Research Focus

Issue No. 46 AUGUST 2001

PROMOTING THE APPLICATION OF RESEARCH IN BUILDING AND CIVIL ENGINEERING

IN THIS ISSUE

Indy car track uses TRL research

TRL has been assisting Colas in the construction of the UK's first Indy car track. Construction of the 2 km circuit, to high standards of evenness, has recently been completed at Rockingham, near Corby, Northamptonshire.

F2 car tests out the track

Colas have previously built a test track for Toyota to a similar tight specification for surface profile, which was checked using a Japanese 10m-long computerised straight edge. On this occasion Colas came to TRL for advice and TRL proposed the use of HARRIS to monitor the track evenness. HARRIS, the Highways Agency Road Research Information System, is the result of research under contract to the Highways Agency, for developing a traffic speed road monitoring system using the latest developments in laser technology.

Using on-board processing each layer was surveyed and reported in a day's visit, enabling corrective action to be taken where required prior to laying the next layer. Prior to laying the final surface, the track was tried out using a F2 car and the thumbs up given.

For further information please contact Stuart Wood at TRL (01344 770041; fax: 01344 770356; E-mail: swood@trl.co.uk).

MATERIALS & IT

Web access to concrete research

Concrete.Info, the world's largest bibliographical database specialising in cement and concrete, is now on the Web. It contains nearly 120,000 references to the international literature on its subject, covering materials science, production, civil engineering, standards, design and construction. It is a resource for locating reports, articles and conference proceedings on research and innovation, as well as best practice guidance and case studies. Over 400 journals from around the world are drawn on, and conference papers are indexed individually.

Concrete.Info is powered by Headfast software, specially tailored to the Internet, which provides index searching, Boolean operators, truncation facilities, a speedy sort function and full printing or e-mailing options. Menu-driven help is available on screen. The database is fully searchable by author, publisher, title, source and comprehensive subject keywords. It is updated regularly and is accessible by password.

All records are backed up by documents held at, and available from, the BCA's Centre for Concrete Information – itself a major research resource built up over the past 65 years.

For further information please contact Gina Al-Talal, British Cement Association (01344 725 700; fax: 01344 727 202; E-mail: galtalal@bca.org.uk; Website: www.concrete-info.com).

ABOUT RESEARCH FOCUS

Aims

The principal aim of *Research Focus* is to promote the application of research in building and civil engineering.

Supported by many organisations in the British construction industry, its brief articles on current research are written for practising engineers, architects, surveyors and their clients with the objective of disseminating research news as widely as possible. Its sponsors wish to promote the benefits of research, improve contacts between industry and researchers, encourage investment by industry in research and the use of research in practice, and facilitate collaboration between all the parties involved.

Formally, *Research Focus* is an unrestricted newsletter containing invited factual records or case studies of building or civil engineering research projects. Articles may be reproduced, provided the source is acknowledged.

Enquiries and Comments

If you wish to know more about a specific project, you should contact the person named at the end of the relevant article. Look on the back page for addresses, telephone and fax numbers of the sponsoring research organisations and professional institutions. General information about their activities may be obtained from them directly.

We welcome your ideas on ways to improve *Research Focus* and so help it to achieve its goals. If you have a suggestion, or an article about an interesting piece of R&D, please send it to the Editor, Roger Venables, at the address below.

Editorial Advisory Panel and Editor

Overall editorial policy is set by the Editorial Advisory Panel which comprises:

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DISTRIBUTION

If you receive *Research Focus* by direct mail (i.e. not with NCE) and the address it is sent to is incorrect, if you would like additional copies for circulation within your organisation, or if you would like to be added to the direct mail list, please contact Dr John Bennett at the Institution of Civil Engineers, 1 Great George Street, London SW1P 3AA
(020 7665 2205; fax 020 7799 1325;
E-mail: john.bennett@ice.org.uk).

Research Focus is also downloadable from the ICE website (www.ice.org.uk) and readable using Acrobat software.

