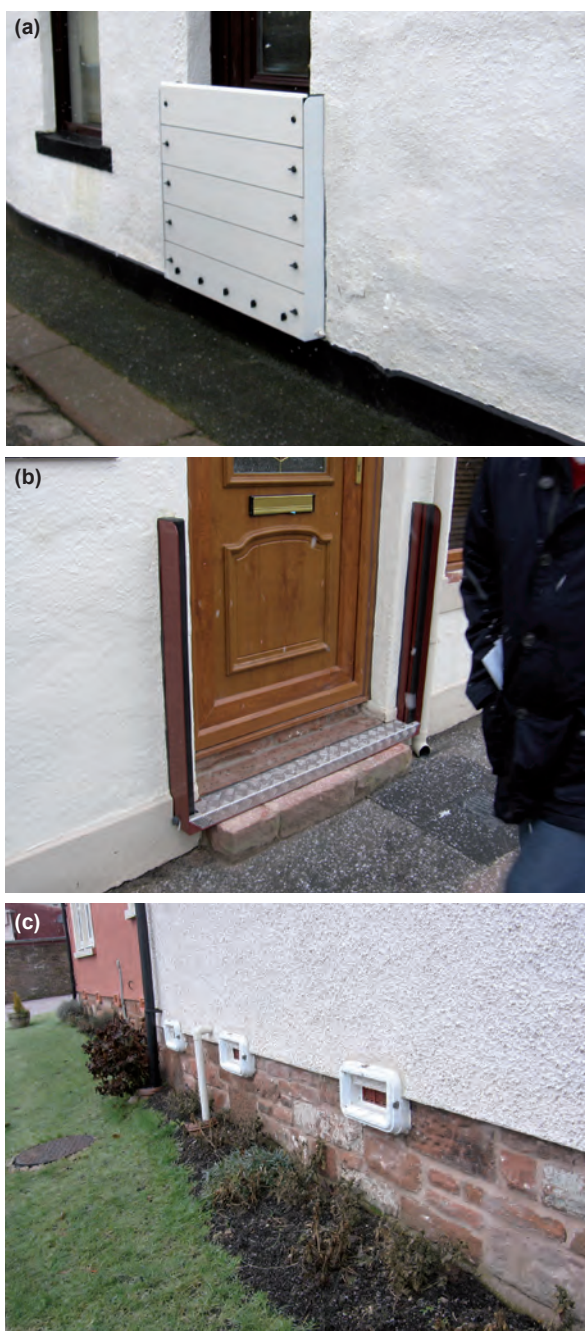


Figure 2: Flood resilience measures: (a) flood board for a window, (b) frame for a flood board, (c) frames for airbricks

The following specific objectives were addressed in this research.

- *Objective 1:* To undertake a desk-based review of recent research, current legislation and regulation and state-of-the-art guidance.
- *Objective 2:* To develop the training seminar series on flood-resilient planning and building; this may result in one or more training options for different groups of stakeholders.
- *Objective 3:* To deliver three pilot training seminars for key decision-makers and practitioners.

PROJECT OUTCOMES/CONCLUSIONS

BRE has developed a training course on flood-resilient planning and building. The course addresses the issues that arise from the increasing risks from flooding in the UK, and indeed in other countries. Increasing urbanisation, development of marginal areas and climate all contribute to a likely increase in flood events in the UK. Climate change has the potential to increase not only the frequency of flooding, but also to increase the exposure of the building stock.

The delegates to the training courses have included regulators (the Environment Agency), central government (DCLG and Defra), builders, contractors and insurers. This group plus local authorities are liable to form the main target group for the training courses held in the future.

PUBLICATIONS/RESEARCH OUTPUT

The training is now being supported by a publication which is being produced on flood-resilient building with funding from BRE Trust and is expected to be published by IHS BRE Press in early 2012.

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MEASURING THE IMPACT OF INNOVATION ON THE CONSTRUCTION PROCESS:

Learning from the BRE Innovation Park

Paul Cartwright

Housing Group, BRE

SUMMARY

Innovation in the construction process is as important as innovation in construction products. Innovation in new products is critical but the way products are put together on site is as critical to ensure that a building can be delivered on time and to the required budget. The BRE Innovation Park at Watford showcases a wide range of innovations in individual products as well as whole house construction systems. This applied research examined the impact on the construction process of using different products and systems. Speed of build and improved efficiency of the process are two of the selling points for using innovative products and systems such as modern methods of construction. This applied research project measured the superstructure construction of three different systems on the Innovation Park to examine construction efficiency and speed of build.

BACKGROUND

Measurement of construction processes is critical to understanding how the process is performing. However, due to the other demands of managing a construction site, measurement is often not done in the detail that can quantify the process and identify where inefficiencies in the process are occurring and what the actual speed of build is.

The downturn in the economy in the past few years and the recently announced spending cuts means that efficiency is of increasing importance in the delivery of buildings. Although private house building has slowed considerably affordable housing is still required and many new homes need to be delivered but at a lower cost.

A number of studies have been done over the years to investigate the impact of modern methods of construction including offsite construction systems. However, the studies often lack the quantitative data that is necessary to provide a strong evidence base. The SmartLIFE project, completed in 2008, provided an opportunity to compare four different construction methods against efficiency, speed of build and construction waste on real-life housing developments^[1].

This project has provided an opportunity to examine three further construction methods but only on single demonstration units during their construction on the BRE Innovation Park at Watford:



Figure 1: Demonstration units on the BRE Innovation Park, Watford: (a) clay block system superstructure for the Natural House, (b) insulating concrete formwork superstructure for the Creo House



Figure 2: Pouring concrete for the external wall of the Creo House

- the Creo House, using an insulating concrete formwork system
- the Natural House, using a clay block system
- the Cub House, using a modular steel system.

Measurements were taken during the external wall construction of each unit.

RESEARCH PROGRAMME

The objective of this project was to measure the construction process for the different methods and measure construction efficiency and productivity.

BRE's CALIBRE and SMARTAudit tools are real-time measurement tools using the latest handheld and web-based technology to collect and synchronise data with a web-based database that allows for analysis of data within minutes of collecting it. The CALIBRE tool uses an activity sampling methodology to measure:

- where work is being carried out on site
- what work is being carried out (work packages and tasks)
- how efficiently time is utilised (recording delays, work repetition or double handling)
- how much waste is being generated.

While CALIBRE measures time 'waste', SMARTAudit measures material waste. The tool measures the volumes of different wastes generated on site, who generates the waste, the specific waste package and the cause of the waste generated.

The construction processes were measured during the superstructure construction phases of each development. This provided an opportunity to compare the processes for each of the different building fabrics. The data collected was analysed using the analysis software as well as using additional analysis to compare methods. The data is disseminated through charts showing how resources have been used including resource profiles and efficiency charts.



