Research Focus

Issue No. 35 NOVEMBER 1998

PROMOTING THE APPLICATION OF RESEARCH IN BUILDING AND CIVIL ENGINEERING

IN THIS ISSUE

Bringing air and light to the working environment

BRE is leading a major Partners in Technology project to design, develop and test a prototype of a pre-packaged, made-to-measure building facade unit for new and refurbished buildings. It will integrate natural ventilation, daylighting and solar protection under intelligent local control and with photovoltaic power.

The overall aims are to contribute to reducing energy consumption in buildings and, consequently, CO_2 emissions by:

- encouraging wider uptake of naturally ventilated and daylit buildings, thus addressing the issue of optimal use of non-renewable resources;
- improving design and construction capability to deliver an improved quality of indoor environment for occupants and so improve the productivity of people in buildings;
- developing renewable-energy powered multi-functional facade elements.

Major outputs from the project will be:

- a pre-packaged and application-specific building facade unit that integrates natural ventilation, daylighting and solar protection under intelligent local control and with photovoltaic power;
- an industrial controller (based on artificial intelligence techniques) to optimise the interactive operation and (when required) integrate with the energy system of the building.

The project is focused on large commercial and public buildings where space heating, space cooling and electrical lighting contribute significantly to energy use. The facade units will be stand-alone, easily inserted into external openings in rooms and will provide natural ventilation and daylighting.

Solar protection will be through external shading or electrochromic windows. 'Smart' controls will provide integration to avoid conflicts and cooperate with any central building energy system to reduce energy usage and assist in local control. Photovoltaics will provide any necessary power although flexibility will be provided to tap into existing mains supply.

The principal technical issue to overcome is the integration of the different elements to be used. Combining natural ventilation, solar protection and daylighting in an optimum way will require the development of new intelligent control algorithms. In addition, these will need to be integrated into any other energy or environmental systems in the building. It is estimated that even a modest ten per cent take-up of the proposed facade unit or its components in new and refurbished buildings could save up to 110 Peta Joules of delivered energy in five years, together with a CO_2 reduction of 10 million tonnes.

The other UK partners in the project, which forms part of a European JOULE project called AIRLIT-PV, are Oscar Faber, COLT International and Oxford Brookes University.

For further information please contact Dr John Palmer at BRE (01923 664494; fax: 01923 664711; E-mail: palmerj@bre.co.uk).

The photovoltaic facade of BRE's environmental building

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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Research Focus is published by the ICE, typeset by PJM Design and produced by Thomas Telford Ltd, 1 Heron Quay, London E14 4JD. ISSN 0960 5185

Egan: The next steps

Arrangements for implementing *Rethinking Construction*, the report of the Construction Task Force chaired by Sir John Egan, are now being taken forward by the Department of Environment, Transport and the Regions (DETR).

It can hardly have escaped the attention of the construction world that the report of Sir John Egan's Construction Task Force, published in July, had strong words about the prevailing culture of the industry. The Task Force felt that radical changes were essential. 'The industry as a whole is underachieving', was Sir John's conclusion. '[It] has low productivity and invests too little in capital research and development and training'. In perhaps its most stinging criticism, the report goes on to say about the industry that 'too many of its clients are dissatisfied'.

However, it should not be overlooked that the report was written from a point of view of concern about for the industry's future wellbeing – in particular, a strong desire to achieve improvements in performance and profitability. The report's main recommendations for improvement were to set up:

- a 'Movement for Change' in construction;
- arrangements for improved training and welfare (including working conditions);
- demonstration projects, as best practice exemplars;
- a knowledge centre for construction;
- a range of targets for improvement – principally, to improve productivity by 10% a year (see separate table).

The report also focused on the need to replace costly and inefficient tendering processes with long-term partnering arrangements.

All very well, one might say, but how can this be achieved? Follow-up action is already under way. Firstly, a senior level steering group has been set up to direct the implementation process, chaired by Construction Minister Nick Raynsford. Sir John Egan will serve on the steering group alongside other senior representatives of the industry. The steering group's role will be to review the progress being made towards the Task Force targets, monitor the demonstration projects and to set new directions where these are required in order to keep up the impetus for change. It will also review the progress of public sector clients in implementing the Task Force's recommendations.'

Responsibility for taking forward the recommendations of the Task Force will rest with the Movement for Innovation, the setting up of which directly addresses one of its main recommendations. The Movement, which will report to the steering group, will be led by a management panel comprised of Task Force members with the a secretariat provided by DETR. It aims to organise the Movement's affairs and activities, support the demonstration projects and allow dissemination through the DETR's Best Practice Programme. An initial conference to establish the Movement is planned for early November – both Sir John and Deputy Prime Minister John Prescott are expected to speak at the conference.

Clearly, Sir John will continue to play a pivotal role in taking the Task Force Report forward. The last word goes to him: 'We know that there are plenty of ambitious and dynamic people out there who want the opportunity to lead change. Let us give them that opportunity.

For further information on the Construction Task Force and Movement for Innovation please contact, Anthony Maude at DETR (0171-890 5923; fax: 0171-890 5529). Rethinking Construction can be located at the DETR web site: www.construction.detr.gov.uk.

DETR
Environment Transport Regions

SCOPE FOR SUSTAINED IMPROVEMENT

(from the Construction Task Force Report)

	Indicator	Improvement per year
Capital cost –	All costs excluding land and finance.	Reduce by 10%
Construction time –	Time from client approval to practical completion.	Reduce by 10%
Predictability –	Number of projects completed on time and within budget.	Increase by 20%
Defects –	Reduction in number of defects on handover.	Reduce by 20%
Accidents –	Reduction in the number of reportable accidents.	Reduce by 20%
Productivity –	Increase in value added per head.	Increase by 10%
Turnover and profits –	Turnover and profits of construction firms.	Increase by 10%

Colour and contrast guidance for interior design

A new design guide will assist designers and managers of buildings to decorate internal spaces to assist the majority of visually impaired people without detriment to fully sighted users.