Improving projects through standardisation, pre-assembly and modular construction

The Egan report, *Rethinking Construction*, identifies standardisation and pre-assembly as having key roles in improving UK construction performance. Although attractive to some, there has been a general, industry-wide reluctance in the UK to accept and acknowledge potential benefits offered by standardisation, pre-assembly and modular construction (SP&M). The decision to optimise SP&M is often not made early enough in the design process, resulting in inefficient adaptation of traditional designs.

Standard components can be used to construct …

Anecdotal evidence suggests that SP&M are 'cost effective', but previous research has failed to uncover firm evidence in support of this claim. Two academic-industrial partnerships, with research bases at Nottingham and Loughborough Universities, are currently developing decision-making toolkits that appraise the opportunities for using SP&M.

MEDIC (***M**odular **E**ngineering **D**esign **I**ntegrated **C**onstruction*) is being carried out at the University of Nottingham. The MEDIC project is studying knowledge and experience transfer from prefabrication of building services to building designers and clients. The work is being carried out in collaboration with six industrial partners and is sponsored by EPSRC for a duration of two years.

IMMPREST (***I**nteractive **M**odel for **M**easuring **PRE**-assembly and **St**andardisation benefit across the construction supply chain*), at Loughborough University, complements MEDIC by measuring SP&M benefits across the entire supply chain, and also dovetails with CIRIA's toolkit on Standardisation and Preassembly strategy. The project aims to produce an interactive modelling tool that facilitates the evaluation of benefit arising from use of SP&M by allowing comparison with traditional methods.

The project is being undertaken in conjunction with 11 industrial partners and is funded by EPSRC and the former DETR. The research team is looking for further collaborators to extend the study into electrical services, frame, envelope and internals.

IMMPREST and MEDIC are live projects. Dissemination of information to both industry and academia is via workshops, seminars, conferences and the internet. The toolkits will be available on CD; please check the websites for launch dates.

For further information please contact:
***MEDIC** – Ana Brankovic, School of Civil Engineering, University of Nottingham (0115 846 6055; fax: 0115 951 3898; E-mail: ana.brankovic@nottingham.ac.uk; Website: www.civeng.nottingham.ac.uk/medic/start.htm).*
***IMMPREST** – Nick Blismas, Department of Civil and Building Engineering, Loughborough University (01509 223782; fax: 01509 223981; E-mail: N.G.Blismas@lboro.ac.uk; Website: www.immprest.com).*

Whole buildings … these are very different to people's perception of the 'post war' prefab

The use of new materials and composites in delivering customer needs and benefits

A study recently completed by Buro Happold for CRISP (the Construction Research and Innovation Strategy Panel) sought to understand how new materials are selected or developed and how they can bring benefit to clients. New materials in this context includes new applications for existing materials as well as genuinely new materials.

There are many barriers in the construction industry to the rapid introduction of new materials or systems. To some extent these are necessary, as safety must be a primary concern, but opportunities need to be taken to provide a better product.

Another key point is the difference in perspective of different industry players. This leads to groups seeking to address various objectives, and not necessarily those that best serve clients. For example, a structural engineer may be seeking a material with a better strength-to-weight-ratio. However, whilst their client may be interested in the increased light or lower costs that reduced structure can bring, interest in material properties for their own sake is unlikely.

The three-part study comprised:

- a telephone survey of engineers, architects and others involved in using or specifying new materials;
- a survey of recent research initiatives and publications related to 'new' materials, both in general and in the construction industry;
- a survey of broader literature relating to the uptake of new technologies.

The team took a fairly loose description of 'new' to include materials and systems for which there is a substantial growth potential, as well those that have thermal and cost benefits as radically new materials. A list of 100 'new' materials was identified, indicating benefit to clients. Examples include:

- ETFE foil cushions, which have thermal and cost benefits (as used in the Eden project and Hampshire Tennis Centre, Eastleigh);
- cardboard made from recycled paper (as at Westborough school);
- timber gridshells that use a low-cost renewable resource (as in the Weald and Downland museum – see picture);
- fibre-reinforced polymers, which bring shape flexibility and cost/weight benefits (as in the Glasgow Wing Tower cabin and mast).

