PRACTICAL APPLICATIONS FOR CONSTRUCTION AND THE BUILT ENVIRONMENT

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IN THIS ISSUE

Seismic testing of FlexiArch™

Masonry arch bridges are one of the oldest forms of bridge construction and have been used for thousands of years. They were originally built of stone or brick, but modern rigid arch bridges are built of reinforced concrete or steel. The introduction of these new materials allows arch bridges to be longer than previously achieved with lower rise-to-span ratios and, with reinforced concrete as the main material, can either be cast on site or manufactured as precast. However, a common problem with such bridges is corrosion of the reinforcement, which can lead to high repair and maintenance costs. Therefore a bridge with no or low amounts of reinforcement is a significant step change and should provide bridges with improved durability and whole life performance.

The FlexiArch™ is a patented system for the rapid construction of an arch, based on modern precast concrete methods, which in service performs like a conventional masonry arch. The patent holder, Professor Adrian Long FREng of Queen's University Belfast, has worked closely with Macrete Ireland Ltd for nearly 10 years on the development of the system. Two Knowledge Transfer Partnerships (KTPs) between Queen's University and Macrete have had significant input from Professor Long, Dr Su Taylor and Dr Daniel McPolin.

The method of construction (see Figure 1) utilises precast concrete voussoirs in combination with polymeric reinforcement and a concrete screed so that when lifted it takes up the prescribed arch geometry under gravity forces. Thus no centering is required and construction is very rapid. The system is very sustainable as it has no corrodible reinforcement and the flat-pack FlexiArch elements can readily be stacked during storage and for transportation to site.

In their current KTP, Macrete and the University are aiming to create FlexiArch design tools, and develop a range of complex-geometry FlexiArch systems for new bridges, and to strengthen existing bridges. However, the rest of this article discusses a collaboration with the University of California, Irvine, which is supported by a Royal Academy of Engineering Global Research Scheme Award to Dr Su Taylor at Queen's.

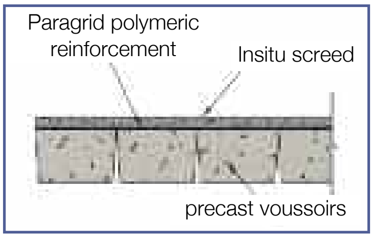


Figure 1 (top): *The key elements of the FlexiArch design.*
Figure 2 (above): *Construction of a FlexiArch Bridge.*

To date, there has been no physical monitoring of the system under seismic loading. The collaboration aims to test the FlexiArch bridge system under seismic loading and to model its behaviour. It is anticipated that the 'FlexiArch' will perform at least as well as conventional masonry arches which have been in service in seismic areas of the world for centuries.

This partnership will enhance the knowledge of the behaviour of FlexiArch under seismic loading and make use of advanced sensor technology for structural health monitoring. Figure 2 shows the FlexiArch rings being installed to form an arch bridge, and shows other elements of the design. The research will use intelligent data interpretation to predict damage via full-scale testing at Irvine, and to establish the behaviour under seismic loading to validate predictive modelling.

For further information about the Royal Academy of Engineering Global Research Award Scheme, please contact Angus Baker (020 7766 0606; E-mail: angus.baker@raeng.org.uk).

For further information about the current research, please contact Professor Long (028 90974005; E-Mail: a.long@qub.ac.uk) or Dr Su Taylor (028 90974010; E-mail: S.E.Taylor@qub.ac.uk).

New guide for assessing reservoir safety risk

A joint project is under way to develop a methodology for assessing risks affecting the safety of the wide range of reservoirs and dams found across the UK. The guide will use a commonly agreed framework that is technically robust, scalable and proportionate.

Since the House of Lords Select Committee review of dam safety in 1982, there have been various attempts to introduce a quantified approach to the assessment of dams and reservoirs, but none have gained universal acceptance. Internationally, various developments of a similar nature have been made, but with limited transferability to the UK.

It has become clear that a structured risk assessment framework (along with associated tools and techniques), that specifically reflects the context of the UK dam industry is becoming increasingly required to support asset and business management, and to minimise risk to lives and the environment.

The new 'Risk Assessment for Reservoir Safety' project is developing a framework and associated methods that will build upon existing Environment Agency concepts and take into account recent approaches used for fluvial and coastal flood risk assessment. It is important that this framework and methods will be able to meet the needs of the dams and reservoirs industry, and this project is being carried out in close consultation with them.