About one million people in the UK have some form of visual impairment affecting central or peripheral vision or the whole visual field. In addition, it is estimated that there are a further 700,000 people who have some significant loss of vision, but not sufficient to be considered for registration. These people might, for example, be unable to read a newspaper even when using normal reading glasses.

Whilst it has always been known that the provision of 'adequate' colour and luminance contrast could have a major impact on the ability of visually impaired people to use environments safely and effectively, the absence of information as to how subtle, rather than how bold, two colours had to be in order for a contrast to be discerned between them has made the provision of suitable environments difficult to achieve.

THE PROJECT

Project Rainbow, funded by the LINK Construction Maintenance and Refurbishment Programme (LINK CMR), was led by the University of Reading's Research Group for Non-Handicapping Environments, in the Department of Construction Management & Engineering, with industrial support provided by the Joint Mobility Unit (a service provided by the Royal National Institute for the Blind and the Guide Dogs for the Blind Association) and ICI Paints. The project was led by Keith Bright and Geoff Cook.

Before Project Rainbow, the lack of guidance based on firm research meant that the natural reaction of designers was to provide contrast using high chroma combinations such as black and white or black and yellow. However, the extensive use of such colour combinations within a building would not only produce environments which were unacceptable to other users, they would also unnecessarily restrict design freedom.

The two main aims were therefore: firstly, to establish the colour and luminance thresholds of a representative sample of visually impaired people and secondly, to identify the problems they experience when interacting with the built environment, especially the strategy they adopt when navigating around and identifying features. These two aims allowed not only the provision of colour and luminance contrast within an environment to be considered, but also the position within that environment where its use could be maximised.

COLOUR AND LUMINANCE PERCEPTION

Visually impaired people are generally less confident than fully sighted people in differentiating colours. However, if the colour difference is above a certain threshold level, confidence improves significantly. By using structured laboratory and 'real world' tests, the perception thresholds of a representative sample of both fully sighted and visually impaired people were determined and translated into guidance for architects, designers and building managers.

Visually impaired people are often concerned when there is insufficient contrast at skirting board level. Contrast only at dado height as in this example can give the impression of the room being much larger than it is – the contrast at dado height suggesting that this is in fact the junction of the wall and the floor.

All projections or elements that do not fall into the visual field or cannot be detected by mobility aids, such as canes or guide dogs, are potentially very dangerous. Even someone with good vision who is simply not concentrating could collide with these stairs and be seriously injured.

A corridor used in the 'real world' tests at ICI Paints. The colour scheme included obvious and subtle contrasts to test a participants' ability to perceive differences.

Based around current design practices, which may involve the selection of 'warm' and 'cool' harmonies or contrasts to particular colours, the design guide describes (using over 300 tables) how colours can be selected to assist visually impaired people to discern contrast and, at the same, offer considerable freedom to the designer.

INTERACTING WITH THE BUILT ENVIRONMENT

When navigating around, most visually impaired people concentrate their residual vision in a continual downward scan of the area within two metres and they are seeking to identify a feature or object by its contrast with the surroundings. This strategy is adopted regardless of whether a guide dog or mobility aid is used.

For visually impaired people, the size and shape of a feature are vitally important in identification and this is especially so when identification needs to be made quickly.

However, by far the most suitable way of providing a visual clue to the presence of any feature, and what that feature might be, is undoubtedly by the provision of adequate colour and luminance contrast with the shape and size being useful supporting information in the decision process. In the context of search, navigation and identification, the Project has identified critical surfaces and special features at which special attention to colour and luminance contrast will help many visually impaired people.

BENEFICIAL OUTCOMES

This study has, uniquely, established and considered the visual and navigation abilities, not the 'disabilities', of visually impaired people and what opportunities exist to assist them in the built environment. This has given the work a positive orientation and also offers the prospect of improving the built environment for all building users.

Further information, including details of the design guides, can be obtained on the Web Page for the Research Group for Non-Handicapping Environments: http://www.rdg.ac.uk/AcaDepts/kc/nhe/ or by contacting the Group Administrator, Mrs Val Keane (01189 316734; fax; 01189 316735; E-mail: V.A.Keane@reading.ac.uk)

Testing fire resistance of timber frame buildings

A major project investigating and testing the fire resistance of medium-rise timber frame buildings is now under way at BRE Cardington. With backing from the Partners in Technology scheme and the TF2000 Consortium, and scheduled for completion by March 2001, the main aims are to show that the performance of a complete timber frame building subject to a real fire is at least equivalent to that obtained from standard fire tests on individual elements, and to demonstrate that this form of construction can meet the relevant functional fire performance requirements of the Building Regulations for England And Wales and the Building Standards for Scotland.

The project will evaluate levels of safety for residents of medium rise timber frame buildings given a particular fire scenario based on statistical data for fire loads in residential accommodation. Other objectives include:

- validating the parametric approach adopted in Eurocode 1 with regard to fire severity and duration;
- assessing the means of determining external flame spread;
- allowing an assessment to be made of the likely spread of fire both across compartment boundaries and by upward flame spread through ventilation openings and cavities;
- providing information to be used to verify analytical models used to predict thermal and structural behaviour at elevated temperatures;
- measuring the extent of charring to elements of the structure;
- providing information on the performance of connectors and connections subject to fire.

The intention is to carry out a full scale fire test in one of the four flats on a storey of the timber-frame building at Cardington. The compartment will be fully fitted out, and furnished with a pre-determined value of fire load towards the upper end of the spectrum for residential accommodation in flats. Ignition will be from a single source, most probably in the living room/kitchen area. Timber cribs will be used for ignition in this location and flame spread will be completely uninhibited. The ventilation to the compartment will be arranged to represent a worst case scenario consistent with the form of construction and the regulatory requirements.

It is the safety of the occupants which is the prime consideration in a test of this nature. The test should provide useful information on fire growth and development, the assumption being that there will be a fully developed fire. The compartmentation should prevent a fire in one flat from spreading to adjoining flats through party walls, windows, floors or communal stair and lift shafts, or from compromising the integrity of the means of escape.

To assess the performance of the structure in maintaining both the safety of the occupants and the integrity of the compartmentation for the required period of time, the building will be comprehensively instrumented.