Buro Happold observed that:

- very little research undertaken focuses on client benefits;
- most research into new materials and their application in buildings is undertaken by prime producers;
- research into the use of low-tech materials such as adobe is hampered as no industries have interests in improving their market position;
- the dominant influences on the choice of materials are cost and safety (especially in a fire), as they have been for over 200 years, with visual appearance also very significant for finishes;
- research institutes representing materials used in building construction fund very little research of their own although they are often active in multi-participant, collaborative research projects;
- university research into materials is not well focused on the direct *application* of the materials;
- broadly, few of the issues on which clients make their decisions are directly linked to materials.

Gridshell structure under construction for the Weald and Downland museum. Architect Edward Cullinan (Buro Happold).
(*Photograph courtesy of Mackley Construction Happold*).

The study team recommend that the construction industry would benefit from focusing more carefully on customer or client benefits. This could be accelerated by studying certain other industries, for example automotive, aerospace and shipbuilding. This applies particularly to how materials can meet clients' needs. Secondly, suggestions have been made for areas where research could usefully be funded. A CRISP Task Group is now considering these and putting its opinions to funding bodies.

For further information please contact Buro Happold: Andrew Cripps or Bill Harris (020 7927 9700; fax: 020 7927 9701; E-mails: andrew.cripps or bill.addis@burohappold.com. *Contact CRISP via Martin Lockwood at Davis Langdon Consulting (020 7379 3322; fax: 020 7379 3030; E-mail: martin.lockwood@davislangdon-uk.com; CRISP Website: www.crisp-uk.org.uk).*

dti Department of Trade and Industry

Timber in coastal engineering

Research Focus 45 featured HR Wallingford's work on 'Building sustainable coastlines'. Staff at HRW start a new project this summer entitled 'The use of timber in coastal and fluvial engineering'. Work has again been funded by the former DETR and project partners include the Timber Research and Development Association, coastal local authorities, British Waterways and the Environment Agency.

'When correctly used, timber is an attractive engineering option in terms of both whole-life cost and sustainability,' says Jonathan Simm who leads the study. 'The new project will provide guidance on how to use timber effectively, promoting environmental best practice, including re-use and recycling.'

For further information please contact Jonathan Simm at HR Wallingford: (01491 822355; fax: 01491 825539; E-mail: jds@hrwallingford.co.uk) or Matt Crossman (01491 822273; fax: 01491 825539; E-mail: mpc@hrwallingford.co.uk)

Photograph courtesy of Mackley Construction

www.cladding.org – a website on cladding for all

A new website providing information from research into cladding is now available at http://www.cladding.org http://www.cladding.org. The aims are to provide a learning resource for those in education and research, and provide a bridge to industry.

Cladding.org is the website of Task Group 25 – Facade systems and technologies – of CIB (International Council for Research and Innovation in Building and Construction). It is managed by the Centre for Window and Cladding Technology. The site covers all aspects of cladding and facades, including:

- structural performance;
- weatherproofing and sealing;
- building physics;
- materials;
- construction process;
- durability.

The whole range of building envelopes and cladding elements is embraced, including domestic and industrial building, and architectural cladding.

The site is independently funded and therefore does not reflect narrow industry interests. It includes papers from refereed conferences (for example, from the International conference 'ICBEST '97' which the Centre hosted in 1997) and has links to researchers and research institutions.

For further information please contact Brenda Apted at CWCT (01225 826541; fax: 01225 826556; E-mail: b.a.apted@bath.ac.uk).

CENTRE FOR WINDOW AND CLADDING TECHNOLOGY

Flood of research projects

Researchers at HR Wallingford have been awarded six new contracts by the former DETR. One of these, 'Design of flood-resistant buildings', looks at how property can be protected against flooding – a highly topical subject after the problems of last winter, when an estimated 7000 properties suffered flood damage.