Figure 3: Collecting data on site using the CALIBRE tool

RESULTS

All houses constructed had a high proportion of non-added-value time of between 13% and 17%. This compares with between 10% and 12% for established systems. Supply chain and design issues had an impact on construction efficiency. The supply chain issues included delays to materials arriving on site and working on sites with difficult access.

Design issues had a major impact on the Creo House and Natural House. The Creo House system, designed to be a fast-build system, required additional components in the process including shuttering and reinforcement, that made the process resource-intensive. The Natural House required structural steel work to be incorporated in the aerated clay block structure.

The modular system was the most straightforward system with regard to process as most of the efficiency issues that are associated with trade interfaces are tackled in the factory. However, non-added-value time was high proportionally during construction due to waiting times between module lifts.

All systems measured have scope for improvement in the construction process to allow them to become more effective when going to scale. The use of the Innovation Park has allowed the project teams to test their products and processes in a controlled environment and take forward improvements to their live developments. Measuring the processes on larger scale projects would allow for benchmarking of performance and specific issues to be quantified to assist with deciding on where improvements to the process would be most valuable.

PROJECT OUTCOMES/CONCLUSIONS

The three systems measured are very different and this was reflected in the results. The key findings were:

- Although, some of the products were intended to deliver improvements in speed of build and efficiency, a number of process innovations are still required to ensure these benefits can be realised. Product developers need to ensure that the buildability and site process issues are integral to the product design process.
- The fastest on-site method was the steel modular system, followed by the clay block system and the insulating concrete formwork system.
- The efficiencies of the construction processes on site were lower than larger developments because of the learning curve involved during the process, including:
 - design
 - use of innovative products
 - supply chain issues.

PUBLICATIONS/RESEARCH OUTPUT

More information about the measurement process and the findings are provided in a case study downloadable from the BRE web site at www.bre.co.uk/page.jsp?id=360

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BRE CENTRE OF EXCELLENCE IN SUSTAINABLE ENGINEERING, CARDIFF UNIVERSITY

Yacine Rezgui

Professor, Sustainable Engineering

The vision of the BRE Centre of Excellence in Sustainable Engineering is to pave the way to a new generation of digital buildings that have lifelong resilience and adaptability to their environment, usage and occupancy, enabled by:

- smart materials and products
- integrated design and manufacturing systems
- total life-cycle approaches.

The following research challenges underpin our vision and approach.

- How do we confer optimum resilience, sustainability, and continual fitness for purpose on our existing building stock?
- How do we deliver new or refurbished human-centric buildings that address lifetime requirements and that are capable of performing optimally within the constraints of unknown future scenarios?

The central and foundational principles which respond to these two challenges are adaptability and resilience.

In essence, buildings should have the ability to be context-aware, ie factor in environmental and occupancy (user needs, behaviour and lifestyle patterns) aspects, and thus be adaptive to change. There is a need to re-think the concept of a building and move from traditional 'low-value' components towards extended IT-aware materials and products embedding various forms of 'intelligence'.

The complementary expertise of our academic staff and researchers spans six main research themes:

- *Smart materials and products*
Material and structural performance enhancement to different combinations of specifications and the development of novel materials with embedded resilience

- *Virtual manufacturing and supply chain management*
Design and manufacturing business models that promote sustainable and total life-cycle integrated product development approaches
- *Building intelligence*
Design and deployment of digital technologies to support stakeholders' activities and knowledge needs across the life-cycle of a building project
- *Building resilience*
How risk management and built environmental protection can be integrated into design and construction sustainability principles and approaches
- *Energy and sustainability*
Management of energy in buildings with a view to delivering lifelong sustainable facilities
- *Comfort, health and well-being*
Comfort conditions of occupants and socio-technical aspects that underpin user interaction with buildings and building systems via digital interfaces

The concept of a dynamic and self-updatable digital conceptualization of a building, that fully exploits latest advances in ICT (including pervasive sensing technologies) is central to the Centre's vision. These digital technologies will help maintain a dynamic representation of a building necessary to provide real-time building performance (including energetic) accounts, while ensuring the building has lifelong adaptability to its usage and environment.

More information can be found at:
www.engin.cf.ac.uk/research/resInstitute.asp?InstNo=16

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SUSTAINABLE CONSTRUCTION SERVICE PLATFORM: The 'SCriPt' Project

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SUMMARY

SCriPt aims at developing a one-stop-shop experience on sustainable construction aimed at stakeholders across the construction supply chain. This knowledge portal is service-based and underpinned by a low-carbon ontology, providing access to relevant knowledge resources and tools to assist designers and other stakeholders in the delivery of sustainable interventions.

BACKGROUND

The SCriPt project (funded by the Welsh Assembly Government (WAG)/A4B) is a collaborative industrial initiative of 30 months' duration (commenced 1 January 2010) conducted by Cardiff School of Engineering, Cardiff University, in association with BRE Wales and Constructing Excellence in Wales.

Wales is required to meet EU commitments relating to reducing greenhouse gas emissions by at least 80% below 1990 levels by 2050^[1], and the WAG aspiration for zero carbon for new buildings^[2] is earlier than proposed in the rest of the UK. Sustainable construction is a multidisciplinary, complex subject, exacerbated by the existence of a variety of overlapping and fragmented knowledge resources in the form of, and embedded in, text documents, spreadsheets, drawings, images, video, databases (eg product libraries), etc. A recent feasibility study^[3] at the Cardiff School of Engineering indicated a need for a centralised, authoritative resource for information and knowledge-sharing.

RESEARCH PROGRAMME

Objectives

SCriPt therefore aims to create an advanced, web-based (Web 2.0 enabled) 'one-stop-shop' that will pave the way to better educated, more engaged and energy-responsible/responsive building professionals and citizens. This aim translates into the following measurable objectives:

- consolidate and develop industry consensus around the requirements for the proposed Platform
- deliver a comprehensive and dynamic low-carbon knowledge base that underpins SCriPt.

- specify value-added services that exploit the low-carbon knowledge base, including low-carbon, third-party services and low-carbon tools
- implement, deliver, and deploy SCriPt using web services' architecture
- test and validate the SCriPt solution
- ensure wide adoption of SCriPt by building professionals (including SMEs), through capacity building and low-carbon, awareness-raising initiatives.

Methodology

The project plan takes an iterative and incremental development approach, which involves continuous industry consultation across the entire built environment supply chain, including regular workshops and one-to-one meetings. It is imperative for the ultimate success of the platform that stakeholders are involved throughout. Historically, the low take-up of advanced information and communication technology solutions for knowledge management (KM) and information sharing in construction has been in part due to issues including overlooking the social dimension of KM and the lack of awareness about value in sharing knowledge and expertise^[4,5].