For further information please contact Dr Vahik Enjily or Mr Tom Lennon at BRE (01923 664392; fax: 01923 664783; E-mail: enjilyv@bre.co.uk or lennont@bre.co.uk).

The six-storey timber frame building at BRE Cardington which will be used in the project.

HIGHWAYS

Hard shoulder or running lane?

The West Midlands office of the Highways Agency, tasked with finding ways of enabling more traffic to use the heavily congested sections of the M6 around Birmingham, has converted the hard shoulder between Junctions 7 and 8 into a running lane for a trial period. Use of the hard shoulder is one measure in the Agency's toolkit of innovative techniques.

A significant proportion of traffic joining the M6 at junction 8 leaves at the next junction to travel along the A34. During peak hours this caused problems when lane 1 was occupied with vehicles just using the short section of motorway between the two junctions. The same also occurred in the opposite direction.

TRL was commissioned to undertake surveys of vehicle flows and speeds both before and after commencement of the trial in February '98. The numbers and types of incident occurring have also been monitored to determine whether they could be attributed to the new layout. Further surveys will be undertaken after about a year to examine the longer-term effects.

For further information please contact Malcolm Pickett at TRL (01344 770519; fax: 01344 770643; E-mail: malcolmp@t.trl.co.uk).

STRUCTURES & TRANSPORT

Worked example of integral steel bridge design

The concept of designing bridges as 'integral bridges', that is without any expansion joints, is being encouraged by the UK Highways Agency in their desire to improve bridge durability. A new SCI publication should help designers to respond.

This third SCI publication dealing with the design of such bridges is called *Integral Steel Bridges: Design of a Multi-span Bridge – Worked Example*. It gives a worked example for the design of a multi-span, fully integral bridge that utilises H-pile abutments, steel tubular pile column intermediate supports and a composite plate girder deck. Calculations are provided for each design stage, together with a detailed commentary explaining the background to the methods used, references and the parameters chosen. Computer-based numerical techniques have been used to enable full soil-structure interaction to be considered in the analysis. At the abutments, a design is proposed for the fully integral connection between the steel H-piles and the composite deck. Vehicle collision loading on the intermediate supports is considered and two cross-head options are investigated.

Funds for the research and development leading to this publication were provided by the following British Steel plc Divisions: Section, Plates and Commercial Steels; Piling; and Tubes & Pipes.

For further information please contact Ms Sarah Houghton at SCI (01344 623345, fax: 01344 622944, E-mail: reception@steel-sci.com / E-mail: s.houghton@steel-sci.com) or visit the SCI website: www.steel-sci.org).

Irrigation – improving maintenance planning

Researchers at HR Wallingford have developed a computer-based procedure to help assess irrigation schemes and pinpoint areas where repairs would be most cost-effective. MARLIN (Maintenance and Rehabilitation of Irrigation Networks) was devised HR in collaboration with the Irrigation Department of Sri Lanka with funding provided by the UK's Department for International Development.

Around 30% of world food production relies on irrigation, but many irrigation schemes fail before their allotted life span. A major reason is the deterioration of the infrastructure, as canals become blocked, canal linings leak and control structures fall into disrepair. Cash for maintenance and rehabilitation is scarce and funds may not be targeted effectively.

MARLIN was initially developed for use on the Muruthawela scheme in southern Sri Lanka. 'The procedure allows you to take a more objective view of where best to spend money,' says Gez Cornish of HR. 'It involves three steps: defining assets; assessing their condition using a scoring system, and preparing a maintenance plan for priority works.'

A schematic map is prepared on computer. Step one asks operators to identify canal reaches and any associated structures. Field staff then carry out a condition assessment using simple 'yes/no' questionnaires generated by the MARLIN program. Results are expressed as condition scores. 'A Priority Index is used to rank the importance of different maintenance needs. The Index takes account of the type of asset and the area it serves,' says Cornish. 'Higher scores indicate greater priority and that the poor condition of an asset threatens irrigation supply to a large area of the scheme.'

Lists of items for maintenance can then be drawn up, guided by the Priority Index. 'MARLIN identifies priority items and offers you the option of entering repair costs' says Cornish. 'It helps users to develop a needs-based budget.'

Field inspection of a serious lining failure

MARLIN's condition assessment procedure is function-based and seeks to link condition to hydraulic performance. In this way it helps managers to justify maintenance through sustained or improved scheme performance. This is important where maintenance funds are limited and must be used to best effect.

A Spanish version of MARLIN is currently being tested on the Alto Rio Lerma Irrigation District in Mexico, in collaboration with the International Water Management Institute (IWMI).

For further information please contact Gez Cornish at HR Wallingford (01491 835381; fax: 01491 832233; E-mail:gac@hrwallingford.co.uk).

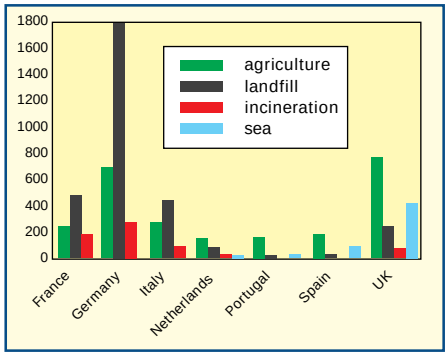
Sludge here forever and a day!

Work is under way at the School of Water Sciences at Cranfield University to investigate the factors affecting water removal from sludge and to provide a simple and cost-effective way of reducing dewatering costs.

Sludge is a solid-liquid waste end-product that can be organic or inorganic in nature. One good example is sludge produced during the sewage treatment process which, in the UK alone, produces about 11,000,000 tonnes of dried solids each year. Sludge producers are more than aware of the inherent problems associated with its disposal. As sewage sludge consists of only 0.25–12% solids, treatment is required before it is disposed either to sea or land. Although the removal of water from the sludge, called dewatering, is an expensive process, the application of other sludge treatment processes, such as sludge thickening and anaerobic digestion, result in a change in sludge content, which can reduce dewatering operating costs.