The main research work will start in September 2001 and involves partners from BRE, Environment Agency, CIRIA, the Association of British Insurers, National House Building Council, Severn Trent Water and a range of organisations concerned with the construction and housing industries. The project is preceded by a Scoping Study dealing with the issues of protecting property from flooding (and repairing it), work initiated by the Environment Agency and DETR and started in April.

The HRW project will build on the findings of the Scoping Study and review and evaluate existing flood resistant products and techniques. 'We aim to test and validate the best of these and recommend regulations for their use on at-risk properties,' says Pam Bowker of HRW. The results should benefit householders and insurers, by reducing the risk of trauma and damage during floods. It should also help local authorities and emergency services by easing the demand on their services.

For further information please contact Pam Bowker at HR Wallingford (01491 822425; fax: 01491 825916; E-mail: p.bowker@hrwallingford.co.uk).

Buildings that save water

Relatively little guidance on the use of rainwater and greywater systems in buildings existed in 1997. Since then CIRIA has been active in a number of areas to help improve knowledge and good practice regarding these systems.

CIRIA has led a series of linked projects, in partnership with BSRIA, and in collaboration with a wide range of stakeholders including the former DETR, the Environment Agency, water utilities, universities, suppliers and manufacturers.

The *Buildings that save water* project has now provided three reports to assist in decision-making when selecting rainwater or greywater systems, to promote good practice in their installation, operation and maintenance, and to provide technical information and data from a number of the sites monitored as part of the initiative. Information is given on issues such as barriers to use, water conservation strategies, economics, regulation, water quality, components and materials, uses of reclaimed water, and detailed issues for rainwater and greywater systems in their own right.

The work has drawn many conclusions that are of interest to a wide range of individuals, and has identified ways in which rainwater and greywater systems may be improved in the future. During the life of the project the systems have continued to evolve and develop but many of the areas identified have not yet been resolved. These matters need to be addressed if rainwater and, particularly, greywater are to provide safe alternatives to using mains water.

The project was funded by Anglian Water Services Ltd, CIRIA, Creda Ltd, Department of the Environment, Transport and the Regions through the *Partners in Innovation* scheme, the Drinking Water Inspectorate (DWI), Essex and Suffolk Water, the National House-Building Council, North West Water, Southern Water Services Ltd, Thames Water Utilities Ltd, The Environmental Protection Group Ltd, Dwr Cymru (Welsh Water plc), Wilo Salmson Pumps Ltd and Yorkshire Water Services Ltd.

Greywater recycling plant

For further information please contact CIRIA (020 7222 8891; fax: 020 7222 1708; E-mail: rfocus@ciria.org.uk; website: www.ciria.org.uk).

CIRIA

Robustness test on concrete frame building

A section of a corner column of a seven-storey concrete frame building was removed from the ground floor in a recent test to examine the robustness of the building.

The building was the European Concrete Building Project cast in-situ concrete frame at BRE Cardington. The DETR-funded test was done to:

- examine the robustness of the building (designed to EC2) and enhance the confidence of engineers in this form of structure in the event of accidental damage to a column;
- gain a better understanding of the whole-building behaviour of a real structure;
- calibrate analytical modelling tools to allow better prediction of the behaviour of other complex structures;
- demonstrate the use of advanced monitoring techniques.

Before removing the column section, engineers installed a rig, supported by hydraulic jacks, to temporarily take the load of the column. During the test the hydraulic pressure was reduced in steps to zero, leaving the corner of the building to hang unsupported.

A section from the ground floor corner column of a seven-storey building has been removed to test the building's robustness.

More than 200 sensors were installed in the building to monitor downward deflection, creep deflection and cracking. The building performed extremely well – downward deflection was just 35 mm. The building was left unsupported for almost 3 days during which creep deflection was about another 3 mm. Only minor cracking developed in the slab and columns.

This test was followed by upward movement testing in which the hydraulic jack system lifted the corner of the building, introducing a greater load into the corner column. The building moved up 52 mm under an up-thrust of 1545kN (over twice the dead load downward), resulting in only modest cracking.

