Research Focus

Issue No. 36 FEBRUARY 1999

PROMOTING THE APPLICATION OF RESEARCH IN BUILDING AND CIVIL ENGINEERING

IN THIS ISSUE

New wave-modelling techniques nearing commercial application

New tools for modelling wave effects could help engineers test breakwaters and other coastal structures without recourse to physical models. Researchers at HR Wallingford and Oxford Brookes University have developed an advanced numerical model called NEWMOTICS-2D which simulates the hydraulic response of coastal structures to wave attack, although more development is needed before its commercial application.

Professor William Allsop, project leader at Wallingford, explains: 'Current methods of studying wave attack rely either on physical modelling or on the use of empirical formulae. Both have limitations – physical models can run into scaling difficulties, whilst empirical models are valid for very limited cases.' Present numerical models involve considerable simplification of wave breaking – *the* process that is really important in forces, armour damage and other aspects of structure design.

The research team set out to extend the scope of existing models, allowing them to predict wave-induced pressures and flows at coastal structures. So far, the work has spanned five years.

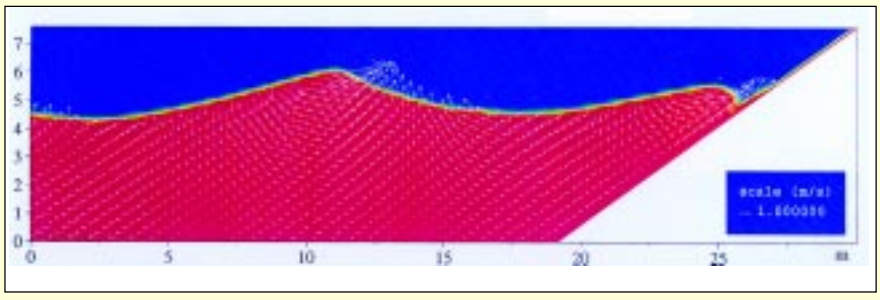
Much of the damage caused by wave attack occurs when breakers collapse against structures such as vertical breakwaters or jetties. It is extremely difficult to simulate this action mathematically since it involves representing a very complex free water surface – one that breaks up as it hits the structure. During the early stages of work (part-funded by DETR, HR Wallingford and Oxford Brookes University), the team evaluated different numerical methods that might be used to simulate such complex flows. They settled on the Volume of Fluid method, which represents fluid within many small mathematical 'cells'.

Having developed an initial version of NEWMOTICS-2D and linked it to a visualisation program, the researchers tested it against results from physical model tests in a wave flume. In general, NEWMOTICS-2D represented the shape, amplitude and speed of test waves very well, though some simulations gave problems for high relative wave heights. Wave shape at test structures was well represented, as (in most cases) were the shape, height, speed and phase of reflected waves. Later versions of the model have since improved its performance for these more severe conditions.

'Although the model is not yet ready for commercial application, we hope to test it alongside traditional methods on selected project studies over the next few years,' says Allsop. 'Further development is required, particularly in refining the model grid, but this type of program should, in the longer term, prove to be a useful design support tool for coastal engineers.'

For further information, a recent Conference paper on the model, or an animation, please contact Professor William Allsop at HR (01491 835381; fax: 01491 832233; E-mail: nwha@hrwallingford.co.uk).

NEWMOTICS: Wave breaking on slope



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, lively 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 or, in the case of EPSRC's research programme, from Catherine Coates at EPSRC (01793 444176).

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.

Distribution

If you receive *Research Focus* by direct mail (i.e. not with *Civil Engineering*) 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 Lesley Wilson at the Institution of Civil Engineers, 1 Great George Street, London SW1P 3AA (0171-665 2242; fax 0171-799 1325; Email wilson_l@ice.org.uk).

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MANAGEMENT

The contractual role of construction programmes

Construction programmes are an important management tool but their consideration of contractual value raises a number of important questions. There is a demonstrable need for a more sophisticated approach in dealing with time-related problems in construction contracts, particularly in view of the increased significance of clauses that deal with compensation for disruption. Programmes can be beneficial because of the analytical base they provide and, on balance, they have the capacity to deliver benefits, provided that expectations are realistic.

It is this view that has led to a study of the contractual status of construction programmes by Peter Talbot. The study addresses four critical underlying issues:

- What is the legal status of construction programmes?
- Is there a beneficial contractual role for programmes?
- Are they an effective medium for delivering the benefits?
- How can they be given meaningful contractual effect?

The study has concluded that there is some uncertainty about the legal status of programmes and that this status can be enhanced both intentionally and unintentionally.

If intended benefits are to be available to both parties, then the precise role of the programme should be agreed at the outset. Provided that there is an appreciation of the difficulties, and expectations of what programmes are currently able to provide are realistic, there is the capacity to deliver the identified benefits. However the realisation of these benefits needs appropriate and flexible contractual mechanisms and these can be developed on the foundation of those to be found in more recent forms of contract.

The new emphasis on the role of contracts in stimulating good management has already generated new programming obligations. It is in this context that the greatest benefit can be derived from enhancing the contractual role of programmes, rather than through the adjustment of traditional forms.

However, more detailed information is needed about the way in which contractual mechanisms work in practice. Current and future research is likely to lead to improvements in the reliability of programming techniques. Developments in computer systems will enable the programming process to be extended into new areas. Much consideration is needed about the ways in which these changes could be absorbed into construction contracts.

The Contractual Role of Construction Programmes is available from the Chartered Institute of Building (01344 630700, fax: 01344 630777).

For further information please contact Peter Talbot Associates, 10 Berwyn Road, Richmond, Surrey, TW10 5BS (0181 878 1978); fax: 0181 878 1978; E-mail: talbotp@westminster.ac.uk).

ENVIRONMENT

Reducing waste with landfill tax credits

The reduction of waste in the construction industry is one of the main goals identified by Sir John Egan's Task Force. The areas to be tackled are being identified at the Pegasus Court Social Housing Project in Oxford, by adapting CALIBRE (a computer based performance monitoring method) to monitor the amount, type and cause of waste on the construction site.

CALIBRE was developed by BRE's Centre for Performance Improvement in Construction (CPIC) to map the construction process and code every activity on site. At Pegasus Court, fully trained observers will map and visually record waste through-out the construction project, which is due to end in November 1999.

Partners in the project include Willmott Dixon Housing Ltd, Ealing Family Housing Association, Oxford City Council and DETR. It is being funded with landfill tax credits provided by RNSC/Biffaward through BRE Waste Environmental Body (BREWEB).

For further information on this and other landfill-tax-funded projects at BRE, please contact Clodagh McGrath (01923 664461) or Gilli Hobbs (01923 664856; fax: 01923 664786; E-mail: hobbsg@bre.co.uk. See also: www.bre.co.uk/bre/enviro.html)

Waste minimisation: the implementation challenge

Latest estimates suggest that the construction industry in England and Wales generates over 50 million tonnes of waste each year. To provide both environmental and economic benefits, it is vital that this quantity of demolition and construction waste is reduced. Already a great deal of guidance has been produced by the DETR, CIRIA, BRE and other organisations on how to reduce, reuse and recycle wastes. However, there is still a widespread lack of implementation of waste minimisation practices across the industry.