Conceptual framework

The underlying principle of SCriPt is to federate sustainable construction resources (including knowledge, expertise, best practice, and software tools and applications; Figure 1). The Sustainable Building Portal led by the Wales Low/Zero Carbon Hub will be used as a starting point, enhanced by the integration and delivery of user-friendly, value-adding services that exploit the

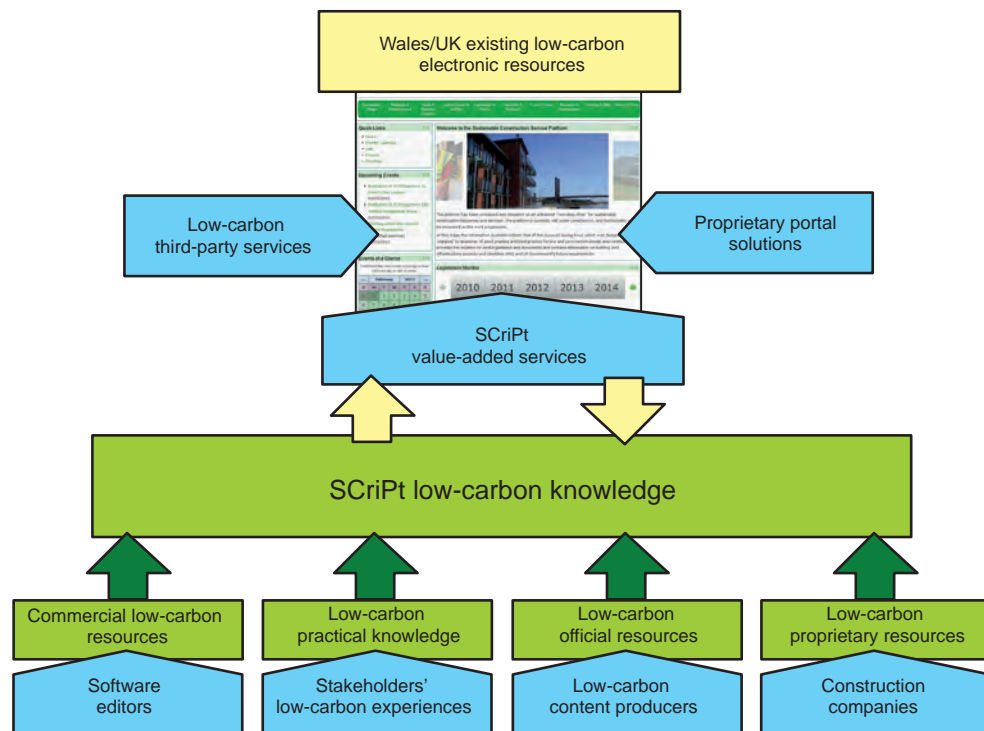


Figure 1: SCriPt conceptual framework

wealth of low-carbon knowledge embedded in these resources. Low-carbon knowledge exists and originates from different sources:

- *Official resources*: publicly available information which is, in principle, available to all companies, and is partly stored in electronic databases.
- *Proprietary resources*: company-specific information that may form the intellectual capital of construction firms. It resides both formally in company records and informally through the skilled processes of the organisation.
- *Practical knowledge*: knowledge acquired by individuals drawing from the preceding sources; it is mostly in tacit form, and where codified it mainly resides within users' computers, and hence is not shared by others.
- *Commercial resources*: this knowledge is formalised and conceptualised by software vendors through their commercial offering. This can only be accessible through the functionality exposed via their software.

Existing services co-exist as several low-carbon (related) solutions:

- *Low-carbon third-party services*: commercial low-carbon and building energy calculation tools (including energy-compliance tools). These services are used to access the above listed *commercial resources*.
- *Proprietary portal solutions*: corporate portals developed by SMEs and large construction companies with a view to maintaining their own corporate knowledge. Such portals are used to manage the above listed *proprietary resources*.

RESULTS TO DATE

The research results to date indicate that the problems faced in the built environment sector with respect to sustainable construction are not merely a KM issue; there is also an imperative for behaviour change. The proposed platform should provide not only information and low-carbon tools, but also include a dynamic interface to sophisticated functionalities including:

- user profiling
- smart search facilities based on a shared sustainability vocabulary (ontology)
- tailored news services
- bi-directional channels for information sharing
- CPD facilities.

The initial prototype platform has now been created and is accessible at www.sustainablebuildingportal.co.uk.

Figure 2 shows a screenshot of the prototype home page.

The potential scope for the platform is huge, therefore the initial developments have focused on dynamic elements such as news and events services, and provision of basic networking technologies (wiki and forums); the information originally provided on the sustainable building portal has also been migrated to the SCriPt platform prototype. It also includes functionality for users to create their own account, which via the initial user profiling functionality allows users to personalise their own SCriPt platform according to their discipline, interests, and other preferences.

SCRiPt
Sustainable Construction Service Platform

Search:

My SCRiPt / Create account / Why register?

Sustainable Design | Buildings & Infrastructure | Costs & Financial Support | Guides Codes & Articles | Legislation & Policy | Materials & Products | Project Team | Research & Development | Training & Skills | Wales LZC Hub

Quick Links [+]

- News
- Events Calendar
- Wiki
- Forums
- Site Map

Upcoming Events [+]

- Institution of Civil Engineers St. David's Day Lecture
01/03/2011
- Institution of Civil Engineers G&S Written Assignment Group
01/03/2011
- Working within the revised Waste Regulations (Breakfast seminar)
02/03/2011

Events at a Glance [+]

Underlined dates have events occurring on them. Click on a day to view its events.

February							2011						
S	M	T	W	T	F	S	S	M	T	W	T	F	S
30	31	1	2	3	4	5							
6	7	8	9	10	11	12							
13	14	15	16	17	18	19							
20	21	22	23	<u>24</u>	25	26							
27	<u>28</u>	1	2	3	4	5							

Welcome to the Sustainable Construction Service Platform [+]

The platform has been conceived and designed as an advanced "one-stop-shop" for sustainable construction resources and services. The platform is currently still under construction, and functionality will be increased as the work progresses.

At this stage the information available reflects that of the *Sustainable Building Portal*, which was designed as a 'signpost' to examples of good practice and best practice for low and zero carbon design and construction. It provides the location for useful guidance and documents and contains information on building and infrastructure projects and identifies WAG and UK Government's future requirements.

Legislation Monitor [+]

2010 | 2011 | 2012 | 2013 | 2014

2010 Regulations & Requirements

Feed-in tariffs for small scale renewable energy systems will apply from 1st April 2010. Figures published.
UK changes to the Building Regulations will also apply in Wales.

