Structural strength when you need it

Most structures are designed to withstand a worst case loading that will only occur rarely. In these cases, the structure is effectively overdesigned for most of its life. As part of an on-going UCL-Expedition R&D collaboration, an adaptive truss prototype developed by EngD Researcher Gennaro Senatore demonstrates that it is possible to save much material in structures by optimal material distribution and controlling deflections through strategically located sensors and actuators.

This 6m long high-tech cantilever truss is not only enabling a novel research experiment, it also demonstrates a new engineering design philosophy where strength is dealt with separately to movement. The steel members making up the truss have been sized to prevent collapse, but instead of adding more material, the more onerous requirements of deflection and movement are precisely controlled by linear electric actuators keeping the truss rigid.

The novel design approach extends further so that day-to-day loads (which are typically a fraction of the full design loading) do not need the actuators to kick in. Only when larger infrequent loads occur, such as crowds on a bridge a few times per year or a football stadium full for 90 minutes once per week, do the actuators operate to control movement – so over the life of the structure little operational energy is needed. Compared to a conventional structure, this new engineering thinking has led to a prototype with 80% less material, 76% less whole-life energy and six times more slender.

How does the prototype work?

A large scale prototype has been built in the civil engineering laboratory at UCL, to help establish the practicalities and validate some of the findings of the theoretical studies. The prototype is a 6m long cantilever transparent platform supported by a very slender space frame (40:1 span to depth, only 150mm deep). The frame consists of 45 passive steel members and 10 electricity powered linear actuators.

The platform is designed to withstand the weight of a person walking on it. The deflection of the platform will be controlled in real time by a state of the art control system. The frame is fully instrumented to monitor the stress in the passive members, the deflected shape and operational energy used.

How could this change the industry?

This technology will transform the way we think about buildings. In a world which is going through massive and critical changes as a result of climate change, depletion of cheap fossil energy and financial challenges, it is lean, low-carbon, smart and adaptive. The project also demonstrates the benefits of cross discipline teams with civil, structural, mechanical, electronics and control engineering all involved. The trend to build taller, slender structures and associated concerns about their environmental impact make adaptive structures a potentially transformative technology.

This project is part of research conducted by UCL’s Centre for Urban Sustainability and Resilience and the Department of Civil, Environmental and Geomatic Engineering. It has been funded by the Institution of Civil Engineers, the Institution of Structural Engineers, EPSRC and Expedition Engineering. For further information please contact Rabinder Phull (02076 652237; E-mail: Rabinder.phull@ice.org.uk).
Retailers switching the lights

Over the past year, research has been undertaken by the British Retail Consortium to understand what the role of LED lighting could be in driving energy efficiency in retail, one of the most energy-intensive industries in the UK. The research formed part of a Green Construction Board project and the British Retail Consortium worked within a group also involving the Department for Business Innovation & Skills, the Lighting Industry Association, the Chief Construction Advisor, the British Council of Shopping Centres, Sainsbury’s, Marks and Spencer, Philips, and the Retail Energy Forum. The group set out to find out what retailers had been doing already as well as what the benefits and challenges were in switching to LED lighting.

Energy is a key strategic issue for the retail industry today and the research suggests that those retailers that are acting on energy efficiency now will be better able to manage the impact of rising energy costs in the future. Energy is a significant operational cost for UK retailers, so energy efficiency represents a huge opportunity to maximise profitability for the long term as well as achieving social and environmental goals.

Some key statistics on energy in retail

- Retail is the second highest energy consuming industry in the UK;
- Cost of energy to retail in 2013 was £3.3bn – expected to rise to at least £4.4bn by 2020;
- Electricity accounts for approximately 77% of total energy consumption and 90% of overall energy costs;
- Lighting in 2013 used 43% of total electricity, by far the leading source of energy consumption;
- Carbon from retail energy in 2013 was 16 MtCO₂e, a fifth of emissions from all businesses in the UK.