The common risk analysis framework will feature:

- the use of a common approach – from flood embankments through to small and large dams;
- reservoir flood risk integrated into national assessment of flood risk; and
- compliance with the European Floods Directive requirement to address flood risks from all sources in a structured and traceable manner.

The framework will also be of support to OFWAT in its role of determining capital expenditures by water companies.

The project is building on the outputs from two recent projects: (i) '*Scoping the process for determining acceptable levels of risk in reservoir design*' (Defra Report FD2641, 2010); and (ii) '*Scoping study – Modes of dam failure and monitoring and measuring techniques*' (Environment Agency Report SC080048/R1, 2011).

The project is funded by the Environment Agency and is being delivered by a team of industry experts led by HR Wallingford. The Project Steering Group includes representatives of water companies, geotechnical engineering consultants, reservoir engineers, and the Environment Agency. The team is consulting with the wider dams and reservoirs industry through practitioner workshops. The risk assessment methodologies will be piloted on reservoirs in England and Wales.

For further information, please contact Mike Wallis, HR Wallingford (01491 822373; E-mail: m.wallis@hrwallingford.com).

Sywell Reservoir, Northamptonshire. The new Guide to Reservoir Safety Risk Assessment will be applicable to the wide variety of dams in the UK.

Correction/addition to HR Wallingford article in IRF86

In Issue 86 of IRF, the HR Wallingford article on the international good practice handbook on flood defence embankments unfortunately left out some of the supporters of the work and included a few that were not. The correct full list of supporters of the UK-Ireland input being managed by CIRIA is as follows, with those missing from IRF86 highlighted in bold text: the Environment Agency, the Office of Public Works Ireland, the Scottish Government, the Building Research Establishment, HR Wallingford, **BAM Nuttall**, **Black & Veatch**, **the Institution of Civil Engineers**, **Opus**, Royal Haskoning, Halcrow, Mott Macdonald and Atkins.

HR Wallingford is leading and coordinating the technical input from the UK and Ireland. Details of all of the partners and funding organisations, including those from France, Germany, The Netherlands and the USA as well as the UK, can be found on the project website at www.leveehandbook.net.

For further information, please contact Mike Wallis, HR Wallingford (01491 822373; E-mail: m.wallis@hrwallingford.com).

IRF distribution change: you can still ask for a physical copy

This is the first issue of IRF to be mainly distributed electronically. However, as indicated in recent issues, if you are an ICE Member or Fellow or another sponsor's contact who would prefer to receive your IRF as a physical copy, you will still be able to have one. If you do, please email the Editor's PA, Melanie Manton (irf@venablesconsultancy.co.uk), with your name, address ICE Membership grade and number, or the name of the sponsor who sends you a physical copy, asking to be added to the IRF (physical) mailing list.

Low carbon project design

In the absence of any agreed national guidance, a significant number of civil engineering companies have developed or are starting to develop carbon tools. Although many in the sustainability community are wary about the results of a narrow focus on the carbon agenda, the reality is that the UK climate change legislation has imposed a tight timetable for an 80% reduction of carbon omissions to 2050; hence we need tools to help us to understand possible actions and progress better.

A selection of projects that represent those that are or need lower-carbon performance (photos by Roger Venables).

On 23 November, ICE published its report on low carbon trajectories to 2050. Produced by a Steering Group chaired by Tim Chapman of Arup as part of a Presidential Commitment by Peter Hansford a year ago, the report recommends a number of commitments for ICE, and a number of priorities for government and society. These are:

Priority 1: Establish a shared understanding of the purpose and performance requirements of UK infrastructure

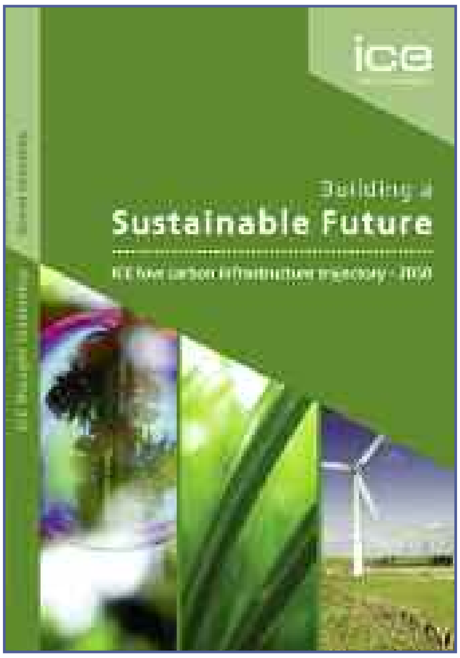
Infrastructure exists to meet the economic, social and environmental needs of the nation. In practice this means that minimising carbon emissions associated with infrastructure is likely to require trade-offs between many potentially conflicting objectives. To make such decisions in a consistent and rational way will require a widely shared understanding of the purpose and performance requirements for our national infrastructure.