Figure 2: Home page for the prototype of the Sustainable construction service platform

CONCLUSIONS

Sustainability requires the engagement of every single constituent of the supply chain, from concept design to operation. The research therefore explores ways of creating circles of impacts that bind professionals, government authorities, official institutions and citizens through virtual communities with shared visions. This requires raising awareness and changing behaviour, which the proposed platform aims to enable.

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CLouDBIM: Exploring the feasibility and potential for cloud research in the architecture, engineering and construction sectors

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SUMMARY

The CloudBIM project is funded by the EPSRC. It explores the feasibility and potential for utilising cloud capability to address data storage and processing needs of stakeholders in the architecture, engineering and construction sector, with a view to delivering a cloud platform for research. CloudBIM involves close consultation and interaction with major participants in the area to assess stakeholders' perceptions about outsourced, virtualized cloud storage for supporting multi-site, multi-team collaborative projects. A prototype cloud platform (based on CometCloud) and associated governance model are being developed and will be made available to the AEC research community.

The project will deliver several reports based on a number of 'people-based' activities, involving BRE and Knowledge Transfer Network for the Modern Built Environment (MBEKTN), along with a prototype using real building information modelling case studies provided by Bentley, a leading CAD developer. A key outcome will be to spur a wide range of research-oriented activities through a strategic roadmap aimed at the exploitation of the resulting CloudBIM platform.

BACKGROUND

Architecture, engineering and construction

Architecture, engineering and construction (AEC) is a highly fragmented, data-intensive, project-based industry depending on a large number of very different professions and firms, with strong data-sharing and data-processing requirements across the building life-cycle, from concept design to demolition. The process of designing, re-purposing, constructing and operating a building involves not only the traditional disciplines (architecture, structure, mechanical & electrical, etc.) but also many new professions in areas such as energy, environment, and waste with large data-sharing requirements. In this context, data management across the project life-cycle tends to be fragmented, lacking an overall data management policy. Additionally, data sets relating to a particular project can often be stored in:

- local computers of designers/architects, often with limited network connectivity, persistence and availability
- independently managed, single company-owned archives, where access is dictated by a company-specific policy or by a charging model

- ad-hoc document archives in the context of a particular building project, based on access policy associated with the project.

Efforts have been invested to identify data requirements at different life-cycle stages to allow a more effective exchange of data between software applications across the life-cycle of a building facility^[1,2].

Building information modelling

Building information modelling (commonly known as BIM) is the process of generating and managing data and information about a building during its entire life-cycle from concept design to demolition^[3]. Industry Foundation Classes (IFC – ISO/PAS 16739: 2005) are a commonly used form for BIM. They are open data model specifications for defining building components' geometry and other physical properties in a way that enable CAD users to transfer design data between different software applications. They are intended to provide an authoritative semantic definition of building elements, their properties and inter-relationships. Data associated with IFCs can include:

- textual data
- images (such as building schematics)

- structured documents, including scanned documents that do not expose their structure
- numerical models
- designer/project manager annotations.

The IFC specification is developed and maintained by BuildingSmart (a division of the International Standards Organization) in which Bentley (a software developer and project partner) is an active player, and has been included in several ISO standards. The IFC with its standard set of rules for data storage, data exchange and protocols provides an ideal framework to manage data related to a building throughout its life-cycle.

The National Building Information Model Standard (NBIMS), developed by a US-based BuildingSmart group, describes three categories of BIM.

- *A product or intelligent digital representation of data about a capital facility.* BIM authoring tools create and aggregate information which, before BIM, had been developed as separate tasks with non-machine interpretable information in a paper-centric process.
- *A collaborative process* which covers business drivers, automated process capabilities, and open information standards use for information sustainability and fidelity.
- *A facility life-cycle management tool* of well understood information exchanges, workflows and procedures which teams use as a repeatable, verifiable, transparent and sustainable information based environment used throughout the building life-cycle.

However, several barriers need to be addressed before industry will be comfortable in its adoption. Some of these issues include trust, security, privacy, interoperability, ownership and rights of project data. The Cloud Computing model^[4-6] offers a unique opportunity to solve the AEC industry-wide data-sharing, access and processing requirements provided that key socio-organizational and technical issues related to the project-based nature of the industry (such as ubiquitous network access, reliability of data centres, stability of message-exchanging and intellectual property rights) are resolved.

RESEARCH PROGRAMME

Objectives

The CloudBIM project aims to deliver a cloud computing platform for the UK AEC research community to host and spur a wide range of impact-creating research activities. The measurable objectives are to:

- investigate the feasibility, benefits and limitations of using Cloud computing capability to support data storage outsourcing for BIM (Building Information Model) project data
- develop a governance model for outsourcing BIM data, taking into account stakeholders' privacy, security, ownership and intellectual property rights across the building life-cycle
- specify and implement the CloudBIM proof of concept cloud prototype
- identify the 'governance-performance' benefits and costs of storing BIM data across virtualized data storage

capability made available over the Cloud, focusing on three key metrics:

- network overheads in using externally sourced, virtualized storage
- economic costs associated with utilising such capability
- privacy constraints associated with utilising such storage for business sensitive data, as viewed by industry end users
- devise a strategic research roadmap for the exploitation of the CloudBIM platform by the AEC research community.

Methodology

The project involves collaboration and consultation with:

- producers and end-users of BIM data drawn from the 8000 representatives from industry operating in the built environment space of the MBEKTN
- BIM-related software developers such as Bentley (who have developed tools for CAD and a BIM editor)
- project managers such as Lee Wakemans who understand the sensitivities involved in sharing project data across stakeholders and the project life-cycle
- a building authority, BRE, who can advise on the legal and regulatory framework for adoption of the resulting CloudBIM platform.

CometCloud (a software infrastructure implemented at Rutgers University, and enabling applications on virtual Cloud infrastructures to be managed through policy-based access; for more information visit www.cometcloud.org) will be used to implement CloudBIM. CometCloud has been demonstrated to work across a private cloud implemented at Rutgers University and the Amazon EC2/S3-based public cloud. The CloudBIM prototype will be hosted at Cardiff and Rutgers.

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A USER-FRIENDLY AND COST-EFFECTIVE LOW-CARBON SOLUTION INTEGRATING RENEWABLE ENERGY SOURCES AND TECHNOLOGIES IN WELSH HOUSING STOCK

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SUMMARY

The refurbishment of existing housing stock with energy efficiency measures incorporating renewable energy technologies is vital in achieving the UK's carbon emission and renewable energy targets. Existing renewable energy technologies tend to be expensive and difficult to adapt and integrate into existing domestic buildings. The project would hence involve creating a user-friendly, cost-effective renewable energy product solution easily deployable in Wales and adaptable to the UK housing stock.