To compound these issues, current attitudes to sludge disposal are changing. The impact of recent legislation will result in an increase in the volume of sludge being produced. Furthermore, at the end of this year, disposal at sea will be outlawed, resulting in a further 28% of sludge which will have to be disposed of by alternative methods.

Landfill disposal is the most favoured option, but the landfill taxes place increasing pressure on sludge producers to minimise the final sludge volume. A large increase in sludge incineration is expected, estimated to increase by 2006 to 20% of UK sludge being treated by incineration. A review of sludge processing is needed and any cost-cutting options resulting in a drier sludge will be welcomed.



EU sludge producers with 1990 disposal routes.

A whole range of factors can influence sludge nature, from its origin through to the use of added chemicals during processing. Water binds strongly to sewage sludges, making them difficult to dewater. The sludge is bound together through the intertwining of bacterial cells and the production of bacterial extracellular polymer (ECP). It is probable that the presence of ECP can greatly influence the efficiency of water removal as one of its known functions is to enhance the survival of bacteria by preventing desiccation. Therefore sludge with a high ECP concentration is more difficult to dewater than one that contains less ECP.

Research to be completed at Cranfield aims to clarify the role of ECP in sludge dewaterability, and then manipulate ECP to form sludges that are easier to dewater. The project will utilise Cranfield University's own sewage works, an invaluable facility with a constant supply of sewage!

This work could have a large potential impact on the sludge producers, providing process operational guidelines to help sludge producers form a sludge that is easier and therefore cheaper to dewater.

For further information, please contact: Dr Joanne Quarmby at The School of Water Sciences, Cranfield University, Cranfield. MK43 0AL (01234-750111 ext 2546; fax: 01234-754225; E-mail: j.quarmby@cranfield.ac.uk).

EPSRC

Civil engineering technology – building on UK strengths

How much does my business depend upon the application of good technology? Where does my business's technology come from? How up-to-date am I – how do I know what the latest technology is? How much do I – or should I – invest in the technology that underpins my business? What is my technology strategy to sustain and advance my business? What shall I do differently tomorrow as a result of reading this report? These are some of the major challenges to readers of the Report – called *Thriving in a Global Market: Technology Strategies for Civil Engineering Exports* – from the £330,000 Project on Technology support for Civil Engineering Exports led by the ICE over the last 2 years.

The Report presents major messages and recommendations to industry, government and the research community about the role of technology in maintaining industry competitiveness in overseas markets. It is a civil engineering industry response to the UK Government's Foresight initiative to increase the already-substantial UK success in export markets. The Report and its detailed Appendices provide a knowledge base of information on world construction market trends, and define supporting technology needs.

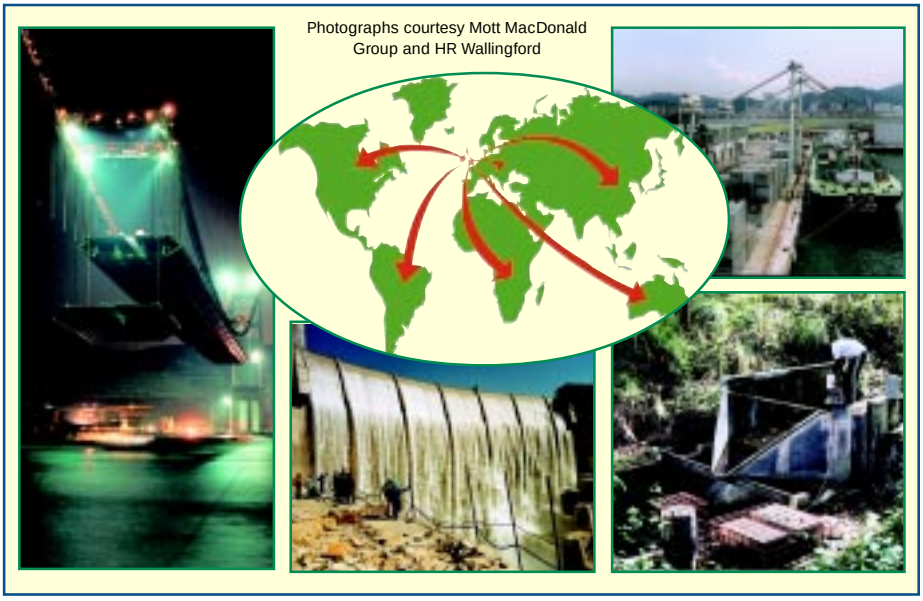
The Report was launched at the ICE on 22 September by ICE President Sir Alan Cockshaw, Construction Minister Nick Raynesford and the ICE's Project Director Mike Thorn of HR Wallingford. The Launch Meeting particularly highlighted the message of the first recommendation - that UK industry must compete globally by adding intellectual value, with industry and Government investment focusing on technologies that create or maintain a leading edge. It was attended by many of the senior figures in the industry who participated in the project and in the development of the Report's recommendations.

In welcoming the Report, Mr Raynesford said: 'The Report reflects what the industry is thinking about success in export markets. I very much hope it will be a Report on which the industry acts and thrives'.

In introducing the main findings, Project Director Mike Thorn stressed: 'It is crucial to develop a targeted strategy for Britain to compete for overseas business. The Report will be a vital reference for civil engineering contractors, consultants and suppliers who need or wish to take advantage of the many opportunities abroad'.

The project's objectives were to:

- assess technological and export performance trends in the major overseas markets for UK civil engineering;
- assess comparative strengths and weaknesses in UK civil engineering technologies compared to overseas competitors, and to propose measures to build on the strengths and rectify the weaknesses;
- identify technologies that are considered critical to export success in civil engineering, and their interaction with other techniques such as financial engineering;
- identify and promote appropriate research programmes to cultivate UK expertise in the identified areas;
- engender a greater export promotion culture in the UK civil engineering research community, industry and professions, and to direct the industry towards supporting R&D aimed at enhancing or strengthening civil engineering exports.