The UK Government, through the National Infrastructure Plan, should set out the future requirements for each aspect of infrastructure expressed as output-based performance requirements. This will need to include level of service to be provided, accessibility, reliability and resilience, alongside carbon emission targets and other aspects of sustainability. These performance requirements should be reported on through a *National Infrastructure Scorecard* that also includes measures of the adequacy of investment plans and the health of the underpinning skills and research base.

Priority 2: Establish an effective, transparent and predictable carbon price as the centre piece of a package of incentives for developing low carbon infrastructure

Carbon emissions are a classic example of negative externalities resulting from market failure. An effective and stable carbon price should be a potent mechanism for addressing this failure and will encourage asset owners to invest in low-carbon technologies and other measures. It will also encourage users of infrastructure to make the necessary changes to their behaviour.

The UK Government is felt by ICE to be right to commit to setting a carbon floor price. This should form the centre piece of a package of incentives to encourage investment in low-carbon infrastructure and changed behaviour by its users.



Priority 3: Systematically apply the concepts of Capital Carbon and Operational Carbon to infrastructure decision making

Carbon emissions are associated with each stage of the infrastructure life cycle: design; construction; maintenance; usage; dismantling and/or refurbishment. Capital Carbon (CapCarb) is the carbon expended in creating an asset and where Operational Carbon (OpCarb) comprises carbon emissions from all aspects of operation and usage of items of infrastructure. Often, options that are more-carbon-intensive in the construction phase allow for significantly reduced emissions during use or the operational phase. Engineers must be engaged in projects at the inception stage and must contribute to the task of balancing Capital and Operational Carbon to minimise whole life emissions.

In a break from much current practice, these assessments must include the carbon arising from the *use* of infrastructure, such as vehicles on road or rails, and must take a system-wide view of the impact of individual projects on the performance of networks.

A concerted research effort is needed to create usable inventories of carbon emissions for all stages of asset life in each network. Government should also identify the most effective way of ensuring that all public and regulated infrastructure owners consider the CapCarb and OpCarb of their assets in their strategic investment plans.

Priority 4: Establish a high level evaluation methodology for use at the appraisal stage of infrastructure projects

The greatest carbon savings in an infrastructure project can be made at the appraisal stage by selecting the best strategic option before detailed design and construction begin. This is therefore the crucial point for balancing capital and operational carbon, whilst still meeting the fundamental objectives of the scheme. Prevalent industry practice tends to seek carbon savings at later stages in projects when the most radical options to reduce carbon are no longer possible.

An industry effort is required to develop a high-level evaluation methodology for use at the appraisal stage of projects. This will enable investment decisions to be made in full knowledge of the whole-life carbon impacts of options.

Priority 5: Make greater use of demand management

A number of elements of UK infrastructure are under considerable stress from very high usage levels, leading to high levels of congestion at periods of peak demand. This creates additional carbon emissions in those networks and reduces the social and economic value of that infrastructure. "Predict and Provide" would lead to higher emissions through unnecessary new build, often just to cover isolated peaks of extreme demand, and may in itself create additional demand, leading to further congestion.

If infrastructure is to meet performance requirements and deliver its full range of benefits to society, ICE's low-carbon steering group believe that greater use must be made of a variety of measures to manage demand for infrastructure services.

ICE will engage with all stakeholders to address the adequacy of the UK research effort into low carbon infrastructure and identify, and promote future needs to enable universities and research funding bodies to coordinate their efforts into a concerted programme to improve the carbon efficiency of infrastructure.

For further information please contact Simon Whalley, ICE (020 7665 2210; E-mail: simon.whalley@ice.org.uk).

Designing resilient cities: good practice guidance

Civil engineers create the infrastructure on which cities depend, with design lives stretching towards 100 years. The question of whether these are good investments can only be answered with "it depends on how the future develops". However, predicting the future is complicated: perhaps the only certainties are change and that we must live within our planetary boundaries. Current influencing factors include climate change, the UK Government's emphasis on localism, the global recession, peak oil, rising world populations, and the continuing urbanisation trend. How civil engineers respond to these factors will underpin the resiliency of our cities and how we live, work and play in the future.