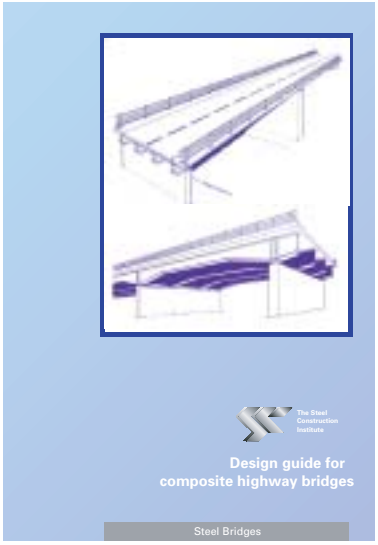
For further information please contact Stuart Matthews at BRE (01923 664559; fax: 01923 664786; E-mail: matthewss@bre.co.uk).

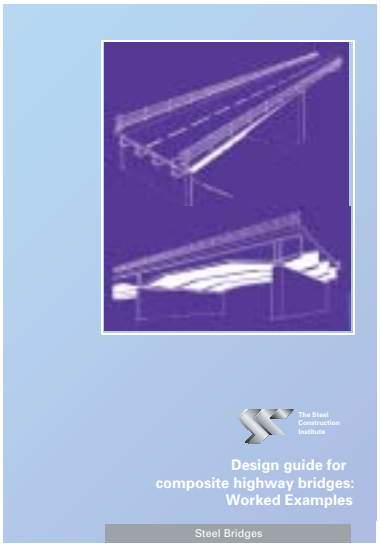
BS 5400-3:2000 Design code for steel bridges

The revised design code for steel bridges, BS 5400-3:2000, has recently been re-published. Sales of this new document were suspended by BSI in January, because of typographical errors, but since then the document has been thoroughly reviewed and corrected and is now available for use in bridge design. Implementation by Technical Approval Authorities, through the Design Manual for Roads and Bridges, is expected later this year.

The revised code contains extensive updating of many design rules (from those in the original 1982 version). In particular, the rules relating to the evaluation of lateral torsional buckling (LTB) and the restraint system associated with LTB have undergone a major revision.

The intention of the new LTB rules is that they are more able to reflect the actual restraint systems that are used in practice – both intermediate restraints within spans and restraints at supports – although this will inevitably involve the designer in more extensive calculation. Another major revision concerns the rules relating to notch toughness. These have also been amended significantly, again with the intention of reflecting better the range of circumstances that occur in practice.





To help designers come to terms with the new rules, the SCI has re-issued its commentary on BS 5400-3 and its composite bridge design guides, all of which have been revised to the new rules.

To purchase a copy of *BS 5400-3:2000 Design code for steel bridges*, please contact BSI (020 8996 9000; E-mail: info@bsi.org.uk).

To purchase the SCI design aids *Commentary on BS5400-3: 2000, Code of Practice for the design of steel bridges*, the *Design guide for composite highway bridges,* and the *Design guide for composite highway bridges: Worked examples*, please contact the Steel Construction Institute (01344 872775; E-mail: publications@steel-sci.com.

For further information please contact David Iles, Manager Bridges, The Steel Construction Institute, (01344 623345; fax: 01344 622944; E-mail: d.iles@steel-sci.com).

Assessing the benefits of sustainable urban drainage

Current UK drainage systems tend to use gullies and pipes to collect runoff from developed land and carry it into watercourses. Sustainable urban drainage systems (SUDS) use filter strips and drains, swales, permeable surfaces, infiltration devices and ponds to encourage a more natural but managed return of runoff to the water table and thus to promote biological cleansing. This approach helps control flooding and prevent pollution, whilst recharging groundwater supplies. Two recent HR Wallingford contracts funded by the former DETR involve research into sustainable drainage. Both projects aim to increase industry confidence in the benefits of such systems.

Cath Abbott of HRW will lead a team monitoring sites where commonly used SUDS have been installed. Water quality and quantity will be monitored in response to rainfall on each catchment. 'We will then disseminate practical information and guidance on how to select, design and maintain these systems,' she explains.