BACKGROUND

The UK is required to meet EU energy reduction commitments to achieve an 80% cut in CO₂ emissions by 2050^[1], and 15% of its total energy supply from renewable energy sources by 2020^[2]. The built environment sector alone would contribute 3.3% towards this renewable energy target^[3].

The UK has one of the largest existing domestic housing stock (26 million) in Europe, which would require a holistic energy retrofit if the UK is to meet its energy and CO₂ reduction targets. In fact, the report published by the Renewable Advisory board (RAB 2020 vision)^[3], states the number of typical installations in each renewable energy technology to be done as retrofit on existing residential stock in order to achieve the target of 3.3% [or 5 million tonnes of oil equivalent (Mtoe)] of total energy target (Table 1).

The problem

There is a growing market for renewable energy products arising from financial incentives like the Feed-in-Tariff and Renewable Heat Incentive provided by the UK Government. The Government is revamping its policies and building regulations to encourage and develop this market. For example, The General Permitted Development Order (GPDO)^[5] amendment to the UK Town and Country Planning Act relaxes the need for planning permission for the installation of some renewable energy solutions in dwellings.

However, despite these policy changes, the market in large-scale development, manufacturing and supply of products for renewable energy in the domestic sector is underdeveloped.

Even though many companies now are offering a variety of renewable energy products (Figure 1)^[6,7], none of these looks at the embedding and integrating of renewable energy solutions from concept design to maintenance after installation specifically in the domestic sector. The companies look at a stand-alone product without designing a holistic low-carbon solution integrating these products efficiently, thereby challenging the commercial viability of these products. Hence these products tend to be complex (not user-friendly) and expensive.

RESEARCH PROGRAMME Objectives

The research underlying this project is concerned with developing a user-friendly and cost effective low-carbon solution integrating renewable energy sources and technologies, targeting existing and new homes in Wales, and in the rest of the UK. The product would be adaptable for large-scale deployment for retrofit as well as new build housing stock. The project is part of a Knowledge Transfer Partnership (KTP) between BRE Wales and Cardiff University of 3 years' duration, whereby the research will be published as a PhD.

**Table 1: Contribution of each sector in the built environment in order to meet the energy targets
Reproduced from RAB 2020 vision⁽³⁾**

Sector/technology	Contribution (Mtoe)	Typical single domestic production (MWh pa)	Number of installations (thousands)
New-build residential	1.1		
New-build non-residential	1.0		
Existing build residential* consisting of:			
Photovoltaics	0.09	1.5	680 ^a
Solar hot water	0.23	2.25	1300 ^b
Micro-wind	0.33	4/2 ^c	1170 ^c
Air source heat pump	0.74	6	1140 ^d
Ground source heat pump	0.81	10	950 ^e
<i>Total</i>	2.2		
Existing build non-residential	0.7		
Total	5		

* All analysis is based on 26m existing homes.

^a Approximately 1 in 38 UK homes; this is ~7% of 10m homes UK Government Department, CLG, estimates to be suitable for installation in *Review of sustainability of existing buildings*⁽⁴⁾.

^b 1 in 20 UK homes; this is ~7% of 19m homes UK Government Department, CLG, estimates to be suitable for installation in *Review of sustainability of existing buildings*⁽⁴⁾.

^c 15% of 5m rural homes installing a system generating 4 MWh pa, +2% of 21m urban and suburban homes installing a system generating 2 MWh pa.

^d 8% of 1.5m gas boiler replacements made annually installed with an air source heat pump.

^e 15% of the 3.9m homes estimated to be off the gas grid, +2% of 1.5m gas boiler replacements made annually.



Figure 1: (a) Solar thermal panels by Kingspan® Solar, (b) Solar PV panels by Solarcentury

Methodology

The KTP project will refer to the following methodology.

- Conduct a state-of-the-art review of the literature in the area of renewable building energy with a focus on the domestic sector.
- Conduct a comprehensive market review of existing renewable energy products and implementation approaches, and ways in which these address home occupants' comfort needs.
- Specify an adaptable renewable energy packaged solution taking into account large-scale deployment needs, as well as available state-of-the-art renewable energy products.
- Devise a total life-cycle renewable energy intervention methodology and associated instruments, easily adaptable and deployable, while providing clear
 - carbon reduction and energy-saving accounts as well as
 - medium- to long-term cost payback projections.
- Develop a 'taxonomy' for existing homes in Wales with a view to devising renewable energy packaged solutions and associated in-house capability and expertise adapted to existing housing types.
- Deploy the above renewable energy packaged solutions in the context of the existing renewable energy programme led by BRE Wales in the Heads of the Valley.
- Validate and optimise the deployed domestic renewable energy packaged solutions.
- Develop best practice guides and recommendations on the deployment of renewable energy solutions and organize in-house training and capability across the whole BRE Group, particularly BRE Wales.

RESEARCH OUTPUT

The proposed KTP will deliver the following primary output.

- A coordinated approach to support renewable energy solutions deployment in the domestic sector that factors in comfort requirements, climate change and environmental impacts.
- A holistic renewable energy retrofits methodology and associated intervention (including design) instruments.
- Cost-effective, off-the-shelf, user-friendly, renewable energy product solutions easily adaptable/customisable and deployable in the context of the Welsh and UK domestic building stock.
- Best practice guides and recommendations on the deployment of renewable energy retrofit solutions.

The above expected research output will pave the way for the following revenue-generating outcomes for BRE Wales and the entire BRE Group.

- Enhanced, and in some aspects unique, consultancy capabilities in renewable energy design and implementation. Given the strategic importance of the use and deployment of renewable energies, the proposed KTP will help intensify consultancy activities across BRE.
- Delivery of an ambitious training and capacity building programme through the provision of a wide range of training courses, seminars and conferences in the area of domestic building renewable energy.
- Large-scale initiation and involvement in ambitious renewable energy retrofit and new-build programmes in the domestic sector in Wales, across the rest of the UK, and in Ireland.

- Enhance national building regulations informed by the development and use of cost-effective and innovative renewable energy solutions.
- Deliver the BRE sustainability agenda by helping reduce environmental impacts of buildings, communities and businesses at all stages, from planning and design, through use and refurbishment, to end-of-life disposal.

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FUTURE ADAPTABILITY OF BUILDINGS

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SUMMARY

There exists a plethora of economic and ecological pressures to reduce the energy consumption of buildings^[1,2]. There are many new technologies in achieving this, such as micro- and meso-energy systems^[3] and nano materials which provide high thermal insulation^[4]. However, it is hypothesised, that these strategies need to be combined in an integrated dynamically interacting solution so that their performance is maximised. For that reason, and to prove the above hypothesis, a methodology needs to be derived that can evaluate a building and provide tailored information on what opportunities are available to enhance a building's adaptability, resilience, energy efficiency and sustainability.