The Urban Futures research programme has provided a means to address these challenges by focusing on the likely long-term performance of today's urban design solutions. It aims to change the way that engineers deal with long design lives, and thus the way they think about the relevance and shape of their projects.

Urban Futures is a four year research project which started in May 2008, funded by the Engineering and Physical Sciences Research Council. The project consortium is led by Professor Chris Rogers at the University of Birmingham and includes researchers from Birmingham, Exeter, Lancaster, Birmingham City and Coventry Universities. Professor Rogers is also Chair of the ICE's Innovation & Research Expert Panel, which has created a vision for the future research needed to advance the industry: "Engineering to Live within Planetary Boundaries: Civil Engineering Research Needs". The initiatives are wholly complementary.

The Urban Futures Method provides a way to assess the resilience of today's engineering solutions, many developed in the name of sustainability, by exploring their ability to continue to deliver their function in the face of future change. If the solution works across a range of alternative futures, the investment is likely to prove robust; if not, the solutions can be altered in an informed way, or they can be implemented in the knowledge that they might prove a risky investment. Either way, enhanced confidence in urban design should result.

One of many futurologists' views of the infrastructure challenges ahead.

By incorporating a scenarios analysis based upon four distinct, extreme-yet-plausible, future scenarios, the Method guides the user through the complexities of thinking about the impacts of changes in society, technology, economy, environment and policy. This is made possible because the characteristics of all four futures have been established in considerable detail, and thus it is possible to 'enter' each future to explore a solution's performance.

The four futures build on the work of the Global Scenarios Group:

New Sustainability Paradigm, in which individuals and communities share common values around sustainable living within the resource limitations of the planet;

Necessary Conditions	New Sustainability Paradigm (NSP)	Policy Reform (PR)	Market Forces (MF)	Fortress World (FW)
Non-potable water demands must exist	Sustainable water using behaviour and willing adoption of highly water efficient technologies greatly reduce non-potable water demands	Policy requires adoption of highly water efficient technologies, but behaviours remain unchanged; non-potable water demands reduce	No change in user behaviour and no adoption of water efficient technologies; non-potable water demands remain high	Non-potable demands are high inside the fortress (technology and behaviour mirror MF) and low outside the fortress (poverty and scarcity drive very low water use)
Enough water must be collected to meet non-potable water demands	Even with relatively low volumes of water collected in summer months demands can be met all year round	Ability to meet non-potable demands in summer months (when daily collection < supply) requires large RWH tanks	Ability to meet non-potable demands in summer months (when daily collection < supply) is unlikely to be practical: very large RWH tanks needed	In dense high occupancy areas outside fortress both demand and potential for collection are low. Large RWH tanks inside fortress might not be adequate to meet demand
Enough water must be available (from existing supplied and stored water) to meet non-potable water demands	Supplies are unchanged and demands greatly reduced; there is surplus potable water to cover for summer water shortages, but it is unlikely to be needed	Supplies are unchanged and demands reduced; there would be some surplus potable water to cover for summer water shortages; small RWH tanks might run dry	If potable water supplies remain unchanged and since demand is high, RWH tanks are likely to run dry for long periods in the summer	Inside fortress the situation is as for MF if potable water supplies remain unchanged. Outside fortress limited collection and storage might not meet demand, even though it is low
System must be acceptable to the community	Highly acceptable solution, since people accept sustainability arguments and are willing to change their behaviours	Variable acceptability, but wide uptake; policy dictates this	Low acceptability and little uptake of RWH as water is relatively cheap and systems are expensive (unless the cost of water increases)	High acceptability and uptake as security of supply is important both inside and outside the fortress

Key: red = condition does not continue in the future, amber = condition is at risk of not continuing in the future, green = condition does continue in the future

Policy Reform, in which strong governance and policy directives forces society to operate more sustainably even though values remain largely unchanged;

Market Forces, in which the market is freely allowed to dictate policies and behaviours;

Fortress World, in which a wealthy elite secure the resources they want inside fortresses and the impoverished majority live outside the fortresses subsisting on whatever resources remain.

The basis of the Method is that, for each sustainability solution, the intended benefits are defined and the conditions necessary for their continued delivery are determined. Each necessary condition is then assessed in the four futures.