The reasons given for this lack of action include:

- practitioners' lack of awareness of the benefits of minimising wastes;
- that they may not have had previous experience of using such materials;
- that they may construe the risks and costs of using re-used or recycled materials as too high.

These issues are being addressed in the latest work being carried out by CIRIA on improving practice in waste minimisation. The research will involve at least ten demonstration schemes that will be set up on live design, construction, and demolition sites throughout the UK. This work has been supported by a number of organisations: DETR, SNIFFER (the Scotland and Northern Ireland Forum for Environmental Research), the BOC Foundation, the ARC Environment Fund, and the construction industry in general.

CIRIA has appointed Scott Wilson as research contractor for this work, and will be working with them to ensure that a full range of projects are included in the study. It is important that the study covers sites and projects that are situated throughout the UK and which are at different stages of the construction process. Waste reduction, reuse and recycling practices will be implemented on these demonstration projects using guidance that has been produced by CIRIA* and other organisations. Progress will be closely monitored both by those involved in the projects on the ground, and by Scott Wilson. Information will be collected and analysed on a range of issues, including the practical steps that can be taken in order to apply appropriate waste minimisation initiatives effectively, and the financial and environmental effects of such initiatives.

In the final stage of the study, two sets of guidance notes will be produced. The first will be strategic guidance aimed at guiding decision-makers to focus their attention on the benefits of waste minimisation. The second set of notes will be practical guidance on implementation aimed at designers and construction project managers. They will present the results of the demonstration projects in a way that enables others to implement the good practice lessons that, it is hoped, will have been learned. It is also anticipated that information obtained in the study will be used to update CIRIA's Waste minimisation in construction training pack.

ARC Recycled Materials, Pinden Plant and Processing

Information on the progress of the demonstration projects will be available throughout the study in a number of ways. A project newsletter will be produced at regular intervals and distributed widely.

In addition, case study reports will be produced for each individual demonstration project to describe the initiatives that were implemented and to identify the specific benefits that they generated. A series of workshops will be held throughout the project to consult with the industry and to demonstrate the results which participants in the study have achieved by applying good practice in reducing, reusing and recycling wastes.

The project and its outputs will encourage the minimisation of demolition and construction waste by increasing the industry's awareness of the financial and environmental effects, and by changing perceptions of risk to improve the industry's confidence.

CIRIA are seeking to identify different types of design projects and construction sites, at various stages in the project process, to act as demonstration projects. If you are a client, designer or contractor, you could gain useful information on waste minimisation by hosting a demonstration project.

For further information about providing a site, or if you would just like to receive a project newsletter in due course, please contact Claire Woolveridge at CIRIA (E-mail: claire.woolveridge@ciria.org.uk or by fax: 0181-222 1708).

* For example:
- Waste minimisation and recycling in construction – A review (CIRIA SP122)
- Waste minimisation and recycling in construction – Site guide (SP133)
- Training pack (SP148)
- Design manual (SP134)
- Boardroom handbook (SP135)
- Managing materials and components on site (SP146).

New tests for sulphur compounds

Existing test methods for sulphur compounds in soils and rocks used as backfill suffer from a number of drawbacks, particularly for determining reduced species such as pyrite.

The Transport Research Laboratory and the University of Sheffield are carrying out a programme of research for the Highways Agency to develop improved test methods. The research will lead to recommendations for a revised suite of laboratory and in-situ tests for sulphur compounds in structural backfills, appropriate methods of sampling and storage, and limiting values for species, such as reduced sulphur, which are not covered by existing guidance. The research will be implemented by means of revisions to the relevant sections of the Specification for Highway Works and the Design Manual for Roads and Bridges.

For further information please contact Murray Reid at TRL (01344 770283; fax: 01344 770748; E-mail: jreid@trl.co.uk).

Water, water everywhere, but it still isn't enough

Nearly 20 billion litres of water are used in UK homes every day. The water is carefully regulated and treated so that it is safe to drink – but a third of it is then used to flush our toilets.

A little under a third is used for bathing, showering and washing clothes. This 'greywater' and is then disposed of, but could be treated and reused for flushing toilets or for watering gardens, etc.

The UK has enjoyed ample water supplies and the freedom to use it as we please, but recent summer shortages show that this may become a thing of the past. Changing patterns of weather and housing occupancy have put an increasing strain on supplies. Water consumption has risen by 70% in the last 30 years, and the millions of new homes being planned for the next 20 years will exacerbate the problem unless action is taken.

Recent projects at BRE, where a new Water Centre has been formed to provide a focal point on water and wastewater issues, have been concerned with water conservation measures, their effectiveness and impact on users and infrastructure.

The first tenants of a housing association scheme in Essex are currently benefiting from one such study to cut water use (and bills), being carried out in partnership with Essex & Suffolk Water, Bovis Homes, and Moat Housing Group on behalf of Plume Housing Association.

The project is monitoring water-using appliances in a new development of 37 houses in Heybridge, Maldon in Essex with the aims of producing a specification for water efficient housing and promoting water conservation. Twelve of the houses are fitted with water-efficient appliances and three with greywater systems. The remaining 22 will be used as a control for comparison.

The water-efficient appliances include six-litre-flush WCs, spray taps and water efficient showers. Greywater is taken from baths, showers and hand basins, treated and then re-used, for example to flush toilets. Water use will be monitored closely and water savings assessed over a 14-month period. Feedback will be obtained from those occupying the houses to gain their views on the water saving measures installed.

BRE's Martin Shoulder checks the water consumption of each appliance in the home from an external meter box.

For further information please contact Martin Shouler at BRE (01923 664459; fax: 01923 664088 E-mail:shoulerm@bre.co.uk).

TRL evaluates tendon monitoring system

The Highways Agency's programme of special inspections of post-tensioned bridges has identified faults in some structures. Generally, the stock is in good condition but, in the long term, wire fractures may occur reducing the effective cross-section of tendons. Monitoring for wire fractures is a useful way of providing data for bridge managers.

Funded by the Highways Agency, TRL has carried out trials of the Canadian SoundPrint® system. This employs continuous acoustic monitoring to detect events caused by fracturing high tensile steel wires, such as those found in post-tensioned concrete bridges.

Trials were first carried out on post-tensioned elements in the laboratory grounds at TRL (see photo). Wire-break events were created on exposed tendons by cutting or accelerated corrosion. Later, full-scale site trials were started on a bridge in service. To avoid damaging the bridge in the trials, wire breaks are created in external tendons specially mounted on the concrete surface. Data are sent off site for processing using the Internet having first been screened automatically to minimise data transfer.

The aim is to show that a single wire fracture can be:

- detected above the ambient noise level;
- distinguished from other acoustic events;
- located in position.

The trials at TRL were successful in all three respects, although the noise level was low and other acoustic events were artificially created. Trials on the full-scale structure are still in progress but the conclusions to date confirm the laboratory results. Successful completion of the trials is likely to lead to the method being included in the Highways Agency's list of approved monitoring methods.