Under the Switch the Lights Campaign the group found that Lighting was the highest source of energy use for the retail industry and represented an important opportunity in delivering energy efficiency. Their analysis demonstrated a number of findings that show the benefits that switching to LED lighting in a retail setting can bring:

- Typical savings were around 40% but up to 60% energy reduction could be achieved through switching to LEDs that are associated with moving to LED lighting, especially in leading retail businesses is a huge blockage. The investment required to completely change the lighting across hundreds of retail stores is very high and the availability of this level of capital is constrained in the current challenging economy. This is especially true in businesses that have already been investing in energy efficient lighting.
- There are other financial constraints that retailers face that may also be issues for other industries. Through working with retailers the group found that the technology write off cost was a significant barrier to investment and was slowing investment in LED. Where retailers have historically been investing in energy efficiency, lighting in many cases had already received significant investment over the last 10 to 15 years, moving from high energy use lighting such as halogen to higher-efficiency T5 and T8 lighting systems. Incumbent lighting systems will have a lifetime which would have been factored into the initial investment so, if you are investing in even more efficient lighting part way through a technology’s lifetime, there will be a loss of value associated to removing technology prior to its end of life – a double whammy of costs to your rate of return of investment.

Another very difficult barrier to overcome is that many retail designers are still wary of using LED lighting in their store designs. When LED lighting technology initially hit the market in the late 1990s it did not deliver on lighting levels or colour. Many early adopters of LED in retail were finding that it was changing the colours of products on sale and as a result were seeing returns of goods on the basis that they were a different colour when at home. Similarly supermarkets were finding that it would make food look grey and dull and not particularly healthy.

LED technology has moved on...
Innovation & Research Focus

Significantly since then and that difficult period of innovation has given us much better colours and light levels. The Switch the Lights report has a number of case studies from retailers that demonstrate that LED lighting creates a much better environment than even existing T5 and T8 lighting schemes – in some cases the change to LED has resulted in increased sales. But the myth of LED hasn’t kept pace with the level of innovation of the technology. Many retailers have spoken to say that there are still problems in convincing other areas of the business that LED is a good solution not just in energy savings but in design and environment.

The group found that there are a number of other challenges that retailers are facing in switching to LED:

- Current energy and carbon policy is too complex and is a key barrier to investment. Harmonisation of policies could deliver significant acceleration of deployment of energy efficiency technologies.
- Leases can often have upgrade or improvement works clauses to them, which could impact on the ability to undertake such a project; leases often include dilapidation clauses, which could result in the retailer having to put back in place the old lighting scheme if it vacates the property.
- Store disruption can have a big impact on the overall viability of an LED project as it can result in loss of sales and can damage brand recognition with existing customers unless an effective communication strategy is in place.
- The technology is innovating, and moving so fast that it can be very difficult to identify the right lighting design and may result in choosing a less appropriate design for the intended use at a significant cost.

Whilst these challenges can be significant, retailers have commented that a collaborative approach across the business will often remove them and can deliver much greater benefit in terms of design quality and operations and can help to manage risks associated with store disruption.

In conclusion

LED lighting can be a great driver for energy efficiency in retail and can lead to a much better environment for both staff and customer alike. It can help display products in more flexible and interesting ways and can lead to additional sales. It can also achieve savings on energy use of up to 60% whilst also making a critical contribution to mitigating the carbon emissions of the business. But it is not without its challenges.

- Retailers the group worked with on the project were adamant that a successful project is one that builds consensus across different business areas, so engaging early with the business is critical.
- Being able to create a strong business case was also seen as vital to securing funds to install across your estate and often companies would pilot the project in a few stores first to support their plans for a wider roll out.
- Finally many retailers were extolling the virtues of testing the product in a lighting lab if at all possible to see the product under operational conditions. Whilst it may add cost to the project, being certain about its performance is central to any future LED lighting project.

Retailers are leading the way in LED lighting and are helping their business to not only save money and carbon but also deliver attractive environments for customers. The research conducted has enabled the group to get a good sense of the LED market. The research sent out a very clear message: around 80% of retailers surveyed expected their business’ lighting to be completely from LED by 2020, and speaking with manufacturers, the British Retail Consortium has every confidence this will be achieved.

For further information please contact Andrew Bolitho, Energy, Property, Planning and Transport Policy Adviser at the British Retail Consortium (02078 548942; E-mail: andrew.bolitho@brc.org.uk).