BACKGROUND

The pressure of economic and ecological considerations is escalating to invent new concepts to satisfy occupant requirements with substantial reductions in energy use. The severity of the impacts which could be caused by climate change is mounting, as scientists openly admit that between 2000 and 2007 the rise in greenhouse gases was steeper than predicted^[5]. Together with the threat of fossil fuels running out, it is becoming imperative to design buildings which will optimise their use of energy over their lifetimes.

There are numerous actions that can be taken to make the design of buildings more efficient on a range of fronts. Building regulations are being used as catalysts to ensure building design steers towards sustainability, energy efficiency and an overall reduction in CO₂ emissions. New design concepts are being used to produce buildings that are functionally adaptable to avoid unnecessary demolition, and have a construction that can bring large savings in time and money, such as Newways and Multispace^[6]. Building systems are being modelled over a building's lifecycle not only for optimisation of their performance, but to examine whether high capital cost products can result in sizable future savings^[7]. Even materials can be chosen so instead of simply degrading, they can enhance a building's performance^[8], they can exhibit self-cleaning and anti-graffiti^[4] properties, or even aid structural integrity^[9]. In terms of assisted living, products are available which can give users a chance to stay in their own homes for longer, as well as have a higher quality of life.

There is a tendency to address the above complex issues in isolation. A more integrated and holistic approach is needed using system dynamics theory with a view of paving the way to adaptable digital construction, as illustrated in Figure 1.



Figure 1: The components of adaptable digital construction

The problem

New buildings need to offer an optimized integrated solution and the existing building stock should be resilient, sustainable and exhibit continual fitness for purpose. Currently, design/retrofit decisions are taken that have a long-lasting impact on the energy consumption of a building over its service life and often decisions are suboptimal^[10]. This is due to either not all influences being studied or there is insufficient knowledge about the use of the object. This has a large impact over time as the variations due to different building occupants and climate change are significant. As a result, we face uncertainty in climate, occupant behaviour, building operation, etc. It is therefore necessary constantly to face this complexity and improve our ability to have an impact on these changes^[11].

Nowadays, home styles can be measured through non-intrusive instrumentation in the home, allowing objective assessments, comparisons and recommendations to be made and tracked. For example, wireless sensor network platforms consisting of spatially distributed, wireless-enabled devices/sensors supported by 'cloud' software solutions to monitor and manage key parameters across a range of consumer-orientated and industrial applications are already in development.

By using these technologies, key parameters across a range of consumer-oriented and industrial applications can be monitored and managed. This enables applications that include the monitoring and management of long-life components, healthcare, energy management in homes, among others. The physical information and data gathered from a building can be stored over its whole life-cycle in a central data model. This data model is a product of building information modelling (BIM).

BIM is an information-centric approach to project delivery. It relies on a central data model which stores physical information and data about a building. This can be accessed and edited by all the members of a project simultaneously. It promotes collaboration, facilitates the exchange of data and reduces data redundancy and loss. It can also be used to model a building's physical composition throughout its life-cycle. However, it cannot be used directly to model a building's behaviour over time.

The analysis of behaviour is important, as it is used to determine a building's fitness for purpose. Data from a BIM can be exported to various simulation tools for analysis. Nevertheless, additional models of the same building have to be made in order for this to happen, which exposes the project to some of the original issues in that BIM is trying to avoid, such as data redundancy. Additionally, these simulation tools tend to analyse building systems separately, when in real life components from different systems will influence each other's state.

RESEARCH PROGRAMME Objectives

This PhD project aims to explore the feasibility and possibilities of an adaptable building by exploiting sensing technologies and smart materials. By using sensors, it will be possible to monitor, collect and store data and analyse a range of parameters (eg location and strain of people, temperature, etc.). Applications addressed in the project will include the monitoring and management of long-life components such as building elements (ageing), robustness to climate change, healthcare, energy management in homes, security, environmental monitoring, and manufacturing/supply chain management. Solutions developed will be piloted for use in a range of industrial settings.

Methodology

An extensive literature review addressing building systems and design challenges has been undertaken. Furthermore, a study has been carried out, showing the impact of solar shading devices on the light distribution in the room using daylight modelling software called Radiance and Ecotect. Also, physical phenomena and their mathematical representations have been identified in the thermal and ventilation domain. It is expected that more domains will be examined.

Additionally, a case study will be undertaken where the behavior of a building over 90 years will be simulated, and plans will be made on how its design can be changed so it can adapt to climate change. More case studies will be conducted to establish an overall methodology for determining the state of adaptability and resilience of a building. Ultimately, a tool will be created which will be based on BIM, but it will be capable of calculating a building's performance by dynamically exchanging data between various systems in its data model.

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HOME-CENTRED HEALTHCARE MANAGEMENT FOR AN AGEING POPULATION

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SUMMARY

The changing demographics of western societies, including the UK, reveals the long-term vulnerability and inefficiency of our healthcare model in terms of dealing with older people or, more generally, with patients suffering from chronic diseases and requiring assisted living facilities. This PhD project involves developing knowledge-based assistive solutions to help older people live longer at home while providing them with access to necessary services.

BACKGROUND

An ageing population is one of the crucial issues in developed countries and the UK is no exception. A report on the UK population from the Office for National Statistics (ONS) shows that the percentage of 65 year-olds and over increased to 16% in 2009 and it is expected that 40% of the population will be over 50 years old in 2026^[1]. Another report from the Welsh Government states that nearly 25% of the population was over the age of 60 years in 2008 and it has been over 25% in some areas in Wales^[2].

Statistics on the status of elderly people show that more than 20% of males and 30% of females between 65 and 74 years old live alone and this increases to more than 60% of females from age 75 years and over^[3]. Long-term illnesses such as dementia and arthritis are another concern for elderly people and 50% of over 60 year-olds and 80% of over 85 year-olds live with at least one long-term illness^[4]. More than 800,000 people in UK suffer from dementia and the cost for caring for each individual is £27,647 per year^[5]. Also, the Department of Health estimates that the cost of caring for people with dementia will cost approximately £50 billion a year in the next 30 years^[6].

The problem

Many older people want to spend time in their home environment. Over 40% of people have concerns about having to move into a care home when they become old and nearly 70% of people worry more about losing their independence or becoming dependent on others than dying, according to the survey conducted by the Disabled Living Foundation in 2009^[7]. The home, therefore, is a crucial focal point for ensuring independent, healthy, and socially inclusive living, and should be designed and equipped with the right infrastructure to support and host a variety of services that older people may require to meet their needs. Moreover, easy access to the

social environment (healthcare facilities, care support, supermarkets, cultural centres, opportunities to socialize, etc.) whether from homes, or integrated into homes through adapted digital technologies, is important to offset such potential challenges as isolation, loneliness, and associated physical and mental decline. Access to useful, high quality information is also vital, particularly for those older people suffering from gradual memory loss, to making informed choices.