The project focused specifically on the following sectors in which the UK civil engineering industry has a strong record of success and leadership, and which are expected to offer opportunities for development and growth:

- coastal and river engineering;
- environmental improvement and sustainable development;
- infrastructure for urban development and megacities;
- transport planning and infrastructure;
- water and wastewater engineering;

The prime objective has not been the identification of specific technologies, although these have emerged in discussions and workshops, but to change the attitudes of those engaged in setting research priorities and allocating resources, thus ensuring technical support for the UK's export potential. The interaction of 'technology push' and 'market pull', and the challenge of being able to compete in the face of increasing globalisation of knowledge and availability of skills, have been central to the project.

Success in continuing to compete in what is now a global market is vital to the continued health of the civil engineering industry and our national standard of living. The industry must be able to compete in large, sophisticated markets and not depend on softer targets where technology might still be less critical. Only through sustained investment in core technology through Innovation, Research, Development and Application (IRDA) will the industry survive and thrive, and maintain its contribution to the national economy and strong identity.

Many individual members of the civil engineering profession, major companies and research centres have contributed their knowledge, expertise and vision to this project through its programme of interviews, discussions and workshops. The Report and its appendices are a distillation of the information gathered during the study, of the workshop discussions, and of the conclusions drawn at those workshops and by the Project Team.

The main outputs for the five sectors of the civil engineering industry that were studied during the Project include the recommended priorities for technology development in each sector. In the project's cross-sector workshops. discussion also generated general perspectives and conclusions which are presented as broad Recommendations and Messages as follows.

R1 ***Global competition.*** UK industry must compete globally by adding intellectual value. Industry and Government

investment must focus on technologies that create or maintain a leading edge.

R2 ***IR into DA.*** There is a great challenge to translate Innovation and Research into Development and Application. A higher proportion of industry and Government resources for technological development needs to be focused on Development and Application.

R3 ***Population, development and society.*** The civil engineering industry, its clients and suppliers must embrace environmental, societal and sustainability dimensions in their projects and their use of technology.

R4 ***Strategic research.*** A new industry-Government partnership needs to be forged for the long-term maintenance of centres of excellence.

R5 ***Demonstration projects. Indu***stry has to be able to demonstrate new technology, successfully applied in high-profile projects. Clients, including Government, and the industry must develop mechanisms to enable new technology to be applied, tested and proved on 'home market' projects so that it can be offered successfully in export markets.

R6 ***Integrated and adapted te***chnologies. The future lies in the integration of design and construction, with adaptation to local circumstances. The industry and the research community should seek to advance and exploit those areas where it finds it has, or can gain, real technical superiority, including the creative application of existing knowledge and research results.

R7 ***Design for whole-life value***. Long-term performance and integrity of infra-structure are key issues. The industry must deliver projects that provide good whole-life value for money by integrating techniques for risk management and value management with those for determining and costing anticipated service lifetimes. Clients, including Government, must encourage industry in this direction through suitable project specifications, evaluation and procurement policies.

R8 ***Finance and procurement.*** Financial engineering is an important part of winning projects. Industry must work harder at project integration, and Government needs to give practical assistance in international project financing.

R9 ***International standards.*** Government and industry should lead the development of civil engineering-related codes and standards where they have a value in winning overseas contracts.

R10 ***Education of overseas students.*** High quality engineering education is a UK strength and a human investment that yields future business. Overseas students are the clients of the future, and should be encouraged by Government and industry alike.

Other key messages cover such diverse subjects as:

- creative swiping of ideas and/or technologies from other industrial sectors;
- the application of advanced IT in civil engineering
- the movement and use of technology across time zones
- the economic multiplier effect of projects financed, designed, managed and constructed by UK-based companies;
- the role of specialised technology companies or groups as sources of technological advances;
- the need for new tools for measuring industry success overseas.

The ICE hopes that industry will be inspired by the vision of the Report and will respond to its challenges by examining their own technology strategy in a rapidly changing global marketplace.

Following the launch of the Report, the final dissemination stage of the project will include a series of regional meetings, plus discussions with organisations concerned with export promotion or technology development to present and promote the results to them.

The particular challenge for Stage 3 is to prevent the Report and its recommendations lying idle. The Project Team will be actively 'pushing' the project results and recommendations into the above organisations. We will be inviting them to consider actively how they can take the recommendations forward to assist themselves, their members, and the UK generally, to develop and use technology for increased export success.

As Sir Alan Cockshaw said at the launch:'Starting today and continuing over the coming months, we shall be taking the messages out to industry and the research community. The UK construction industry cannot compete internationally unless it adds value and provides total solutions'.

To participate in these discussions, visit the ICE Export Technology Forum at http://www.ice.org.uk/exports/ or contact the Project Manager – details below.

Copies of the Report (Price £30) are available to UK organisations and individuals from the TTL Bookshop at the ICE (Tel: 0171-665 2019; fax: 0171-222 7500; E-mail: maddox_j@ice.org.uk). For further information about the project or dissemination activities, please contact Roger Venables, Project Manager, ICE Technology for Exports Project, 12 Cranes Drive, Surbiton, Surrey, KT5 8AL (0181-399 4389; fax 0181-390 9368; E-mail: ice-exports@venablesconsultancy.co.uk).

THE INSTITUTION OF CIVIL ENGINEERS

DETR ENVIRONMENT TRANSPORT REGIONS

What has been forecast by the futurologists

As part of the project, a review was undertaken of the literature where authors have examined many diverse trends and made predictions about the future. The potentially most significant predictions are given below to stimulate readers.

- Population will grow irrespective of what controls are used.
- More than 90% of the world's population growth is in developing countries.
- The need for infrastructure will increase but the means of financing that infrastructure will become more complex.
- The gap between the rich and the poor will grow.
- Crime will be the fastest growing industry in the world.
- Water will be the single most important asset for any country.
- Much of the new infrastructure in the developed world will be placed underground as space becomes a premium resource.
- A focus on the environment will be paramount on most countries' agenda.
- The 'job for life' concept will disappear and new employment patterns will evolve.
- Information technology has changed working practices, and will continue to do so.
- Technology will have no respect for international boundaries.
- Patterns of communication will change with electronic commerce and e-business becoming the norm.
- Economic cycles with traditional boom and bust will not change and the key markets for engineering infrastructure will be in Asia and Latin America.
- Africa shows no signs of being a major market for engineering infrastructure.
- Organisations from Central and Eastern Europe will emerge as major competitors in the global engineering and construction market.
- Incorporating intelligence into materials will revolutionise the use of construction materials.
- It will be possible to design a project in weeks rather than months through the use of knowledge-based engineering and object-based modelling.
- Safety will become a major issue in construction as the current level of accidents and injuries become socially unacceptable.
- Small and medium-sized enterprises will grow in importance in the global economy, because they are able to react quickly to change and opportunity.