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Innovation & Research Focus (IRF) is currently sponsored by 7 Research and Professional Institutions. Collectively we have recognised that there are many other organisations who may want to take advantage of sponsorship but have never considered becoming involved before. We are therefore publicly inviting new sponsors – from government and its agencies, the research community, universities, and the private sector, wherever innovation is taking place in and for construction and the built environment.

IRF has been in publication for over 20 years and is published 4 times each year – in February, May, August and November. The newsletter is aimed at influencing the practical engineering and built environment communities and their related disciplines (e.g. environment, flood risk management, climate change, energy, materials and waste management and sustainability) with news from the research and innovation community, plus announcements of outputs, which are particularly important. In the process it promotes the hard work of Sponsor’s in this domain reaching IRF’s readership of greater than 80,000. IRF is available to read as a physical newsletter, as an electronic E-Book, and via the website www.innovationresearchfocus.org.uk.

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www.innovationresearchfocus.org.uk
Tablets replacing paper in construction

Mobile technology helps empower the on-site team and those working in the field by providing access to a wealth of project information. It allows the users to carry out a complete series of traditional paper based processes seamlessly on a single mobile device.

The use of mobile technology within the construction industry is not a new concept; however the uptake of mobile devices in recent years has significantly increased. The introduction of affordable tablet computing within the consumer market and the maturity of the available systems has caused a paradigm shift in innovation within the construction industry.

An engineering doctorate research project is being undertaken by Harrison O’Hara of Costain Group Plc, one of UK’s leading engineering solutions providers and Construction Opportunities for Mobile IT (COMIT), an organisation focused on developing and promoting mobile and technology solutions across the industry. The research engineer is working with the Centre for Innovative and Collaborative Construction Engineering (CICE) at Loughborough University, and is funded by the Engineering and Physical Sciences Research Council (EPSRC).

The focus of the research is initially to assess the user adoption of mobile technology and evaluate the acceptance based on adoptions of existing theories, such as the Technology Acceptance Model. This research is exploring the appetite across the industry and people’s perception of how the technology will impact their daily job roles.

Safety is of paramount importance to all processes and new innovations in the construction industry. It is a critical issue that needs to be addressed fully when introducing mobile technology into live construction environments. Ensuring that the correct company governance, procedures and best practices are always adhered to is a minimum standard that is expected from the major construction firms currently operating in the UK. Therefore, there is a need to research additional technology that further increases the safety of mobile technology. iBeacons have been identified as a potential technology for tracking mobile devices, automating safety warnings and integrating with interactive PPE.

The research will assess the availability of different mobile systems that are available to the construction industry. Over the past decade the functionality of mobile devices has significantly grown from the limited palm devices and handheld personal digital assistant (PDAs). Software vendors have created completely configurable digital tools for the construction industry to manipulate into a powerful onsite tool. An up to date evaluation of the software functionality available to the construction profession will prove to be valuable research for the entire industry.

The research will review the success of existing mobile solutions and new solutions that come to the surface during the research project. If your business is using mobile technology within construction and you are interested in sharing your journey to benefit the whole industry, please get in contact using the details below. Please get in touch if you are interested in attending a COMIT community day and potentially joining an organisation that is leading the way by creating a centre of excellence for mobile computing in the construction industry.

For further information and to get in touch about this article, please contact Research Engineer Harrison O’Hara at Loughborough University, Costain and Construction Opportunities for Mobile IT (COMIT) (Email: h.ohara@lboro.ac.uk or Harrison.ohara@costain.com).
Effect of investments on safety performance of building projects

The construction industry is increasingly reliant on contractors’ voluntary initiatives to reduce construction accidents. A study led by Dr Yingbin Feng, a Senior Lecturer in Quantity Surveying at the University of Western Sydney, investigated the effect of investment on safety performance, and identified some key influencing factors. For the study, a regression/correlation research design was adopted. Multiple techniques were used to collect data from 47 completed building projects. Bivariate correlation and moderated regression techniques were used to analyse the data. The results show that basic safety investments do not produce a constant effect on safety performance, but varies according to site culture and project conditions.