(RIGHT) Sustainable urban drainage system collecting runoff in Colorado, USA

Bridget Woods Ballard leads a separate group looking at the capital costs, operational expenditure, social impacts and ecological benefits of SUDS.

For further information please contact HR Wallingford: Cath Abbott (01491 822488; E-mail: c.abbott@hrwallingford.co.uk) or Bridget Woods Ballard (01491 822382; E-mail: b.woodsballard@hrwallingford.co.uk) fax for both: 01491 825916).

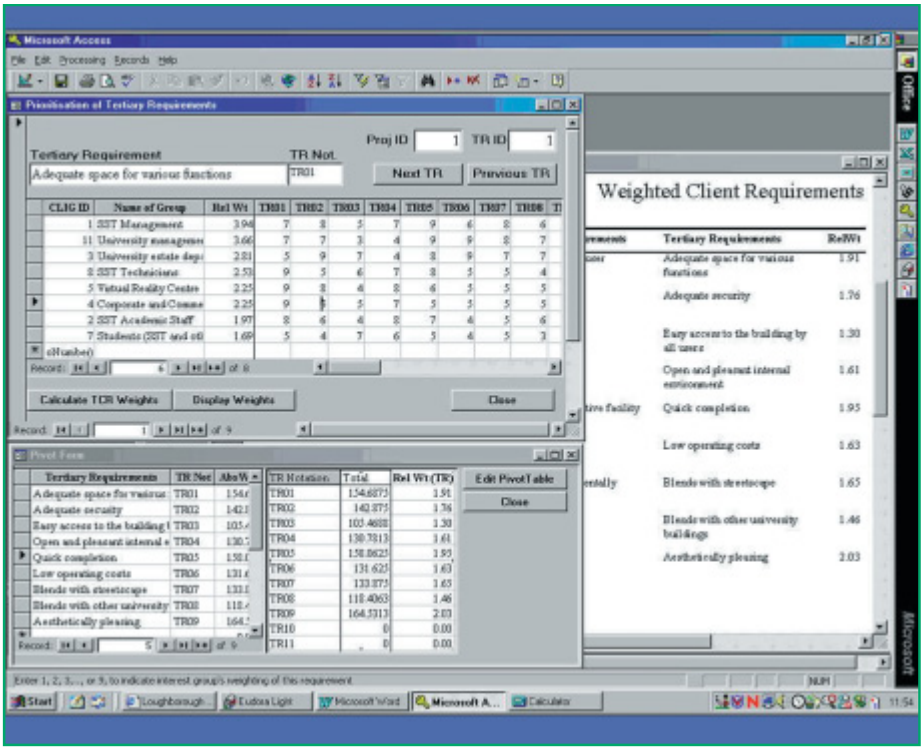
Establishing client requirements

The construction industry has been criticised by both the Latham and Egan reports for often failing to deliver facilities that meet clients' requirements. The problem can be attributed to inadequacies in the conventional briefing process including, amongst others, the lack of a systematic and structured methodology, inadequate focus on the client, poor usage of IT, the use of design solutions to clarify the client's needs, inadequate mechanisms for capturing design intent and rationale, and poor traceability of the client's requirements throughout the project lifecycle.

An innovative and structured approach to briefing has been developed to overcome the above limitations. It facilitates the systematic definition, analysis, and mapping of client requirements to design specifications.

The new approach has been encapsulated in a prototype software, CLIENTPRO, which allows for the clarification of a client's business need for a facility, documentation of the rationale for their preferences, and the capture and prioritisation of the perspectives of interest groups who influence, or are affected by, the proposed facility. It also provides a structured process for prioritising the client's requirements, defining the design solution space (target values), and for translating the 'voice of the client' into measurable design specifications.

Thus CLIENTPRO facilitates better understanding and implementation of clients' requirements, more effective collaborative working, and design creativity. It also minimises uncertainties and downstream problems because of the early consideration of issues affecting the lifecycle of a facility, and provides the basis for effective requirements management throughout the project lifecycle.