Consider a relatively simple example of implementing rainwater harvesting (RWH) as a sustainable local water management strategy for a redevelopment project. This has an intended benefit of reducing the volume of potable water required by the site and, for this example, would mean that the existing supply capacity might be sufficient whereas without RWH additional supplies and associated infrastructure would be needed. There would, of course, be infrastructure costs associated with the use of rainwater for toilet flushing, for example, but in areas of water scarcity this could prove attractive. There might be other intended benefits (e.g. mitigating flooding); these would be assessed separately.

The table opposite lists four necessary conditions that must be maintained in the future if RWH solution is to remain effective, and their assessment in the four futures. The outcomes are listed in the table, yet the reasoning can only be definitively established by consulting the detailed characteristics of the futures.

Each assessment reflects the far future (say 40 years hence) and is done in isolation, i.e. without consideration of how the current situation morphs into the future. Other influences, such as climate change, will alter the context in which a solution is judged (e.g. higher temperatures, more intense rainfall events, longer periods of drought); it is simply a matter of overlaying high, medium and low impact variants to elucidate what the changes might be.

In this case RWH will likely work well in three scenarios as long as the tanks are large; it will only likely work in the Market Forces scenario if pricing controls regulate water use.

The Urban Futures Method is the subject of a new BRE publication: Designing Resilient Cities: a Guide to Good Practice that will be launched in April 2012. It sets out the framework for implementing robust, future-proofed solutions at any regeneration scale.

If you are interested in attending the launch, or if you would like more information about the Urban Futures research project, please contact Joanne Leach, Project Manager, University of Birmingham (0121 414 3544 or 07785 792187; E-mail: j.leach@bham.ac.uk, or visit www.urban-futures.org).

Research network for low impact construction

UNIVERSITY OF BATH

LimesNet

EPSRC Pioneering research and skills

The need to radically reduce the global impact of ground engineering and structural engineering for buildings and infrastructure presents significant challenges for the selection and use of materials.

In recent years, the construction product industry has made significant improvements in materials' manufacture, such as the use of cement replacement materials, greater recycling of steel, and more-energy-efficient processes. However, most new buildings have an increased, rather than a decreased, level of embodied carbon. By the end of the decade over 95% of the carbon footprint of new buildings is predicted to be embodied within the materials from which they are made and only 5% from the consumption of energy in the activities in and operation of the building.

Materials used in ground and structural engineering mostly originate from before the 20th century and nearly all rely on a continued supply of cheap (fossil-fuel-based) energy sources for manufacture. If the UK is to meet agreed 80% carbon reduction targets by 2050 it is clear that significant reductions in the embodied carbon of construction materials is required. High-energy materials and systems are unlikely to deliver these reductions in carbon. Materials with greater resilience to the effects of flooding, extreme temperatures and the effects of drought are also required.

In response to a 2009 Review of Academic Research in Ground and Structural Engineering, EPSRC are funding a research network based at the University of Bath. LimesNet (**L**ow **I**mpact **M**aterials and innovative **E**ngineering **S**olutions **Net**work) aims to build a community of researchers and industrialists that will lead to innovative research into materials and technologies. These will significantly reduce the environmental impact of new and existing infrastructure.

Supported activities include workshops for members, support for international engagement work (overseas missions), research proposal development, and a conference in Bath over 12-13 July 2012.

Initially the material scope for LimesNet is cement and concrete, advanced composites, geo-materials, and renewable (plant-based) solutions. LimesNet has recently awarded over £50,000 to its members for international missions that will support knowledge gathering from international centres of research excellence, build sustainable research partnerships, and identify new challenges for construction materials research. The missions will follow up with workshops for network members to develop potentially transformative research projects. The six missions, supporting 30 members, included destinations in Europe and North America to undertake:

- waste fibres in novel composite materials;
- bio-stabilisation of geo-materials;
- novel textile based formwork;
- whole life cycle impact of cement and concrete structures; and
- low impact concrete structure through efficient structural forms.

A second funding round for International Mission Funding, open to existing and new academic members, has recently been launched.

LimesNet membership currently comprises over 100 leading researchers and sector stakeholders, including product manufacturers, building designers, contractors, and clients. Non-academic membership is drawn from across the construction sector including material and product manufacturers; ground and structural engineering consultants; construction contractors and subcontractors; architects and building environment engineers; and clients, property owners and procurers.

The network is now seeking to recruit further members from the industry, as well as those who generally work outside the traditional fields of construction materials, to develop multidisciplinary solutions for challenges of low-carbon construction materials and technologies. LimesNet membership is free for individuals and organisations.