The main alternative to monitoring is intrusive inspection at sample locations. This leads to uncertainty when, for practical and economic reasons, the number of inspection points is limited. Monitoring the structure with the acoustic system may, by contrast, reveal failures not detectable by a conventional investigation.

Acoustic sensor and accelerated corrosion site.

Continuous acoustic monitoring has been used on unbonded tendons in buildings in Canada since 1994. TRL's trials have shown that the system can be applied to grouted post-tensioned bridges, even though the events are smaller and the environment is noisy.

For further information please contact David Cullington at TRL (01344 770836; fax: 01344 770748; E-mail: dcullington@trl.co.uk).

Transforming waste into profit

Each year, the Bridgewater Paper Company has to dispose of sludge residues comprising 45,000 tonnes of cellulose fibre and 55,000 tonnes of clay filler bound in 100,000 tonnes of water. These substantial quantities of waste residues, which result from re-cycling waste paper, can be converted into construction materials. A project at Salford University is aimed at improving these conversion processes.

In the Bridgewater Paper Company's plant, all of the aqueous residues from different parts of the plant are collected into a single tank and a flocculating agent is added to assist de-watering. The post-flocculated sludge contains small discrete lumps of clay distributed in a randomly orientated mass of fibres. If this material is shredded, pressed into a flat board form and then dried, it has virtually no bending strength. However, if the sludge is removed prior to flocculation and the process repeated, the board has good bending strength, the fibre orientation then being predominantly two dimensional in the plane of the board. (A guideline bending strength value is 13 N/mm^2 at a density of 850 kg/m^3.)

If the fibre-rich streams were collected separately and used for board making, the clay rich sludge could be used for brick making. The clay is mainly white china clay which appears grey due to the de-inking process. When fired it burns to a white colour and could be a valuable additive for modifying the colour of red burning clays. The clay rich sludge will contain some fine fibres which will burn out. This should modify the pore structure giving improved frost resistance. It would however be necessary to monitor the firing emissions for any increased toxicity.

Both pre-flocculated and post-flocculated sludge can be used to advantage as additives in plasterboard. Anchorage, indentation and impact resistance are improved but there is a slight reduction in fire resistance (insulation) times.

Manufacturing boards wholly from negative cost waste material appears attractive. However the material is slow to de-water in the press and is difficult to keep flat whilst drying. The use of a heated platen press would solve the latter problem but is probably not a viable solution for a board containing over 40% moisture.

Surface flatness can be achieved when air drying by conventional techniques if gypsum plaster or ordinary Portland cement are combined with the sludge. The sludge/gypsum plaster composites are suitable for dry internal conditions and the sludge/OPC composites may be suitable for wet external conditions.

These dry binders take up some of the free water and set the board shape prior to drying but the natural bending strength is reduced by their addition.

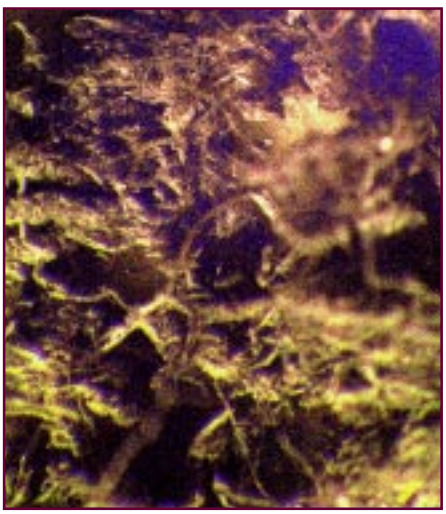
The research at Salford, which is funded by the EPSRC/NERC Waste and Pollution Management Programme and supported by industrial collaborators, is concerned with establishing the minimum binder content required and investigating the physical properties of the boards, including dimensional stability in various conditions. The aim is to increase the performance of the boards produced from the plant's waste and thus improve the overall environmental and commercial performance of the recycling process.

For further information please contact Professor John McNicholas or Professor Peter Webster, Salford University (0161 295 5000; fax 0161 295 5060; E-mail: p.j.webster@civils.salford.ac.uk).

EPSRC

Pre-Flocculation sludge x 20

Post-Flocculation sludge x 20



Cost-effective protection from sewer flooding

The risk that properties may experience flooding from sewers is a key issue for the owners and occupiers of those properties, for the sewerage undertakers, and for the water industry regulator OFWAT. A CIRIA research project has identified the need to consider cost-effective alternatives for protection from sewer flooding.

The most commonly adopted solution for dealing with sewer flooding problems involves carrying out construction works in the sewerage system to increase the flow capacity. However, this approach may not be appropriate if the cost of the works is too high in relation to the number of properties that will be safeguarded from flooding. In addition, the time span associated with the investigation, design and construction of new drainage works can often be five or more years, during which time the affected properties remain at risk from flooding.

A recent CIRIA research project considered all types of sewer flooding problems, whether inside or outside buildings or whether due to lack of sewer capacity or to other causes such as blockages. A guidance document is now being produced to inform sewerage undertakers and other interested parties about the options that are available and the situations in which they can appropriately be used.

For further information please contact Richard Lillywhite at CIRIA (0171 222 8891; fax: 0171 222 1708; E-Mail: richard.lillywhite@ciria.org.uk).

CIRIA

News on scour research

Scour, the erosion of sediment at the base of a structure, is a serious engineering issue: estimates suggest that 12% of seawall failures are attributable to it. Research at HR Wallingford has provided fresh insights into the problem and resulted in the publication of a new report and book. Recent scour projects at Wallingford have been financed by MAFF and the DETR. Staff are also collaborating on a major European scour project, SCARCOST, funded by the EU.

'We have carried out MAFF-sponsored investigations over a number of years in order to improve our understanding of scour processes at seawalls,' says Keith Powell, project leader at HR. Researchers used flume tests to study wave effects at the toe of seawalls fronted by shingle beaches. 'Although we concentrated on vertical walls, we did look briefly at sloping and rough, permeable structures too,' explains Powell. Researchers also ran a numerical model – COSMOS – to investigate seawall scour on sandy beaches. COSMOS uses wave and tidal inputs as well as information on beach sediment size to follow bed sediment levels over storm periods. 'We obtained field data from Blackpool and drew on the results of large scale laboratory tests carried out in the USA to validate the COSMOS approach,' says Powell.

Results from physical model tests show that scour rates depend on various factors, including the initial water depth at the toe of a seawall, wave height and period, sediment size and the type of seawall being considered. Plots of relative water depth at the seawall against sea steepness show the complex relationships between these parameters (see diagrams). Shingle beach results pinpoint two distinct regions of scour. One of these is associated with storm waves acting on beaches at, or just above, the still water level. The other is associated with waves acting on seawalls which are fronted by submerged beaches.