Sample screen shot from CLIENTPRO.

For further information please contact Professor Chimay Anumba, Centre for Innovative Construction Engineering, Loughborough University (01509 222615; fax: 01509 223982; E-mail: c.j.anumba@lboro.ac.uk) or Dr John Kamara (0191 222 8619; fax: 0191 222 8230; E-mail: j.m.kamara@ncl.ac.uk).

Combating the thaumasite threat to concrete

The thaumasite form of sulfate attack can be a serious threat to concrete structures if inappropriate constituents are used in aggressive sulfate ground conditions. A greater understanding and recognition of this problem is needed, particularly at the international level.

Structures made of concrete specifically designed to provide good sulfate resistance in accordance with even quite recent guidance can still be affected by the thaumasite form of sulfate attack.

The full extent of the thaumasite problem is still unknown, but it has the potential to affect a wide variety of structures including concrete foundations and floor slabs exposed to sulfate-bearing ground, roads and sub-bases, tunnel linings and sewer pipes. Following extensive research supported by the former DETR, new BRE and BSI guidance is now in place to deal with this.

Thaumasite was first identified as a deterioration product in concrete in the USA in the 1960s. Since then a growing number of cases have been identified worldwide, but mostly in the UK. This phenomenon, which BRE has termed 'the thaumasite form of sulfate attack' or TSA for short, transforms the fabric of the concrete into a white mush.

TSA differs from conventional sulfate attack in that it is the calcium silicate hydrates (CSH) in the hardened Portland cements that are targeted for reaction and not the calcium aluminate hydrates. CSH is the main binding agent in all Portland cements including sulfate-resisting Portland cements.

For thaumasite to form, all the components comprising this mineral (sulfate ions, carbonate ions and calcium silicate or calcium silicate hydrate) must be available. A prominent source of carbonate ions is limestone present in the building material itself as an aggregate or filler, although cases of TSA are known where the carbonate has been supplied externally.

An external source of sulfate ions is also required and the reaction relies on copious amounts of water. So, concrete foundations containing limestone aggregates in wet sulfate-bearing ground would be considered to be at the highest risk of TSA.

Typically, TSA occurs in the concrete of foundations that are either fully or partially buried, so evidence of TSA is always hidden below ground and cannot be detected by routine above-ground inspections.

Although TSA has become a high profile issue in the UK in recent years, and has been found in some other countries, the level of awareness of this form of sulfate attack is surprisingly low on the international stage. To raise international awareness, and to provide a forum for dissemination of research and exchange of ideas, BRE is arranging the First International Conference on Thaumasite in Cementitious Materials, which will take place at BRE's Hertfordshire headquarters from 20 to 22 June 2002.

For further information please contact Norah Crammond at BRE (01923 664367; fax: 01923 664786; E-mail: crammondn@bre.co.uk).

Concrete subjected to the thaumasite form of sulfate attack can become friable enough to be dislodged by hand

New European tests for asphalts

European technical standards on many subjects are being harmonised. Standards for road materials are due to be implemented from December 2003, when they will replace existing British Standards. Some test methods for asphalt have already been published in BS EN 12697 but these standards should not be used commercially until the full package is in place.

To assist industry, TRL has reviewed all the tests that will become part of BS EN 12697. This review was carried out for the Highways Agency, Quarry Products Association and Refined Bitumen Association and is published as TRL Report 461*.

There are over 40 parts of BS EN 12697, some of which are very similar to existing British Standards whilst others are new to the UK. The review explains what each part covers, whether there is an equivalent British Standard and, if so, what are the principal changes. If there is no equivalent British Standard, a more extensive description of the test is given.