Strategies for window and cladding interfaces

Interfaces, joints and connections between different elements or sections cause more problems than almost any other aspect of a building. There are challenges during design, manufacture and construction as well as implications throughout the life of the building.

These challenges are particularly relevant for the building envelope. Here the joints must perform at the same level as the main areas of wall or roof, but the pressures on them are invariably much greater. They must keep out the weather, but at the same time, accommodate tolerances and inaccuracies and cater for movements both during construction and throughout the life of the building. To exacerbate these difficulties, building designers usually want to minimise the visual impact of the joints.

The envelopes of many of our buildings comprise several different cladding systems. They may include precast concrete panels as well as metal and glass curtain walling. Glazed areas may be enclosed between metal panelled areas. These different systems have different constraints, different opportunities and different cultures. The interfaces are where these differences come into sharp focus.

Alistair Gibb, with a team from Loughborough University, is developing a standardised strategy for the design and construction of window and cladding interfaces, covering both technical and managerial aspects. The £300,000 project is 50/50 industry/Government funded through the Meeting Client's Needs through Standardisation LINK programme, which is jointly funded by EPSRC and the DETR. Eleven industrial partners are supporting the project.

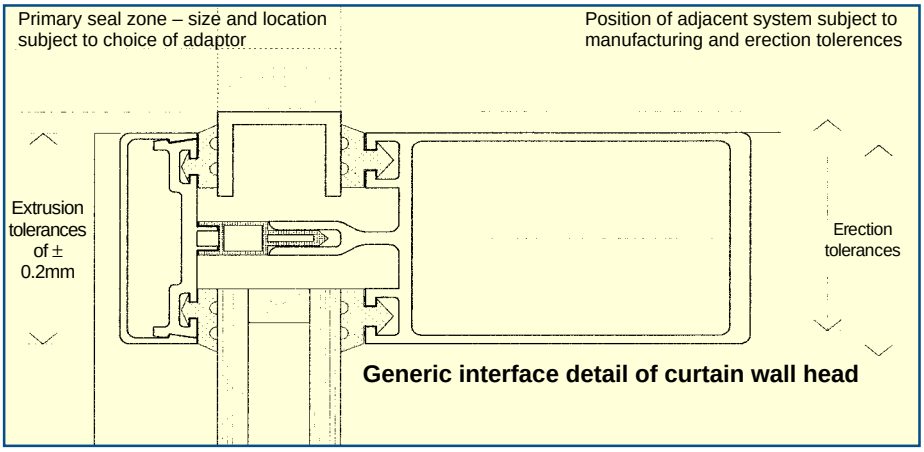
The first phase of the project concentrated on the technical aspects of interface design and developed the following strategy for interface design development:

- identify all the interfaces for the building envelope;
- codify each interface (using a system matrix);
- classify each interface (using generic component profiles and joint types);
- consider key issues (identified from the earlier steps);
- agree strategy for each interface;
- ensure strategy is followed by all parties throughout the project (with periodical reviews).

The project is developing this model and will be testing it on broader industry samples through a number of workshops in November and December 1998.

The main project deliverables will include an interactive CD ROM and hard-copy reports disseminated by CWCT. The CD will include key interface details, approaches, common problems and proposed solutions. The document will enable designers and suppliers to properly consider interface issues during the design phase. This will enable strategies to be developed to avoid the endemic problems occurring on site.

For further information please contact Alistair Gibb, Department of Civil and Building Engineering, Loughborough University, Loughborough, LE11 3TU (01509 223097; fax: 01509 223981; E-mail: a.g.gibb@lboro.ac.uk). The University of Loughborough is a Member of the Centre for Window & Cladding Technology.



Generic interface detail of curtain wall head

3-D computer models for river engineering

Physical models are the traditional tools for investigating river engineering schemes. They are visually representative and reproduce conditions well, but they are also expensive and require specialist facilities. Engineers at HR Wallingford have been investigating the use of 3D computational models in this type of study, under contracts from MAFF and DETR.

'Engineers already use computational fluid dynamic (CFD) models in the aircraft and automotive industries, and there is no fundamental reason why such methods cannot be applied in civil engineering hydraulics as well,' says Dr Paul Samuels of HR Wallingford. 'However, it is important to consider representation of the free surface and turbulence when selecting an appropriate model.'

MAFF has sponsored research to identify which models might be applied in river engineering projects. 'We carried out a review of 16 available models and subsequently applied several of them in river studies,' explains Samuels.

PHOENICS (for example) was used on data from the River Dommel in Holland to investigate head losses around bends, where model predictions were compared with field measurements. In general, predicted velocity profiles agreed well with observed ones and, by modifying the model grid, it proved possible to simulate the effect that increased bend curvature would have on head losses. Another model, TELEMAC-3D was used on experimental output from the Flood Channel Facility at Wallingford and later applied to field data from the River Severn.

Other projects, funded by the DETR, have considered the application of 3D models to river structures (weirs, sluices, spillways and pumping stations) and the suitability of such models for representing flow around river groynes (see *Research Focus* 34).

The research so far indicates that commercial CFD codes will have increasing use in river engineering, though most require some adjustment to achieve the desired end and no single model is suitable for all situations.

For further information please contact Dr Paul Samuels at HR Wallingford Ltd. (01491 835381; fax: 01491 832233; E-mail: p.samuels@hrwallingford.co.uk).

Under the skin of urban stone decay

This project aims to improve current practice in the conservation of building stone by linking surface alteration types to properties of the underlying stone and the possible consequences of their removal or modification during cleaning.