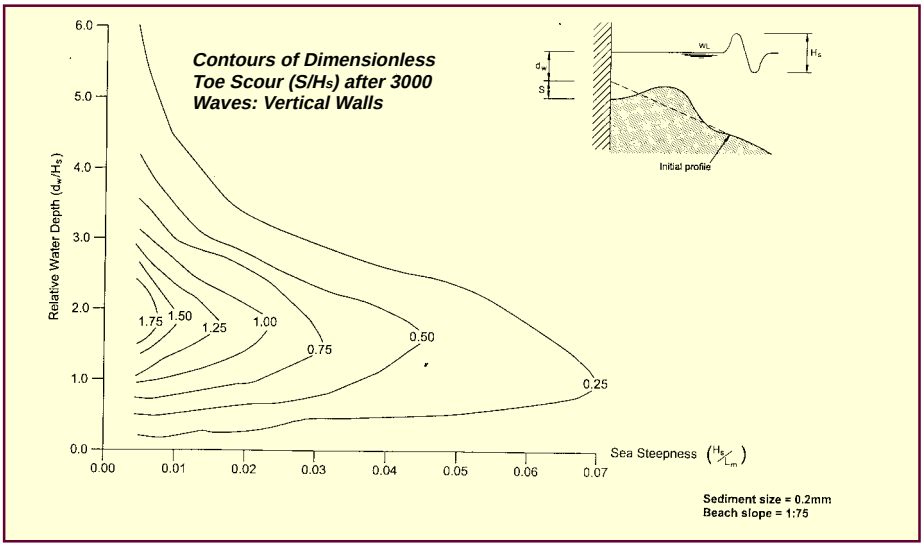
The researchers were able to gain useful insights into the differences between scour at structures on sand and shingle beaches. 'From our results, we identified conditions when maximum scour was likely to occur,' says Powell. Scour timescales also vary. 'Model tests indicate that the scour process takes longer to occur on sand beaches than shingle ones and that, over typical storm durations, scour will not reach an equilibrium depth,' he continues.

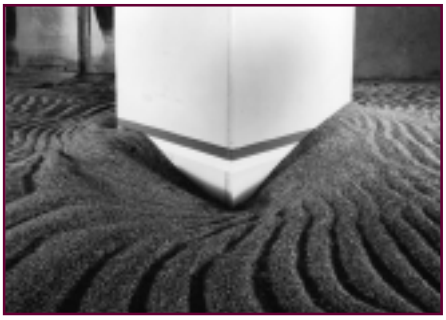
Full results from this project will be made available in a Manual for use during design studies.

NEW BOOK ON SCOUR

A further project on scour, this time funded by the UK's DETR, has been completed by HR's Dr Richard Whitehouse. 'My remit was to consolidate information about scour at marine structures, bringing it together in one reference manual,' he explains. This work forms the basis for Whitehouse's recent book on scour.

Although there is plenty of information available on scour, tracking it down can be time-consuming. The new book, *Scour at Marine Structures*, by Dr Richard Whitehouse brings together published data and information from project studies in one volume, building on an earlier research report produced for the DETR. It deals with scour as it affects a wide range of structures founded on the seabed and also with submerged pipelines.





Scour around a model bridge pier.

Chapters 1 and 2 provide background and highlight the importance of considering scour from the outset of a project. Two subsequent chapters deal with physical and numerical modelling, providing a checklist for the design of physical models and touching on key issues such as the representation of turbulence within a model. Chapter 5 explores the wave/current climate, giving readers information on where to obtain suitable data. Methodologies for calculating sediment mobility and transport are also discussed. The crucial areas of scour prevention and remediation are dealt with in Chapter 6, with techniques being listed for clarity. The final chapter provides a series of case studies.

Throughout, the book is well provided with references and line drawings. Equations are kept to a workable minimum.

Scour at Marine Structures is published by Thomas Telford Publications, 1 Heron Quay, London E14 4JD (0171 6652464; fax: 0171 5373631). Price £45.00. ISBN 0 7277 2655 2.

SCARCOST – A NEW EUROPEAN INITIATIVE ON SCOUR

SCARCOST (Scour Around Coastal Structures) is a 3-year European project looking at the scour risk near coastal structures. Work started in autumn 1997 and is funded by the Commission for the European Communities, Directorate General XII for Science, Research and Development, within its MAST III programme.

Nine European universities and research organisations are participating. Dr Richard Whitehouse of HR Wallingford sits on the Steering Committee. 'There are two parts to the project. One part will look at flow and scour processes, the other at the geotechnical aspects of sediment behaviour.' Different organisations will carry out laboratory research on different types of structure. HR, for example, will concentrate on scour processes and evolution around detached rubble mound breakwaters whilst researchers from Denmark, Portugal and France will carry out generic work on piles and cylinders.

SCARCOST aims to provide detailed, fundamental information on scour processes around a variety of common marine structures, in the form of guidelines. Researchers will benefit by sharing expertise and data whilst, in the longer term, coastal engineers should be able to harness the results in their fight against scour.

For further information on any of these items please contact Dr Richard Whitehouse at HR Wallingford (01491 835381; fax: 01491 832233; E-mail: rjsw:@hrwallingford.co.uk).

The control of adaptive facade elements

A window with automatic shading and ventilation devices was installed at the University of Bath late last year. The window forms part of an ongoing Partners in Technology project to demonstrate the integration of automated facade elements with other building control devices.

In recent years, designers have shown that by making certain parts of a facade autonomous, they can provide a building envelope with the ability to accept or reject free energy from the environment, and thus the opportunity to reduce the energy required to achieve comfortable internal conditions. However, the integration of automated facade elements into a typical building management control system can prove difficult.

Integration issues are being investigated at CWCT by setting up a test room in which currently available window control technologies are brought together with various standard building control technologies. This work will be further supplemented by using the Integrated Building Control demonstration facility at Taywood Engineering to integrate the window with a number of additional fire alarm, heating, security and lighting systems.

An initial review of the issues related to the use of automated devices to control internal environments identified that the interaction between an individual occupant and an automated window can be fundamental to the attainment of user comfort. It was also shown that the factors that affect the design and control of automated facade devices are inherently non-linear, dynamic, multi-dimensional and in some cases unmeasurable. As a result, the project team also intend to develop and utilise intelligent control techniques, such as learning systems, to give the automated window control system a certain degree of flexibility so that it may adapt to specific locations and occupants.