(Top) *Renewable materials is one of four LimesNet research areas.*
(Above) *Delegates at LimesNet launch workshop, September 2011.*

For further information, please contact Professor Pete Walker, LimesNet Project Manager, University of Bath (01225 386646; E-mail: p.walker@bath.ac.uk) or Eloise Spark, Project Coordinator (01225 385235; E-mail: es255@bath.ac.uk) or visit www.limesnet.org.

New on-line acoustic performance prediction tool

The Steel Construction Institute (SCI) has developed an on-line tool to provide structural engineers and architects with a quick and easy-to-use system for working out the likely level of acoustic performance for various forms of construction. The tool – Acoustic Performance Prediction Tool for Separating Floors and Walls – was developed with funding from Tata Steel.

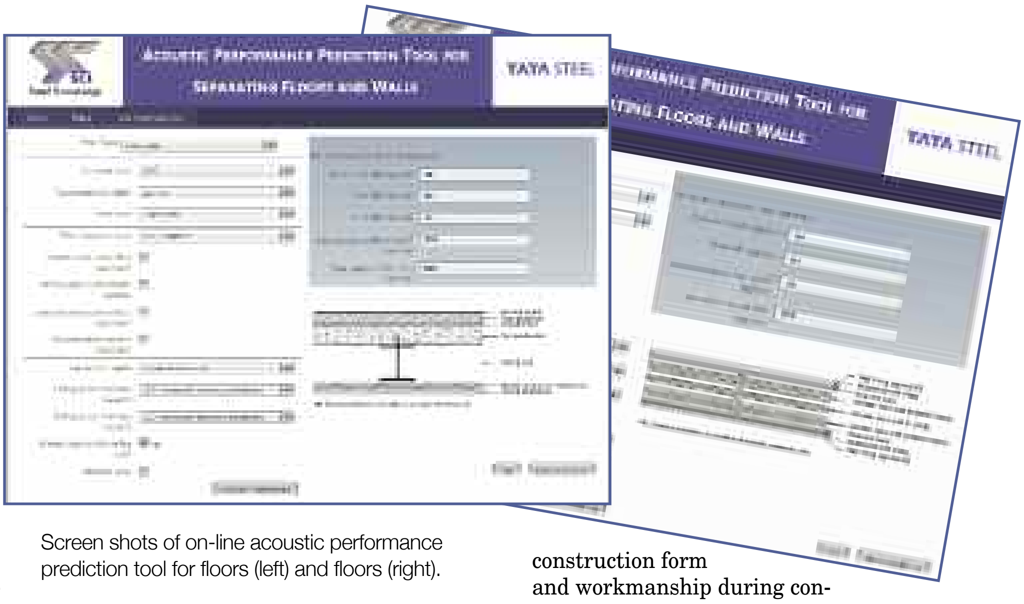
The new tool is able to estimate the acoustic insulation provided by different wall and floor systems used in steel construction. The tool allows the input of different materials and combinations enabling the user to carry out a 'what if' analysis before embarking on a detailed design.

Flooring choices include Tata Steel's Slimdek system; composite flooring; light steel joists; modular; and precast units supported on steel beams. Users can also select from a range of floor treatments and ceiling options. Wall forms are based on light steel framing options including single frame or twin frames with or without acoustic quilting, and a range of different boarding options.

For both walls and floors the airborne sound insulation performance is predicted. Additionally, for floors the impact sound performance is predicted.

The acoustic performance values calculated by the tool are based on the empirical interpretation of actual test data obtained from structures in the residential, health and school sectors. The input parameters of the tool are constrained within specific limits to reflect the range of the source data that has been used to develop the empirical calculation procedure.

The values predicted by this on-line tool are only intended to be used for preliminary design purposes. This is because there are many factors other than specification of the wall or floor format that will affect acoustic performance. For example junction details, exact specification of products, the adjoining construction form and workmanship during construction can all affect real-world performance.



Screen shots of on-line acoustic performance prediction tool for floors (left) and floors (right).

To access the tool go to: www.tatasteelapps.com/acousticperformance.

For further information please contact Andrew Way at SCI (1344 636577; E-mail: a.way@steel-sci.com).

SUSTAINABILITY & ASSESSMENT TOOLS

CEEQUAL for Term Contracts now available

CEEQUAL for Term Contracts is the latest extension of the CEEQUAL Assessment and Awards Scheme for improving sustainability in civil engineering, infrastructure, landscaping and the public realm. It was specifically created for the assessment of engineering and public realm work that is undertaken through contracts covering work in a geographical or operational area over many years. Examples include highway, rail or sewer maintenance, regular interventions in rivers or drainage channels to maintain channel capacity, and a series of minor new works such as road junction remodelling, track maintenance and renewals or minor realignments.