Building stone is normally described, its durability assessed and its fitness for purpose defined on the basis of the characteristics of freshly quarried blocks. These characteristics comprise a combination of aesthetic attributes such as colour with chemical and physical properties ranging from hardness and solubility to rates of moisture absorption and loss. Many of the physical properties are in turn determined by factors such as porosity, permeability and pore size and shape. However, as soon as stone is dressed and placed in a building these properties begin to alter as they adjust to new environmental conditions. This can include exposure to a wide range of pollutants and complex cycles of wetting and drying, and heating and cooling.

One of the most common adjustments by stone in polluted urban environments involves the accumulation of calcium sulphate (gypsum), derived either directly from blown or washed-in pollutants or from the alteration of calcareous stone and/or mortars subject to acid deposition. Accumulations often occur as surface crusts in areas sheltered from rainwash – invariably blackened by incorporated dust and ash – or within the stone at depths and concentrations related to wetting and drying regimes.

To these accumulations can be added salts from other sources such as marine aerosols, rising groundwater and road deicing. Through mechanisms such as crystallisation and hydration, the effects of these salts are frequently disruptive and lead to granular disintegration, flaking and contour scaling. However, their presence also modifies porosity characteristics and hence the physical behaviour of the stone and its susceptibility to a wider range of decay processes.

It can be argued therefore that when assessing the condition of a stone in service it is more appropriate to consider the characteristics of its altered or modified state. Nowhere is this more important than when stonework is to be cleaned or conserved.

Under these conditions there is always the risk that removal of crusts or the dressing back of stonework could trigger rapid breakdown by exposing weakened subsurface layers. This is particularly evident in sandstones where, in polluted maritime environments, complex mixtures of salts can collect in stone weakened by the outward migration and loss of iron cements. Chiselling away the outer 1 cm of this stone can have the short-term effect of removing unsightly crusts and scales (Figure 1), but quite rapidly any reservoir of salts left in the stone can produce a surface efflorescence and renewed scaling (Figure 2).

To better predict the likely consequences of cleaning and crust removal, it is therefore important that:

- methods are available to assess the effects of surface alteration on, in particular, patterns of moisture and salt movement within the underlying stone;
- the impacts of intervention procedures are both modelled and understood;
- the techniques used are readily applicable on site, unambiguous and easily comprehended.

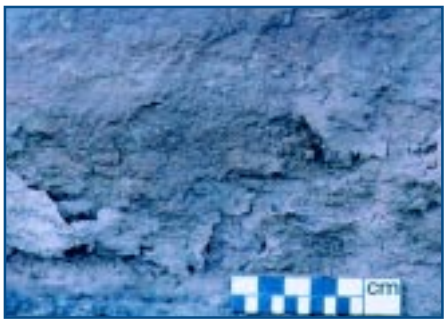


Figure 1: Outer surface of a highly weathered quartz sandstone from a one hundred year old church in East Belfast subject to ongoing high concentrations of atmospheric sulphur, particulates and marine aerosols (photograph, P.A.Warke).

Figure 2: The surface of the same church as in Figure 1, approximately six months after the outer 1 cm of overtly weathered stone had been physically removed. Note the efflorescence formed as the reservoir of salt left in the stone is mobilised and the beginnings of a new cycle of flaking and scaling (photograph, P.A.Warke).

It is these requirements that will be addressed over the course of a three-year, interdisciplinary project in the Schools of Geosciences and the Built Environment at Queen's University. This will bring together field measurements of porosity and permeability on Portland Limestone and Dumfries Sandstone, with exposure trials of test blocks, laboratory analysis of altered stone and simulations of moisture and salt uptake and loss in climatic cabinets. These will in turn be combined to model the effects of surface modification and any subsequent intervention on salt movement and concentration.

The ultimate objective is to identify visual criteria that can be used by architects and builders, in combination with limited on-site measurements, to predict the consequences of different conservation strategies.

For further information please contact: Bernard Smith, School of Geosciences, The Queen's University of Belfast, Belfast, BT7 1NN (01232 335144; fax: 01232 321280; E-mail:b.smith@qub.ac.uk).

EPSRC

Blast-resistant cladding panels developed

Lightweight, blast-resistant cladding panels have been successfully produced and validated from a three-year collaborative project between Pera and CIRIA. The panels, which are 40 mm thick and can be produced to any dimensions, are composed of high-grade glass fibre reinforced polymer laminate skins encapsulating a novel high performance core developed especially for the panels.

The blast performance of the panels was validated by live blast testing. The panel exceeded the requirements of EXR2, (equivalent to the resistance of 11.3 mm laminated glazing) as defined in draft CEN Standard CEN/TC33/WG/AH3, with no visible damage. Other standard tests were carried out to ensure that the panels meet the general requirements for cladding panels.

By adapting technology from the aerospace and defence industry, the panels are manufactured by a single mould process, ensuring consistent high quality and economic production. The cost is less that £200/m2, which relates well to other cladding and to the add-on cost for enhanced blast performance of glazing.

Manufacturers and raw material suppliers involved in the project will now take the technology forward to produce panels for the commercial market.

The work was supported by the DTI through their Carrier Technology Programme, and organisations representing manufacturers, raw material suppliers, the construction industry, and the testing and assessment sector, participated in the project.

For further information, please contact Ann Alderson, Research Manager, CIRIA, (Tel: 0171 222 8891; Fax: 0171 222 1708; E-mail ann.alderson@ciria.org.uk).

CIRIA

Prop loads in large excavations

Embedded walls retaining the sides of large excavations are often supported at some stage in the construction process by temporary props, to reduce wall and ground movements. The props are costly, and the potential advantages of reducing them and/or eliminating some levels of propping in a large excavation are considerable. There is also a widely held view within the construction industry that the procedures currently used in the design of temporary props tend to overestimate actual prop loads. Construction of the London Underground Jubilee Line Extension (JLE) stations at Canada Water and Canary Wharf offered an opportunity to investigate the problem by monitoring temporary prop loads in practice.