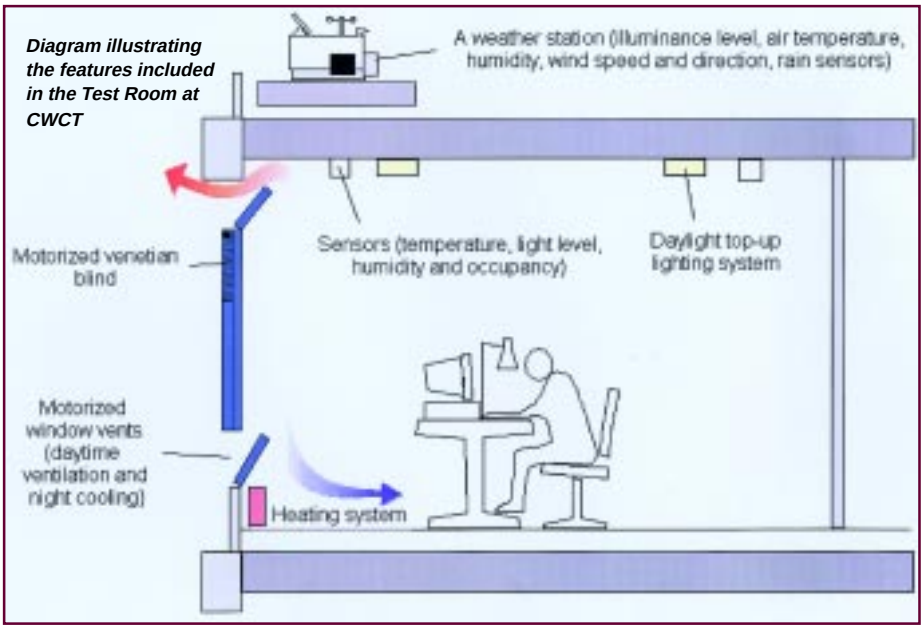


Diagram illustrating the features included in the Test Room at CWCT

For further information please contact Mark Skelly at CWCT (01225 826541; fax: 01225 826556, E-mail: cwct@bath.ac.uk).

CENTRE FOR WINDOW AND CLADDING TECHNOLOGY

MATERIALS

Transfer of adhesives technology

Following the success of the CIRIA/Pera project to transfer and adapt technology from the aerospace and defence industries to the construction industry to produce blast-resistant cladding panels, CIRIA are about to undertake another technology transfer project, this time on adhesives technology. It will examine the use of structural adhesives in industries where they are widely used for joints instead of welds or mechanical fixings, including the aerospace, automotive and marine industries. It will assess the potential for transferring this technology to the construction industry and will identify specific applications to be studied further.

In the construction industry, structural adhesives are currently used mainly for repairs (75%). For new build, the largest uses are for glulam timber, plywood, and structural glazing connections. For other materials such as precast concrete, steel and other metals, masonry and glass fibre-reinforced plastic, there has only been limited use to date.

The advantages of adhesive joints include:

- no damage to the substrate materials;
- simpler joints with fewer components;
- high uniform strength;
- dissimilar materials can be readily joined.

If existing technology is transferred to the construction industry for use in new work it could improve jointing techniques and reduce both construction time and whole-life costs.

The work will include reviewing selected literature; consultation with relevant organisations and experts in the donor and receiving sectors; and a Workshop to discuss and assess the findings. It will draw extensively on related projects being undertaken by others, including The Institution of Structural Engineers, NPL, AEA Technology and TWI.

Work on the project is due to commence in February 1999. The project is being sponsored by DETR and adhesive manufacturers including Scott Bader and Sika. CIRIA would welcome further offers of funding and contact with anyone who would be interested in participating.

Epoxy adhesive was used to bond together the GFRP pultrusions of the advanced composite footbridge at Aberfeldy, Scotland.

For further information please contact Ann Alderson at CIRIA, 6 Storey's Gate, London, SW1P 3AU (0171 222 8891; fax: 0171 222 1708; E-mail: ann.alderson@ciria.org.uk).

CIRIA

Developing a hybrid solar/gas heating and cooling system for buildings

As the millennium approaches, innovators are being encouraged to develop efficient and 'environmental-friendly' systems for cooling and power generation. The Institute of Building Technology at the University of Nottingham has been awarded an EPSRC grant to develop a new system for air conditioning and electricity production in buildings to be driven by hybrid sources such as solar and gas, using natural refrigerants as the working fluid.

To date, there has been little research into the integration of solar power and natural gas. With the proposed system, a gas burner would be used as back-up during periods of low solar insulation. This would enable the system to operate all year and in climates such as that of the UK. The attractions of using the solar and gas combination include reducing pollutant emissions to the atmosphere and low running costs. The wide application of this technology should improve the quality of life world-wide and create employment opportunities in the UK, areas that have been highlighted in the EPSRC mission and Technology Foresight Programme.

The system consists of a solar collector (which uses evacuated heat pipes), a gas burner, a boiler, an ejector unit, a turbo-generator, a condenser, an evaporator and a pump. Heat from the solar collector or gas burner is used to vaporise a refrigerant in the boiler. The refrigerant is then passed through an ejector or turbo-generator, producing cooling and electricity respectively. The refrigerant exhaust from the ejector and turbine units is condensed, releasing heat that could be used to provide heating or hot water supply in buildings. Ejectors have no moving parts and so are simple and reliable. The system uses a high-efficiency turbo-generator together with an innovative pumping method without the need for an electrical input.

The project will involve design, construction and monitoring of a prototype system to provide cooling and electricity outputs of 2 and 1.5kW respectively. The development of this system would be of prime interest to many industrial organisations in the UK and overseas. Several companies, including Thermomax Limited, TTL Dynamics Limited, AVE Limited and BG plc, are currently collaborating with the University of Nottingham on the project.

Professor Riffat inspecting the solar collector

A solar/gas turbine.

For further information please contact either: Professor S B Riffat, University of Nottingham (0115 951 3158, fax: 0115 951 3159; E-mail: saffa/riffat@nottingham.ac.uk) or Dr P S Doherty, University of Nottingham (0115 951 3180; fax: 0115 951 3159; E-mail: lazpsd@ian1.arch.nottingham.ac.uk).

EPSRC

ICE R&D Fund seeks more research projects to support

As many readers of *Research Focus* will be aware, the Institution of Civil Engineers has an R&D Enabling Fund that was set up to encourage all civil engineers to make greater use of research and development in the advancement of their work. The Fund is administered by a Board of Trustees which is actively seeking applications from all branches of the profession, including younger members and those not traditionally involved in research & development, with preference being given to applicants from small firms.

Until recently, there has been no definition of the term 'enabling' other than to assist in starting a worthwhile project that otherwise might not happen. However, the Fund Trustees generally adopt an approach of seeking to add value to research and innovation projects in the field of civil engineering, so that supported projects could include:

- catalytic proposals which may lead to other research projects;
- pilot projects;
- participation in collaborative projects
- technology brokerage (assembling or disseminating knowledge);
- additional special instruments, equipment or materials for research purposes;
- publication of new information or knowledge;
- travel to gather information or other experience for dissemination.

Funding will not be considered for:

- self-education not leading to further research, innovation or dissemination;
- administration and preparation of research proposals;
- projects that are not research and innovation-oriented;
- projects expected to benefit a single individual or company;
- whole funding of large budgets.

As a guide only, support for a package of research from the Fund will be in the order of £5,000 to £20,000. A report on the outcome of the work will be required and the results must be available for open dissemination.

The Trustees will also consider applications for finance to facilitate the appointment of a visiting Research Fellow from industry at a suitable higher education establishment or research organisation, or for a research worker to assist a commercial or local government organisation with a project.

For further information please contact David Williams at the ICE (0171-665 2219; fax: 0171-799 1325; e-mail williams_d@ice.org.uk).