Dr Yingbin Feng’s research tested the effect of safety investments on safety performance under different safety culture and project hazard levels. Safety investments refer to the costs that are incurred as a result of an emphasis being placed on safety control, whether it is in the form of safety training, safety incentives, staffing for safety, personal protective equipment, or other activities. Safety culture reflects the attitudes, beliefs, perceptions, and values that employees share in relation to safety. This has gained acceptance due to its critical role in accident prevention. Project hazard is a natural part of the initial construction site conditions owing to the scope and location of the project. Higher project hazard levels tend to be associated with higher risk levels on site.

Safety investments are further classified into basic safety investments and voluntary safety investments. Basic safety investments refer to the expenses of those accident prevention activities that are required by industry or government regulations and construction process on minimal safety standards. As a compulsory part of safety investments for any individual building projects in Singapore, where much of Dr Yingbin Feng’s research was concentrated, basic safety investments consist of those costs incurred by safety personnel, safety equipment and facilities, and compulsory safety training courses. Voluntary safety investments refer to the expenses of those accident prevention activities that are generally determined by individual companies or projects. This type of safety investment is incurred by the voluntary safety prevention activities such as in-house safety training and orientation, safety inspections and meetings, safety incentives and promotions, and innovative technologies, methods and tools designed for safety.

A popular assumption holds that higher safety investments result in better safety performance. However, the empirical evidence from this research suggests that a higher level of basic safety investments does not always produce a positive impact on accident prevention. The research findings indicate that the effect of basic safety investments on accident frequency rate does not hold constant under different project conditions. Basic safety investments have a stronger positive effect on accident prevention under a higher safety culture level and a higher project hazard level; while the effect of basic safety investments on accident prevention might not be positive if the project hazard level and safety culture level of the project were low. The Risk Compensation Theory (Peltzman, 1975) and Risk Homeostasis Theory (Wilde, 1982) may help to explain why the effect of basic safety investments is moderated by the safety culture and project hazard level.

With investments in basic safety having a stronger positive effect on accident prevention if the project already has a robust safety culture and project hazard level, this research highlights the importance of addressing the cultural factors impacting upon workers’ perceptions of safety and behaviours. Increasing protection and creating a safer environment will not necessarily raise safety performance if site culture has also not improved. The study therefore suggests that contractors’ interventions should combine physical protection with other cultural safety measures.

Dr Yingbin Feng’s research was awarded the Premier Award at CIOB International Innovation & Research Awards 2014. The judging panel regarded the research as original, well written with clearly articulated objectives, and has the benefit of being highly accessible to a wide readership. The paper provides a holistic re-evaluation of safety management within construction. It was originally published in Safety Science, Vol.59, pp.28-45, 2013.

For further information on the article please contact Dr Yingbin Feng (E-mail: Y.Feng@uws.edu.au). For further information on the CIOB International Innovation & Research Awards please contact Dr Chung-Chin Kao (E-mail: cka@cioh.org.uk) or visit http://iaandawards.cioh.org.
Royal Academy of Engineering Centres of Excellence in Sustainable Building Design

With the UK setting ambitious carbon targets for the year 2050 – committing to reducing greenhouse emissions by at least 80% from 1990 levels – the need to reduce carbon emissions of the built environment, which contributes around 45% of UK CO₂ emissions, is more pressing than ever. Four University Centres of Excellence have been set up to support the construction industry through a period of rapid change and to strengthen the UK’s leading position in low carbon construction.

The Royal Academy of Engineering highlighted sustainable building design as a key theme in its 2012 report: The Case for Centres of Excellence in Sustainable Building Design. In order to implement the Government’s Green Deal by 2030, the UK workforce urgently needs a dramatic increase in people skilled in sustainable design. The report thus called for the establishment of Centres of Excellence in Sustainable Building Design, “....to attract the brightest and best of our young people to become engineers and architects with a sound knowledge of low carbon design and so bring about the required revolution in the construction industry.” The Centres link up with industry, professional institutions, and

Government to collaboratively address the skills shortage across the sector, and the pressing need to recruit and retain more students to meet the shortfall.