Environmental management of work undertaken through term contracts, which is often distributed over a wide geographical area and with each item of work often comparatively small, presents special challenges. With up to 2000 works orders per month, project-scale environmental management procedures do not work, and need to be amended. CEEQUAL's methodology has therefore been adapted for this way of undertaking the contracted work.

At one end of the scale, the works covered by such contracts may simply be straightforward road maintenance whereas, at the other end, significant new construction may be involved. For this reason, as well as two Manuals, there is the provision for an increased level of scoping-out of questions compared to projects, to match the scale and nature of the works being assessed under CEEQUAL for Term Contracts.

Term contracts offer a convenient means of carrying out large numbers of discrete jobs of relatively low individual value. Through this mechanism procurement costs per job are minimised by work simply being initiated by a written order or instruction.

The success of such a contract is normally a reflection of the strength of the contractor's understanding of the client's requirements, the teamwork generated amongst the parties, and the successful delivery of these requirements. So it is recognised that any assessment of term contracts should be a team effort between all parties involved in the contract: client, designer (if included), contractor and contract manager or engineer. This approach should maximise the opportunity for any CEEQUAL Assessment to be ultimately successful. It is also why there will be just one type of Term Contract Award compared to five for CEEQUAL for Projects.

Telecommunications installation by Skanska for Network Rail.

Those who wish to use CEEQUAL for Term Contracts will need training either through a 2-day Term Contracts Assessor Training Course or, if already a trained CEEQUAL Projects Assessor, through a one-day extension course.

For further information please contact Roger Venables, CEEQUAL Chief Executive (020 3137 2379; E-mail: roger.venables@ceequal.com) or go to www.ceequal.com/term_contracts.htm.

Bridging the gap between predicted and actual energy consumption in non-domestic buildings

With an increasing demand for more energy-efficient buildings, the construction industry is faced with the challenge of ensuring that the energy performance predicted during the design stage is achieved once a building is in use. However, there is significant evidence to suggest that buildings are not performing as well as expected. Initiatives such as the Technology Strategy Board's Building Performance Evaluation Programme and CarbonBuzz, an initiative of RIBA and CIBSE, aim to illustrate – and ultimately try to reduce – the extent of this so called 'performance gap'.

Previous research demonstrated that in-use energy consumption can usually be twice as much as predicted in compliance calculations. Figure 1 (The reality of predicted and actual energy consumption) illustrates some of main causes that lead to this performance gap. As the figure indicates, 'unregulated' energy loads can represent a significant proportion of the total energy consumption in a building. Yet they are not considered in Part L of the Building Regulations and are thus disregarded in compliance calculations. So it is perhaps not surprising that there is such a discrepancy between predicted and actual energy performance, since they are calculated on different bases.

A research project conducted on behalf of the Centre for Innovative and Collaborative Construction Engineering at Loughborough University, and AECOM, is aiming to shed some light onto the impact of unregulated energy use in office buildings. This collaboration – under the EPSRC Engineering Doctorate programme – is currently investigating the extent and nature of unregulated loads in a number of office buildings around the country.

Preliminary findings have already demonstrated a large variation in electricity consumption, due to small power equipment used by different tenants occupying the same office building. These variations can be attributed to a number of factors including:

- hours of occupation;
- workstation density;
- installed equipment loads; and
- occupant behaviour.

Management decisions, such as running IT updates outside working hours that required employees to leave their computers switched on during evening and weekends, were also observed to have significant impact on electricity consumption.

The overall aim of the study is to understand the impact of each of these individual elements on unregulated electricity consumption within office buildings. Currently, the research is focusing on the impact of occupant behaviour, aiming to establish the extent to which building occupants affect electricity consumption due to small power equipment.

A survey is also being undertaken based on the Theory of Planned Behaviour, illustrated in Figure 2. The assessment focuses on the behavioural intent of occupants to switch off appliances when not in use and investigates the precursors to behaviour individually: 1) attitude; 2) subjective norm; 3) perceived behavioural control. Findings will help inform which of these precursors have the greatest influence on electricity consumption (see Figure 2: Theory of Planned Behaviour).

Future work will build on this study and aim to develop evidence-based benchmarks for unregulated electricity consumption in office buildings. It will include a "tailoring" component allowing the benchmarks to be adjusted according to profiles of occupancy and management behaviour, as well as workstation density, and the specification of energy consuming equipment. It is expected that such benchmarks will inform designers about the impact of each of these parameters on the measured energy consumption of buildings, going some way toward explaining the performance gap.