To support elderly people's needs for staying in their own home while keeping their quality of life (QOL), various health technology and electronic devices have been produced and implemented in the market. Some assistive technology and services such as personal emergency alarms have shown positive effects for older people's lives and for reducing stress experienced by carers^[8]. One of the issues that needs to be examined to maximise the effectiveness of implementing assisted technology for addressing the needs of an ageing society is the level of acceptance of the technology and its usability^[9].

RESEARCH PROGRAMME Objectives

The aim of the PhD research is to explore the potential of adapting and upgrading (including retrofitting) existing information-sharing systems in a community to meet the requirements of an ageing society from a health, safety, social and independent living perspective. All activities of the research should reflect the real-life needs of older people. More specifically, the objectives are to:

- 1 identify the technological, ethical, socio-cultural, and built environment issues that need addressing to design, upgrade (retrofit) and adapt homes to the challenges of an ageing society
- 2 identify and analyse the various activities of daily living (ADL) and instrumental activities of daily living (IADL) scenarios in homes and their constraints as

experienced by older people, especially those who are living with dementia

- 3 specify the design and the basis for technology that can transform homes into safer places and can host or facilitate social, health and care-related services, while addressing the issues identified from objectives 1 and 2.
- 4 define the needs of elderly people and their carers (based on the different conditions identified and analysed in objective 2) to enable them to live continuously in their own homes
- 5 adapt and assemble a 'home' smart and ambient real-time remote sensing infrastructure and specify services (ranging from health and social care to personal finance management) that address the issues identified in objectives 1–3, and assist older people in their daily living based on the needs defined in objective 4.
- 6 deploy and trial an information-sharing system in a selected home 'prototype' and propose a model of a cooperative information-sharing system provided by one of the project partners, BRE.

Methodology

Given the real-life, socio-cultural and technical dimensions, the research will use mixed methods with action research principles covering the entire ageing 'value chain'. This includes a pilot case study of assisted living facilities and interviews with elderly people and their carers. The project will require working closely with local authorities, consultancy organisations such as BRE and various organisations producing sensor devices and assistive technology. It will also require collaboration and consultation with the following societies:

- The British Society of Gerontology (www.britishgerontology.org)
- The British Geriatrics Society www.bgs.org.uk/index.htm
- Age UK (www.ageuk.org.uk)
- The British Society for Research on Ageing (www.bsra.org.uk)
- The Alzheimer's Society (www.alzheimers.org.uk/site)
- Social Care Institute for Excellence (www.scie.org.uk)
- Counsel and Care (www.counselandcare.org.uk)
- Care Quality Commission (www.cqc.org.uk)
- NHS Wales (www.wales.nhs.uk).

RESEARCH OUTPUT

There are three expected outputs from this research.

- A review of current trends and achievement in implementing technology for improving the Quality of Life (QOL) of elderly people.

- A definition of the real needs of elderly people and their carers in order to apply current technology more effectively and appropriately.
- Application of some of the scientific evidences related to improving QOL in practice using various assistive technologies based on real user needs and presentation of an implementation methodology.

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FOREWORD TO THE BRE TRUST PUBLICATIONS PROGRAMME



Disseminating the results of BRE research, development and problem-solving has been at the heart of BRE's work since its formation as the Building Research Station in the 1920s. Over the years, the means by which BRE expertise has been promulgated has steadily developed and broadened, but from the earliest days it has included detailed research reports, concise guides focusing on practical applications of such research, and lessons learned from investigations of problems and failures.

Some fundamental features of BRE publications have remained constant:

- all the information and advice should be based on sound science and engineering
- wherever possible, the work should be directly useful for people in the real world of design, construction and manufacturing
- the presentation should be of the highest standard: publications should be clear and concise, well illustrated, and written in the appropriate language for the intended readership.

These fundamental aspects are being maintained today. The delivery mechanisms continue to change, with readers expecting more rapid online access as well as conventional printed publications.

Over the past two years, BRE Trust has given much higher priority to publications in order to reinforce the importance that the trustees attach to the sharing and dissemination of BRE knowledge and insight. This has taken the form of:

- funding BRE experts to write new publications and revise existing ones that are not fully up-to-date
- putting in place a process for selecting publications that are consistent with the Trust's themes
- reviewing the published outputs to ensure that the Trust is getting good value for money and that the fundamental features noted above are being maintained.

The first two parts of this process are now well established and the post-publication review process will be the subject for further attention in the coming year.

This process is being guided by a small committee which I chair. We are pleased with the way that BRE staff have responded to this initiative: a tremendous number of worthwhile proposals and ideas for new publications has been put forward, so we have had to make some difficult choices about which projects to support.

The following pages feature the publications that have resulted in 2010 from this exciting development. I take the opportunity to thank our publishing partners, IHS BRE Press, for their enthusiastic support for the new programme; their commercial focus reminds us of the need to keep the reader in view at all times. With this in mind, I would like to invite comments and suggestions for subjects on which BRE might produce new publications, and for the most effective ways in which they should be delivered.

Hugh Ferguson
Chairman
BRE Trust Publications Committee

PUBLICATIONS PROGRAMME



BRE TRUST PUBLICATIONS IN 2010

This section provides summaries of the publications that have been published during 2010 whose preparation has been 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 BRE Global, and deal with key topics of concern throughout the community of clients and professionals across the built environment.

MATERIALS

Drying distortion of timber

DG 514, May 2010

Guidance on selecting, conditioning and handling timber, especially how to avoid drying distortion, is given in this BRE Digest. Measures to reduce problems of timber distortion are listed and types of wood where drying distortion can be a problem are identified. Drawings and photographs help to identify potential problems and give guidance on timber suitability.

Assessment of timber structures

DG 517, June 2010

Timber is a capable and widely used construction material, but is vulnerable to degradation when exposed to moisture. This Digest considers the structural role of the timber element which can give an indication of its adequacy. It covers the inspection and appraisal of timber structures (roofs and floors) for signs of deterioration, modification and defects. It also provides information about biological attack of timber (insect and fungal decay).



Sustainable housing refurbishment

IP 18/10, October 2010

This update on refurbishment of housing to make it suitable for modern living, with sustainability in mind, includes tips and links to numerous sources of information and web sites. Many organisations are working towards refurbishing the UK's housing stock, and these are referred to at relevant points.

ENERGY

Planning decentralised energy systems in large new developments

IP 22/10, December 2010

There is increasing recognition that the widespread use of decentralised energy (DE) systems within towns and cities will be integral to realising significant carbon reductions from buildings. Local planning departments are introducing policies to encourage the use of such systems in large new developments. This Information Paper highlights the possibilities of decentralised energy and provides advice on addressing the issues. It is informed by BRE's experience of working with the GLA in implementing the London Plan's energy policies and supporting developers in other parts of the UK. It aims to provide understanding of the issues in implementing DE in large new developments, and how to create sustainable developments that are energy- and carbon-efficient.