The Institution of Civil Engineers

Collaborating to produce aerodynamic architecture

The technology that was developed in the 1960s to test aircraft such as Concorde created a new area of co-operation between the aeronautical and construction industries. A more recent collaboration between Battle McCarthy Consulting Engineers and Imperial College, London, under DETR's Partners in Innovation programme, has looked at the use of wind energy for ventilating a wide range of buildings.

A resulting textbook Wind Towers: *A calculation method for sizing wind towers and wind scoops* offers architects, environmental engineers and aeronautical engineers a design tool to analyse the movement of air through buildings and, ultimately, produce more aerodynamic buildings.

Wind tunnel testing (a primary source for understanding air movement within buildings) became *the* design tool to predict and address the effects of wind upon new buildings and external spaces. Physical models of buildings with wind towers and wind scoops were tested in the tunnel. Computer models (based on computational fluid dynamic analysis) for a number of building types were also assessed. The results provided a thorough understanding of the wind forces surrounding buildings and how best to utilise them.

The building models were tested for a number of wind tower and/or wind scoop designs at different positions, heights and diameters. The influence of the building height and roof pitch were also taken into consideration. These tests enabled a calculation method to be developed allowing designers to correctly size the height, diameter and position of the wind tower and/or wind scoop to provide natural wind driven ventilation. A set of tests of actual building designs were also wind tunnel tested to assess the accuracy of the calculation method. Information was obtained from full scale mock-up models of wind scoops and site monitoring of buildings ventilated by wind towers.

THE CALCULATION METHOD

Approach and methodology – The methodology developed calculations based on the behaviour of models tested in the wind tunnel and on computer simulation. Monitored data was also used as a comparison.

Parameters – The calculation method is designed to allow the user to size a wind tower or wind scoop (or combined inlet and extract device) to supply a required air flow rate. Whilst the method is applicable for a wide range of buildings and site conditions, there are some circumstances where wind-driven natural ventilation may not be appropriate. These include buildings within a particularly sheltered area, or where the building ventilation demand is too great. A separate book *Wind Towers and Wind Driven Ventilation*, which covers issues such as feasibility, design and the application of wind towers/ wind scoops, is recommended in such circumstances.

Process – The calculation method involves a two stage process. *Stage 1* establishes the design wind speed, taking into account adjustment factors for site conditions, before establishing the air volume flow rate required for the building. *Stage 2* establishes the un-corrected base area of the wind tower and/or wind scoop to achieve the air volume flow rate. Adjustments to compensate for factors – including (i) the position and extent of openings, (ii) building resistance and (iii) the height of the wind tower above the roof – are made at this stage.

Wind Towers: A calculation method for sizing wind towers and wind scoops, which contains the test results and calculation method, is available from Battle McCarthy, 57 Poland Street, London W1V 3DF.

For further information about the project leading to the publication, please contact Robert Crangle, CIRM Division, DETR, 3/H2, Eland House, Bressenden Place, London SW1E 5DU (0171 890 5704; fax: 0171 890 5759; E-mail: rcrangle@detr-cirm.demon.co.uk).

DETR Environment Transport Regions

MATERIALS

Improving clear wood finishes

Natural wood finishes bring out the beauty of wood. The problem is that clear coatings – and the underlying wood - are susceptible to photo-degradation if outdoors. Indoors, many wood species are subject to undesirable colour change.

BRE has launched a three-year, industry-sponsored project into ways of significantly improving the resistance of wood finished with clear or semi-transparent coatings both to weathering outdoors and colour change indoors.

A core project aims to improve knowledge of the mechanisms of wood degradation and wood-coating interactions, and to identify the specific physical and chemical factors to be controlled in achieving long term durability of clear and semi-transparent finishes.

Satellite projects will assess, in co-ordinated laboratory and field studies, candidate materials with the potential to stabilise wood surfaces when used as pre-treatments or in coating films.

A novel aspect of the project, which has been attractive for sponsors, is the framework for open sharing of knowledge in the core project, and the protection of commercial interests through evaluation of commercially sensitive products in satellite projects.

Almost all the major coatings and resin manufacturers, manufacturers of pigments and UV absorbers are participating and the wood industries are also expected to be represented.

For further information or if anyone is interested in joining the project, please contact Dr Hilary Derbyshire of the Centre for Timber Technology and Construction at BRE (01923 664147; fax: 01923 664785; E-mail: derbyshireh@bre.co.uk).

BRE

Examples of degraded surface finishes

Improving air quality and energy conservation

The use of a 'ventilated' or 'supply air' window is a way of providing fresh ventilation air to houses in winter whilst reducing heat loss. This is achieved by fixing an extra sheet of glass to the outside of a conventional double glazed window. The air gap that is created can be heated by solar energy if the orientation is favourable but also by the reclaim of heat escaping from the double glazing. A vent at the bottom of the outer pane supplies air to the window cavity and the pre-warmed air then enters the room through a vent at the top of the inner double glazing.

This new component addresses a problem presented by recent changes to the Building Regulations. On the one hand, energy conservation remains a fundamental issue but concern at the extent of pollution sources within houses (for example smoking, formaldehyde emissions from building materials, radon and condensation) has resulted in the need for increased ventilation volumes and larger sizes of vent.

A project has been established to describe the operation of the 'ventilated' window in a simulation programme and to compare the simulation with results from an evaluation of actual performance in a test cell. The test cells are room-sized, highly insulated and instrumented boxes with an opening in the south facing wall. The temperature of the cell is maintained at a constant level. Heat losses and gains are then equal to the power input required to maintain this temperature.

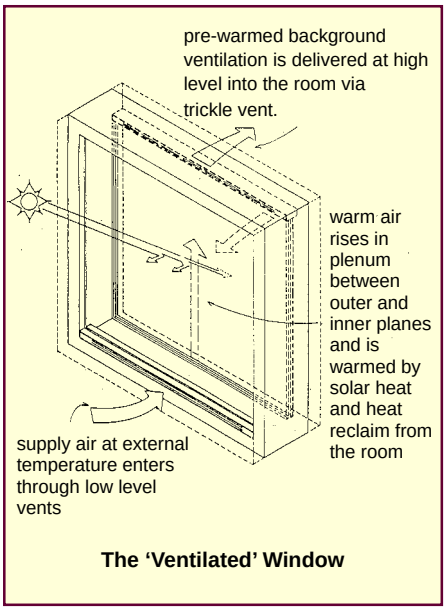
At its conclusion, the study will have determined the heat exchange mechanisms and co-efficients of heat transfer at each of the glass surfaces. It will then be feasible to determine the most advantageous specification for the window glass and optimum sizes for the window and the width of the air cavity.

Earlier experiments at the BRE Scottish Laboratory illustrated the efficacy of the window as a heat reclaim device by running the test cell at night. It was also shown that quite moderate levels of solar gain provide justification for the use of the 'ventilated' window as a passive solar device. There is, however, a potential problem of flow reversal under particular climatic conditions due to a combination of wind speed and direction, and the extent of the temperature difference between inside and outside. Flow reversal may fog up the window as a result of humid air from within the building entering the window cavity and condensing on the cold outer pane.