The Centres were established in 2013 at the Universities: Heriot Watt, Loughborough, Sheffield and UCL, and between them deliver excellence in teaching and research in low-carbon and sustainable building design. The vision of the Centres of Excellence is no less than to create the world’s best architectural and engineering practitioners, who are expert in the theoretical and practical application of sustainable building design and equipped to challenge the current status quo in design practice.

The four Centres of Excellence offer programs at undergraduate and postgraduate levels across the range of civil, architectural, environmental, and structural engineering; construction project management; and numerous specialist postgraduate courses related to sustainable built environment and design. Across the network, the Centres of Excellence work collaboratively to develop a common technical language. The ambition is that social engagement, interdisciplinary design, holistic and collaborative problem solving and embedding sustainability and low carbon design will represent the norm in built environment education.

Between them the Centres have several doctoral training centres and knowledge exchange programmes with industry, and offer CPD, and public engagement activities. The Centres are promoting awareness of the sustainability challenges and their solutions by acting as regional hubs for knowledge, providing an interface between research and teaching and expanding research and knowledge transfer to industry.

In the context of rapid changes in the built environment in the UK and around the globe – due to urbanisation, climate change, natural disasters and political instability – the centres are producing graduates with the desire to change the world: to provide a better, equitable and sustainable quality of life for the future.

For further information please visit the websites of the four centres:

- http://www.hw.ac.uk/schools/energy-geoscience-infrastructure-society/research/cesbd.htm
- https://www.ucl.ac.uk/sustainable-building-design
- https://www.sheffield.ac.uk/sustainable-building-design

Directors of the four Centres met with representatives from industry, the professional institutions and the Royal Academy of Engineering at UCL earlier this year to sign a concordat to cement the network.
A new design method for circular hollow sections

A new design method called the continuous strength method (CSM) has been developed at Imperial College to predict more accurately the cross-section resistance of metallic structural elements. This design process has now been extended to cover structural steel, stainless steel and aluminium circular hollow sections (CHS) offering improved and more consistent predictions of cross-section resistance than current design methods.

Circular hollow sections (CHS) have been used as structural elements since the early 1800s. Design codes, such as Eurocode 3 and AISI 360, currently use cross-section classification and linear elastic, perfectly-plastic material models in predicting cross-section compression and flexural resistances. Comparison with existing experimental data shows these traditional design methods can be overly conservative in estimating cross-section capacity particularly for stocky cross-sections, as seen in Figure 1. There are a number of existing compressive tests where the ultimate compressive resistance is far in excess of the yield load \( N_y \), the assumed maximum compressive resistance.

The CSM features two key differences compared with traditional design methods. Firstly, the concept of cross-section classification is replaced with a continuous relationship between local slenderness and deformation capacity. This better reflects the observed continuous nature of section capacity reducing with increasing local slenderness, rather than the discontinuous nature that section classification currently suggests. Secondly, strain hardening material models are utilised, allowing the limiting material stress to exceed the yield stress as seen in coupon tests. Previous work on the CSM has focussed on plated cross-sections in structural steel, stainless steel and aluminium.

This new design process has been extended to cover structural steel, stainless steel and aluminium CHSs. In order to extend the CSM to cover metallic CHS a comprehensive dataset was collated, comprising over 500 existing stub column and four-point bending experimental results. The dataset was firstly used to identify the cross-section classification currently under way to extend the design process to cover slender class 4 cross-sections and to undertake reliability analyses.

Another benefit of the improved capacity prediction is that cross-sections benefit from enhanced resistance. Table 1 shows the extra capacity that the CSM provides over the Eurocodes for both compression \( N \) and bending \( M \). It can be seen that for the same cross-section, the CSM offers on average between 5% and 13% additional resistance over current design methods.

Traditional design methods have been observed to be overly conservative in estimating the compressive and flexural cross-section resistances of CHSs. The design expressions determined through the extension of the CSM to cover CHSs can be used by structural engineers to design and build more efficient, cheaper and lighter metallic structures. Designers can specify a more locally slender cross-section, where previously a stockier cross-section would have been required. The ultimate aim is for the CSM CHS extension to be incorporated into international structural steel, stainless steel and aluminium design standards. There are also environmental benefits through the adoption of the CSM, with reduced carbon emissions through more efficient material use, leading to more sustainable construction.