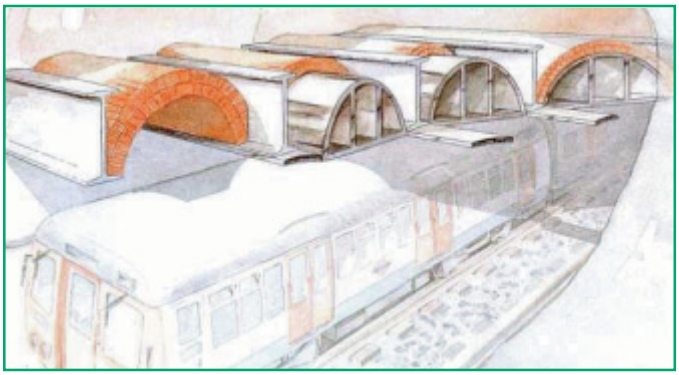
* J C Nicholls, *The harmonised European standard test methods for asphalt mixtures*. TRL Report. TRL 461. 2000.

For further details please contact Cliff Nicholls at TRL (01344 770276; fax: 01344 770356; E-mail: cnicholls@trl.co.uk).

New European permeability tester

Carbon fibre composites

Reducing the cost of ownership of infrastructure in the UK is a clear objective for many asset owners seeking to minimise their financial commitments whilst maintaining and improving the structures for which they are responsible. Large companies tend to be focused on delivering their core responsibilities, so the ability to develop novel, more cost-effective solutions in-house is less than it has been in the past. Accountability of the asset owners has also increased. Programmes such as Partners in Technology have therefore been key in enabling companies to come together, to pool expertise and to support the development and proving of ideas which would otherwise not have been considered. One such idea is that of using carbon-fibre reinforced plastic (CFRP) composites as primary structures in the civil engineering industry.



Schematic of CFRP roof strengthening

CFRP materials are now well known in Formula 1 racing cars and advanced aeroplanes. The key benefit is the same (and often improved) mechanical performance compared to traditional metal structures, but at a fraction of the weight. The performance advantage drives the interest in their use. Weight and performance are not normally key drivers in civil engineering – but interest grows when they result in cost-savings compared to traditional solutions. London Underground Ltd (LUL) operates is such an environment.

Trains need to run for up to 20 hours per day, so any maintenance has to fit within the early hours window when trains are not operating to avoid major disruption for passengers. It can also be difficult to handle heavy items in the railway environment. Lighter components offer the potential of easier handling, reduced time for maintenance, and so reduced cost. CFRP composites are therefore of interest.

Whilst composites have been used for strengthening of structures, they are now being considered for primary structures. LUL need to strengthen jack arch structures, which can be difficult, so they presented an ideal opportunity for which to consider composite materials.

Devonport Royal Dockyard Ltd has led a team, comprising DERA, LUL, MSL Engineering Ltd, Structural Statics Ltd, and Southampton University, on a project addressing the problem and part funded by the former DETR's Partners in Innovation scheme. The consortium had a spread of expertise, including design, composite manufacture, durability of composite structures, structural monitoring and an understanding of the civil engineering environment in which they must work.

The aims of the project (completed at the end of 2000) were to develop a design guide on the use of composites in infrastructure projects and to validate the guide through full-scale testing of a demonstration component – the jack arch-strengthening beam was selected.

The project has successfully designed, constructed and validated a beam 8m long, 1.5m wide, 0.4m deep, and 20mm thick at its thickest section. Under static loading it carried nearly 100kN/m^2. Cyclic loading is still under way (complete by the 2001) to demonstrate long term performance. Key points were addressed at each stage.

- The manufacturing route was developed by DML to enable control of consistency in produced quality.
- Key design considerations addressed by MSL have been summarised in a guidance note being published by Thomas Telford (edited by University of Southampton).
- DERA collected supporting data to demonstrate the life-time of the components.
- Testing and monitoring of the component were completed by Structural Statics Ltd.

An initial assessment of cost-benefit by LUL has indicated the potential of the component, and implementation will be considered following the successful outcome of the long-term fatigue test.

Responsibility for the former DETR's construction research and innovation work has passed to the DTI under the post-election re-arrangement of government departments.

For further information please contact Dr Paul S Hill, DML Composites, Devonport Royal Dockyard, Plymouth, PL1 4SG (01752 324761; fax: 01752 324756; E-mail: paul.hill@devonport.co.uk).

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