Consequently, for the window to function adequately, thermostatically controlled vents will be required to draw the air flow through the window when the temperature gradient within the window makes the functioning of the pre-heat mechanism worthwhile. Otherwise the vents will switch to draw air in directly from outside.

The operational parameters for the vents and window will be the outcome of the project. They are the essential precursor for the pre-production design of the 'ventilated' window, a concept which can be applied to both new build and retrofit applications.

For further information please contact Michael McEvoy, University of Westminster, Department of Architecture, 35 Marylebone Road, London NW1 5LS (0171 911 5000; fax: 0171 911 5171/5168; E-mail: mcevoym@westminster.ac.uk).



The 'Ventilated' Window

STRUCTURES

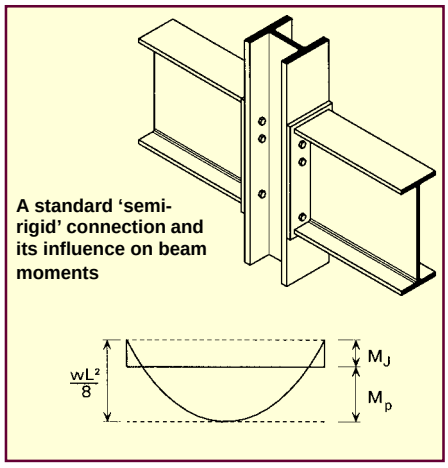
Better braced frames

Traditionally, steel frames are designed assuming either 'pinned' or 'rigid' behaviour of the connection. These two extremes respectively model no continuity or full continuity between the frame members. However, real connections generally behave in a manner which is somewhere between these limits, they are 'semi-rigid', and real frame behaviour is therefore semi-continuous. Furthermore, by tailoring the performance of 'semi-rigid' connections to suit the needs of a particular project, the frame designer can achieve significant economy with respect to the frame members, with little or no increase in connection complexity or cost..

Simplified guidance for the design of semi-continuous steel frames was published by the Steel Construction Institute in 1997. Design of semi-continuous braced frames (P-183) was funded as part of the CIMsteel project. The design procedures given are only a slight variation on 'simple design' to BS 5950, with minimal added complexity. It is hoped that this will facilitate adoption of semi-continuous construction by practising engineers, who will find the design method readily familiar.

One important feature of the method is that it relies heavily on the use of standard connections. Because these have proven ductility and known stiffness, there is no need for the designer to become involved in complex procedures to quantify these two important connection characteristics.

The economic benefits of semi-continuous construction for steel frames have been identified. On average, a 6% saving in frame weight can be achieved, compared with 'simple' construction. Alternatively, rather than designing to reduce beam weight, beam depth can be reduced when semi-continuity is achieved. Significant savings can then be made not only in the cost of the frame itself, but also in the cost of cladding (due to a reduced area). Reductions in structural floor depth can also ease service integration, which may be a further source of cost savings.



A standard 'semi-rigid' connection and its influence on beam moments

For further information please contact Dr Graham Couchman at SCI (01344 623345; fax: 01344 622944; E-mail: g.couchman@steel-sci.com). Full details of SCI publications (01344 872775) and courses (01344 872776) or see our web site: http://www.steel-sci.org.

Thermal crack control in concrete

Wimtec Environmental Limited has completed a report into the practicalities of avoiding thermal cracking in large scale concrete pours during the construction phase. The project was carried out with support from the DETR's Partners in Innovation programme and a number of major contractors.

The project focused on 14 commercial contracts and monitored temperature changes within large scale concrete pours. The graph shows the typical trace of monitored temperature versus time, with the thermocouple positions at top, middle and bottom, and with the ambient temperature shown for comparison.

A range of variables were covered, including:

- mix design;
- insulation protection; and
- spray-on, surface curing membranes.

The insulation materials used were polyethylene bubble film up to 20mm thick and polyethylene foam up to 25mm thick.

For each pour, the potential for thermal cracking was assessed using CIRIA Report 91: *Early-Age Thermal Crack Control in Concrete* (Revised Edition). In most cases, the concrete mix design contained cement replacement materials. The concrete pours calculated to have more limited potential for cracking were those which included limestone aggregates. The predictions of the maximum thermal differentials indicated that the critical conditions would be exceeded in a number of cases.

Temperatures were measured and recorded for up to a week following the pour. The analysed temperature data generally substantiated the calculated values from the CIRIA Report

There were four principal findings from the research.

i) The use of portland cement replacement materials in the concrete reduced the potential for thermal cracking.

ii) The application of the surface membrane created lower temperature differentials, this being less significant when insulation had been applied. The use of surface membranes appeared to reduce the thermal gradient by enabling a more rapid transfer of heat through the water trapped by the membrane.

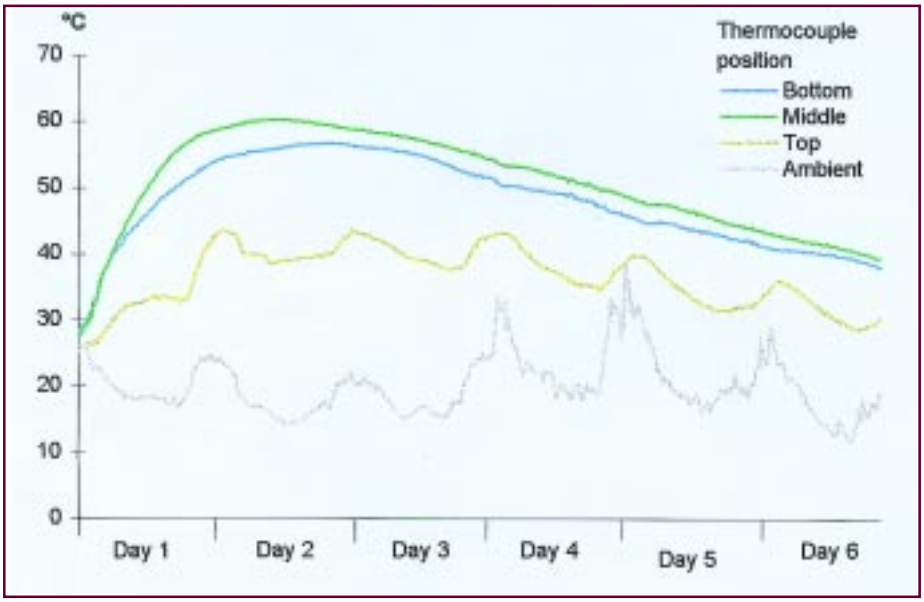
iii) Pours monitored with insulation applied had greater temperature differentials in comparison with those pours where insulation protection was not provided.

iv) As expected, the insulation produced an increase in overall temperature, but also created a greater differential between the core and surface.

One of the original aims of the project was to produce practical site guidance, but the results were not sufficiently positive for this to be practical at this stage. Further research is needed with greater levels of insulation than used in current practice and on the effects of surface membranes and their contribution to thermal gradients.