For further information please contact Craig Buchanan (E-mail: craig.buchanan08@imperial.ac.uk) or Professor Leroy Gardner (E-mail: leroy.gardner@imperial.ac.uk).

<table>
<thead>
<tr>
<th>Material</th>
<th>( N_{CSM}/N_{Eurocode} )</th>
<th>( M_{CSM}/M_{Eurocode} )</th>
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</tr>
<tr>
<td>Stainless steel</td>
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</tr>
<tr>
<td>Aluminium</td>
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<td>1.13</td>
</tr>
</tbody>
</table>

Table 1: CSM compression and bending capacity enhancement over the Eurocodes

The limiting material stresses and strain hardening moduli are predicted using material models that incorporate strain hardening. The cross-section compressive and flexural resistances of the CHS dataset are finally determined through appropriate resistance expressions, using the estimated deformation capacities and material properties.

A graphical comparison between the ultimate compressive experimental loads and the CSM and Eurocode capacity predictions is provided in Figure 2. The graph again shows the over-conservatism of current design methods, with ultimate capacities exceeding the Eurocode predictions by a significant margin. It is evident that, on average, the CSM is more accurate and consistent than existing design methods, with the ultimate experimental capacities being closer to the CSM predictions and the CSM regression line having a reduced gradient. Work is currently under way to extend the design process to cover slender class 4 cross-sections and to estimate the extent to which the cross-section can deform before its resistance decreases, due to inelastic local buckling.
New Director of the CICE

Professor Jacqueline Glass MCIOB has recently been appointed as the new Director of the Centre for Innovative and Collaborative Construction Engineering (CICE), whilst also continuing as Professor of Architecture and Sustainable Construction and Associate Dean for Enterprise at Loughborough University.

The CICE is a Centre of Excellence committed to advanced training and research within engineering and management, in order to develop prospective leaders supporting the future of UK businesses. At the core is the prestigious Engineering Doctorate (EngD) programme, which is designed to produce doctoral graduates that can drive innovation in industry with the highest level of technical, managerial and business competence.

The EngD is a 4-year postgraduate award intended for the UK’s leading research engineers who aspire to key managerial industry positions. Research engineers typically spend 70-80% of their time at the premises of their collaborating company, depending on the nature of the project. This EngD is supported by the Engineering and Physical Sciences Research Council (EPSRC) and industry. Since its inception in 1999, the CICE has supported over 150 innovative EngD research projects. These have been undertaken in partnership with more than 85 different sponsoring organisations throughout the built environment sector and under these research themes:

- Innovative construction technologies;
- Construction business processes;
- Advanced information and communications technologies;
- Sustainable design and construction;
- Transport and infrastructure.

Over the years, the CICE has extended its remit beyond the core design and construction activities supported by leading engineering companies, to research and innovation that spans and influences the entire life-cycle of construction and transport.

Taking on the role of Director, Professor Glass has a keen interest in issues relating to construction, technology and sustainability. She joined the School of Civil and Building Engineering at Loughborough University in 2003, and was previously Deputy Director of the CICE. Her previous experience with industry and extensive track record of collaborative R&D with a range of construction companies were two of the key reasons for her move into a more senior role in the CICE. Outside of the University, she is the Chair of the Supply Chain School’s Horizon Group, and active on a number of British Standards committees.

Jacqueline explains that she is: “...fully committed to the CICE, and the EngD qualification at Loughborough. I intend to continue the good work undertaken by the previous Director, Professor Steve Ison, to increase the impact from our research and innovation, by guiding the Centre team and the 40+ Research Engineers through the next phase of CICE’s development.”

For further information about the CICE, please visit http://www.lboro.ac.uk/research/cice.

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Its sponsors wish to promote the benefits of research and innovation, improve contacts between industry and researchers, encourage investment by industry in research and innovation, by guiding the Centre team and the 40+ Research Engineers through the next phase of CICE’s development.

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