For further information please contact Anna Carolina Menezes, AECOM London (02031 702738; E-mail: Anna.Menezes@aecom.com).

Figure 1: The reality of predicted and actual energy consumption.

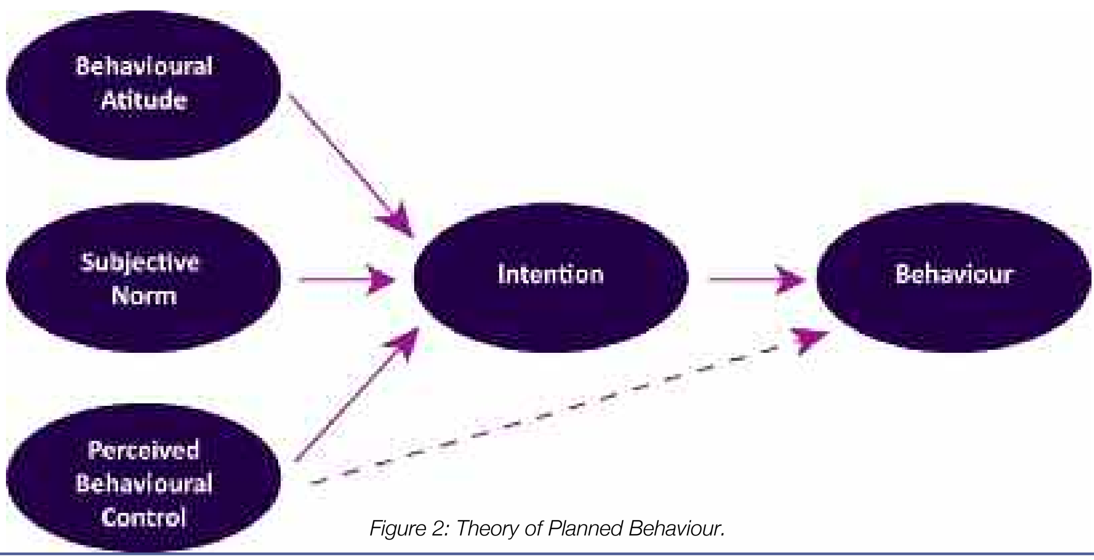


Figure 2: Theory of Planned Behaviour.

Encouraging rainwater harvesting in the UK

Rainwater harvesting is rarely considered for either commercial or residential use in the UK, in spite of the acknowledged scarcity of available water in the south-east of the country. Issues such as the cost of construction, perceived and actual maintenance requirements, and even the embedded carbon cost, all limit the interest in collecting and using rainwater.

Up until now rainwater harvesting has been considered as "green" and only as a mechanism for saving water, despite there being some appreciation that it may give some stormwater benefits in the form of reducing flooding. However, the official position remains that these systems cannot be designed with the presumption that rainwater harvesting helps manage stormwater run-off.

Rainwater harvesting systems can also be used to reduce stormwater run-off rates. (Picture credit: Hydro International)'

Research completed by HR Wallingford (report SR736, 2011) not only demonstrates that rainwater harvesting can provide specific stormwater management benefits, but also provides a unique methodology for sizing the storage tanks to meet specific stormwater control objectives.

This exciting breakthrough means that the use of rainwater to save water, whilst providing stormwater benefits, should favour the use of these systems more widely. This is particularly the case now that best practice stormwater management recognises that stormwater volume control is at least as important as stormwater flow rate. Stormwater volumetric control is required in official documents on rainfall run-off management for developments (such as the guidance in Defra/Environment Agency Technical Report W5–074), and is likely to be in the SuDS standards, which should come into effect in 2012.

Since rainwater harvesting can be designed for specific volume retention of any storm size, this is the only effective mechanism, other than infiltration, available for controlling the volume of run-off. In many circumstances infiltration is not a credible option, due to factors such as high groundwater levels, contaminated land, or low rates of porosity.

In due course, it is expected that awareness of the benefits of:

- soft rainwater for washing clothes and protecting against hard water calcium deposits;
- the protection of rivers due to reduction in water abstraction; and
- the pressures of an increasing population and risk of drought due to climate change;

will all lead to greater uptake of rainwater harvesting.

For further information, please contact Richard Kellagher, Technical Director, HR Wallingford (01491 822419; E-mail: r.kellagher@hrwallingford.com).

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