For further information please contact Richard Sykes at Wimtec Environmental Limited (01753 737744; fax: 01753 792321; E-mail: richard.sykes@wimtec.co.uk).

A graph entitled 'Typical Trace of Monitored Temperature v Time'



DETR R&I Report

The DETR has published an Annual Report on its £26m Construction Research and Innovation Programme. The Report, the first to be published under the Programme, sets out the main developments during 1997/98 and details how £26m of DETR funding for construction-related research was allocated. The Report also considers future trends in research and innovation and lists future targets for the Programme.

For further information and to order copies of the Report, please contact Alan Turnbull at DETR (0171-890-5704; fax: 0171-890 5759; E-mail: aturnbull@detr-cirm.demon.co.uk). The Report can also be accessed via the DETR web site: www.construction.detr.gov.uk.

Exports Report: Read it yet?

Stage 3 of the ICE Project on Technology Support for UK Civil Engineering Exports (see Issue 35, Nov 1998), in which the results are being actively promoted to industry, government and the research community, is well under way.

The Report, *Thriving in a global market: Technology Strategies for UK Civil Engineering Exports*, has already been widely distributed and is available from the ICE Bookshop, complete with extensive source material on CD. The major challenge for exporters or potential exporters is to study the Report and its recommen-dations, and to consider actively and positively how they or their organisations can take them forward to develop and use technology for increased export success. You are invited – indeed encouraged – to contribute to the ICE Export Technology Forum at www.ice.org.uk/export/ or to contact the Project Manager.

To obtain your copy of the Report (Price £30 to UK organisations and individuals), contact the TTL Bookshop at the ICE (Tel: 0171-665 2019; fax: 0171-222 7500; E-mail: maddox_j@ice.org.uk).

For further information, please contact Roger Venables, Project Manager, ICE Exports Project, (0181-399 4389; fax 0181-390 9368; E-mail: ice-exports@venablesconsultancy.co.uk

Minimum requirements for durable concrete

Under a DETR-funded Partners in Technology project, BCA and BRE have reviewed the literature to establish the minimum specifications for concrete to ensure durable concrete in the exposure conditions defined by the provisional European Standard pr EN 206 for the range of binders used in the UK.

Within the forthcoming European Standard pr EN 206, *Concrete-Performance, production and conformity*, durability of concrete will rely on prescriptive specification of minimum grade, minimum binder content and maximum water-binder ratio for a series of defined environmental classes (see Table). In the development of pr EN 206, it has not proved possible within the European Committee for Standardization (CEN) to agree common values for the specification parameters to cover the wide range of climates and the wide range of cements in use in the EU Member States.

The standard will, therefore, almost certainly include indicative values, and it will be left to individual Member States to specify national values where they require them to differ from the indicated values. In the present draft, the indicative values are based on the mean of the range of values currently in use across Europe, and apply only to Portland cements (CEM I cements). No procedure for modifying these values for other cements has yet been agreed.

It is thus clear that the prescriptive specification of durable concrete for construction in the UK is entirely dependent upon the establishment of UK national requirements for minimum grade, minimum binder content and maximum water-binder ratio based on values of minimum cover given in DD ENV 1992-1-1.

It is not acceptable to base UK national requirements on existing British Standards for two reasons:

- Pr EN 206 uses a new system of exposure classification based on deterioration mechanisms whereas existing British Standard exposure classes do not use this system and cannot be related satisfactorily to the new classes.
- There is no UK consensus on durability requirements, as the necessary revision of BS 8110 has not been made because of the higher priority of work on development of the European Standards. There is strong belief that some recommendations in BS 8110 will not provide adequate durability, particularly where resistance to chloride ingress is required, whereas other recommendations may be unnecessarily onerous.

The objective of this DETR project was to review UK and international literature to establish the minimum specifications for concrete necessary to achieve durable concrete, in the exposure conditions defined by the pr EN 206 for the broader range of binders used in the UK.

The review was carried out by staff of the British Cement Association and BRE and has now been published as a book to stimulate wider debate. The subjects covered in the book are the minimum requirements for concrete to resist carbonation-induced corrosion, chloride-induced corrosion, freeze-thaw attack, sulfate attack and acid attack.

For further information please contact Sue Wright at Publications, BCA (01344 725704; fax 01344 727202; E-mail: library@bca.org.uk) or Don Hobbs at BCA (01344 725705; fax: 01344 727203; E-mail: dhobbs@bca.org.uk).

The exposure classes

Carbonation-induced corrosion	*Chloride-induced corrosion: sea water*	*Chloride-induced corrosion: chlorides other than sea water*	*Freeze-thaw attack*	*Chemical attack*
XC1 Dry	XS1 Airborne salt	XD1 Moderate humidity	XF1 Moderate saturation, no salt	XA1 Slightly aggressive chemical environment
XC2 Wet rarely dry	XS2 Submerged	XD2 Wet rarely dry	XF2 Moderate saturation, with salt	XA2 Moderately aggressive chemical environment
XC3 Moderate humidity	XS3 Tidal, splash, spray zones	XD3 Cyclic wet and dry	XF3 Saturated, without salt	XA3 Highly aggressive chemical environment
XC4 Cyclic wet and dry	–	–	XF4 Saturated, with salt	–

SPONSORING ORGANISATIONS

GOVERNMENT

Department of the Environment, Transport and the Regions,
Eland House, Bressenden Place, London SW1E 5DU
(0171 890 5704, fax 0171 890 5759)

RESEARCH ORGANISATIONS

British Cement Association,
Century House, Telford Avenue, Crowthorne, Berkshire, RG11 6YS
(01344 762676, fax 01344 761214)

BRE,
Garston, Watford, Hertfordshire, WD2 7JR
(01923 664000, fax 01923 664010)

Centre for Window and Cladding Technology,
University of Bath, Claverton Down, Bath, BA2 7AY (01225 826541, fax 01225 826556)

Construction Industry Research and Information Association,
6 Storey's Gate, Westminster, London, SW1P 3AU (0171 222 8891, fax 0171 222 1708)

Engineering and Physical Sciences Research Council,
Polaris House, North Star Avenue, Swindon, Wiltshire, SN2 1ET
(01793 444000, fax 01793 444010)

HR Wallingford Ltd,
Wallingford, Oxfordshire, OX10 8BA
(01491 835381, fax 01491 832233)

The Steel Construction Institute,
Silwood Park, Ascot, Berkshire, SL5 7QN
(01344 623345, fax 01344 622944)

Transport Research Laboratory,
Old Wokingham Road, Crowthorne, Berkshire, RG45 6AU (01344 773131, fax 01344 770356)

PROFESSIONAL INSTITUTIONS

The Chartered Institute of Building,
Englemere, King's Ride, Ascot, Berkshire, SL5 8BJ (01344 630700, fax 01344 630777)

Institution of Civil Engineers,
1 Great George Street, Westminster, London, SW1P 3AA (0171 222 7722, fax 0171 222 4294)

Institution of Structural Engineers,
11 Upper Belgrave Street, London SW1X 8BH (0171 235 4535, fax 0171 235 7500)

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