FIRE AND SECURITY

Design fires for use in fire safety engineering

FB 29, December 2010

Technical data and guidance on defining a robust and appropriate design fire for use in the fire safety engineering design of buildings are given in this report. It explains:

- what a design fire is
- how it can be determined
- limitations of current methodologies
- experimental data
- calculation methods.

Current approaches to defining an appropriate design fire, from quantification of fuel load based on surveys of real buildings to experimental measurements, are detailed. Aimed at professionals involved in fire safety engineering design, this guidance can be used to source quantifiable parameters such as heat release rates and fire growth rates that are proportionate to the fire hazard foreseen.

Lessons learned from real fires

DG 515, June 2010

Fire investigations are carried out for many reasons by the police, building owners, building insurers and others. As well as providing critical information about incidents, systematic investigation and study of real fires are essential to develop and enhance our knowledge base and to ensure that such incidents are not repeated. This Digest discusses:

- which organisations carry out fire investigations
- what information can be obtained
- use of reconstructions and computer modelling
- the benefits of fire investigations
- case studies.

Evacuation modelling and human behaviour in fire

DG 516, June 2010

Practical advice and guidance on the use of numerical models to predict human behaviour during emergency building evacuation is given in the Digest. The guidance is intended for designers, fire engineers, building control officers and other enforcers, model developers and researchers. It focuses on evacuation from fires, but much of the discussion is relevant to other emergency evacuation situations.



Sprinkler systems for fire protection of commercial and industrial buildings

DG 518, August 2010

Automatic sprinklers have been used in commercial and industrial buildings for over 150 years. Sprinklers stop a small, unexpected fire from escalating into a large, uncontrolled fire. Historically, sprinklers have proved successful at reducing the cost of fires for building owners and/or occupiers and insurers. This Digest summarises the key information needed by business managers/operators, specifiers, users, insurers and approving authorities to select, design and maintain sprinkler systems.

An introduction to the use of fire modelling

IP 12/10, May 2010

There is usually a point during the design of fire safety systems for buildings or during a fire investigation when a question is asked that involves knowing how much there will be of something, how long it will take for something to happen or where it will happen. To answer these questions, some form of calculation is required, which will require the use of a fire model. This Information Paper discusses some of the problems that may be encountered in fire modelling and suggests tips for effectively presenting results. It focuses on the practical use of numerical models.

SUSTAINABILITY

Delivering a successful demonstration project

IP 20/10, November 2010

This Information Paper shares the knowledge that BRE has gained in the ongoing delivery of its own Innovation Park and experience of working with partners and of other sustainable housing developments. It highlights lessons for new demonstration projects, such as those linked to proposed eco-developments that showcase energy-efficient homes and sustainable technologies.



DESIGN

Health and productivity benefits of sustainable schools

FB 27, September 2010

Research has shown that 'green' schools provide healthier and more productive environments because many of the features of green buildings, including daylight, fresh air, materials with low pollutants, etc., correlate strongly with factors known to contribute to health and well-being. This publication reviews evidence from international research that the environmental design of schools has a positive effect on teaching and learning. The publication explores the potential benefits of:

- thermal comfort
- access to fresh air
- daylight and views out
- acoustic performance
- size and layout of teaching spaces.

Cool roofs and their application in the UK

IP 13/10, June 2010

This Information Paper explains what cool roofs are and how they work, their benefits and their application in the UK. By effectively reflecting and re-emitting incident solar energy, cool roofs mitigate excessive interior heat gains, reducing the need for air-conditioning and improving energy efficiency. Research demonstrates the contribution made by cool roofs to combating the urban heat island effect, thereby helping to reduce the incidence of urban smog formation.

Quantifying the cost of poor housing

IP 16/10, September 2010

Research commissioned by BRE Trust has developed a method of quantifying the cost of poor housing, and the cost-benefit of interventions to improve such housing. This Information Paper provides feedback on some of the early practical uses of the research and how it has been used to quantify the health benefits of energy efficiency measures that improve homes beyond the average for their age and type. The original research suggested that undertaking basic improvements to reduce the hazards in poor housing to an acceptable level could save the NHS £600 million a year. BRE Trust sponsored research reported here suggests that this saving could be doubled if more comprehensive improvements are undertaken.

Designing urban streets to minimise heat island effects

IP 19/10, November 2010

Increasing urbanisation is leading to local climate modification in cities, and in particular to the urban heat island effect. City streets can be designed to take advantage of the convective cooling effect of the wind. This Information Paper explains how street geometry affects wind flow patterns and presents the findings of wind tunnel studies to quantify the resulting convective cooling of the building surfaces. Key factors to be considered in street design are summarised.



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.

BRE, 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 BRE and by the other subsidiary companies are passed 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 articles of association.

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

TRUSTEES AND OFFICERS OF THE CHARITY

The Trustees serving during 2010 are as given in Box 1.

The Trustees delegate the day-to-day management of the charity and management of its subsidiary activities to the Chairman of BRE Group, Martin J Wyatt, and the Finance Director, Russell Heusch.

Box 1: Trustees serving in 2010

Chairman

Sir Neville Simms FEng

Professor John Burland CBE, FEng, FRS
John Callcutt CBE (retired 3 November 2010)

Mark Clare

Professor Les Clark OBE, FEng (resigned 26 November 2009, appointed 5 May 2010)

Mark Farrar

Hugh Ferguson

Richard Gillies

Richard Haryott FEng

Peter Lobban OBE

John Pike (resigned 8 January 2010)

Ray Treen

Hugh Try CBE (retired 3 March 2010)

James Wates (appointed 3 March 2010)

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 2010, the Council had four committees reporting to it:

- Finance and Audit Committee
- Research Committee
- Publications Committee
- Business Development Committee.

Management

The Trustees are expected to:

- give strategic direction to the work of the BRE Trust and group companies
- have an input into the strategic business plans of the group companies

- extend the scope of BRE Trust's charitable activities and seek funding
- develop research and education objectives for the charity and prioritise expenditure against such objectives
- act as ambassadors for the work and objectives of the Trust and its group companies
- benchmark the activities and achievements of the Trust and group companies
- 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.

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 fire safety in the UK
- 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.

BRE TRUST REVIEW 2010

The BRE Trust Review 2010 presents a summary of the year's activities and achievements. The main focus is on short papers from BRE, BRE Global and the five BRE Centres of Excellence, summarising research projects funded by BRE Trust in 2010. The papers demonstrate the breadth and scope of the research that is being supported by the Trust.



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