The research project, which was supported by EPSRC and companies involved in the construction of the two stations, is now complete. Two high-quality case records have been generated and used to assess the suitability of various assumptions and methods of analysis for use in the design of temporary propping systems. The work has also clarified some important issues concerning the way in which prop loads are monitored (for example, for a design using the observational method) and the effects of temperature and certain construction details.

For the stiff, reinforced concrete walls at Canada Water and Canary Wharf, temporary prop loads similar to those measured in the field (neglecting temperature effects) were calculated using limit equilibrium and finite element analysis. In finite element analyses, the key factors were the effect of wall installation and the timescale of excess pore water pressure dissipation in low permeability strata. In limit equilibrium analyses, realistic prop loads were calculated on the basis of fully active conditions in the retained soil and pore water pressures in equilibrium with the prevailing groundwater regime.

Guidelines for the successful monitoring of temporary prop loads using vibrating wire strain gauges have been developed, and the research points to the following general conclusions.

- Although, in design, a margin of safety is essential to allow for events such as the accidental removal of a prop, the over-prediction of prop loads seems to be the result of a consistently conservative set of design assumptions rather than any flaw in the soil mechanics principles.
- Temperature-induced axial loads may account for a significant proportion of the total load carried by a prop installed at a low temperature. These can be estimated from the anticipated temperature rise, the coefficient of thermal expansion of the prop, and the degree of end restraint (perhaps 50-65% for stiff walls) provided by the wall and the soil behind it.
- In the absence of non-uniformities due to a lack of fit at the ends of a prop, bending moments due to wall rotation and/or temperature gradients across the prop of the same order as those due to self-weight effects must be expected. However, a lack of fit between the walings and the ends of a prop could increase secondary bending effects substantially – a point which may need to be considered in design.

Temporary props in place during construction of Canary Wharf Jubilee Line Extension station (courtesy: Tarmac Construction).

For further information please contact William Powrie, Department of Civil & Environmental Engineering, University of Southampton, Highfield, Southampton SO17 1BJ (01703 593214; fax: 01703 594986; E-mail: wp@soton.ac.uk).

EPSRC

GROUND ENGINEERING & STRUCTURES

Earthquake engineering consultation

Following a workshop held in February 1998, SECED (Society for Earthquake and Civil Engineering Dynamics) has published a consultation document entitled: Mechanisms of industrial-academic interaction in earthquake engineering. The document records the discussion at the Workshop and sets out a number of proposals for improving interaction between the research and practitioner communities.

Copies of the consultation document can be obtained free by sending a self addressed envelope to: Liz Marwood, SECED Secretary, Institution of Civil Engineers, Great George Street, London SW1P 3AA (0171 665 2238; Fax: 0171- 799 1325; E-mail: marwood_l@ice.org.uk). The main summary of the document can also be accessed from the SECED website: http://www.bham.ac.uk/CivEng/seced/

The Institution of Civil Engineers

STRUCTURES & TRANSPORT

Best practice guidance on steel bridge construction

A Steel Bridges Group has been established as a technical forum to consider matters of high-priority interest to the steel bridge construction industry and to suggest strategies for improving the use of steel in bridgework. It has recently prepared a collection of guidance notes on a range of topics concerning the design and construction of structural steelwork for bridges: Guidance notes on best practice in steel bridge construction.

The objective has been to provide guides to good, accepted practice. Supported by British Steel SP&CS and the Highways Agency, the guidance notes complement the SCI publication Specification of structural steelwork for bridges: a model Appendix 18/1, which was written for use in project specifications and which makes reference to some of the Guidance Notes.

The notes are grouped in sections covering design, detailing, materials and products, contract documentation, fabrication, inspection and testing, erection and in-situ construction work, protective treatment and other topics.

Comments, feedback and suggestions for further notes are welcome. Please contact Mr D C Iles at SCI (01344 623345; fax: 01344 622944; E-mail: d.iles@steel-sci.com) or visit the SCI website (www.steel-sci.org).

The Steel Construction Institute

Reduce megatexture to control tyre noise

For vehicles operating at speeds in excess of about 60 km/h on dry roads, the noise from the tyres dominates over all other sources. In order to control this form of noise it is necessary to have a good understanding of the mechanisms involved and an understanding of how the surface parameters of importance can be both identified and included in the engineering process. It is also vitally important that any changes that are made to road surfaces or the tyres do not compromise skidding performance and safety and, of course, durability.

Studies at TRL are helping to provide a better understanding of the role of surface texture in governing tyre noise generation. By measuring the longitudinal texture profile of road surfaces using a specially adapted laser profilometer, it has been possible to form the texture amplitude spectra of different surface types and to relate the components of the spectra to the noise generated by vehicle tyres.

The most important correlations were found to occur in the megatexture region with road surface texture wavelengths ranging from 50 to 200 mm. These wavelengths were highly correlated with noise levels and, since they are not normally associated with skidding performance, it follows that reducing megatexture amplitudes will provide lower noise road surfaces without necessarily compromising skidding performance and hence safety.

Recent trials using road surface materials such as exposed aggregate concrete and stone mastic asphalt, both of which can be engineered with low megatexture amplitudes, have shown very promising low noise characteristics coupled with good friction and skidding performance.

In order to gain a better understanding of the tyre/surface as a system, TRL are currently developing a test vehicle for tyre noise testing. The vehicle and its associated instrumentation will be housed in a 7.5 tonne truck. The vehicle encloses the apparatus carrying an independently supported test tyre which can be subjected to a precise load while measurements of noise and rolling resistance are taken. Tests will be conducted at motorway speeds, for the representative measurement of tyre noise, and the vehicle will be operational on trafficked roads thereby avoiding the need to close lanes or carriageways. With this vehicle TRL researchers hope to be able to substantially develop tyre/road surface databases and gain a further level of understanding of how both tyre and surface design can be developed in combination to reduce tyre noise.

New test vehicle for tyre noise testing

For further information, contact Mr Steve Phillips or Dr Paul Nelson at TRL (Tel: 01344 770765 or 01344 770022, E-mail Stevep@e.trl.co.uk or Pauln@e.trl.co.uk).

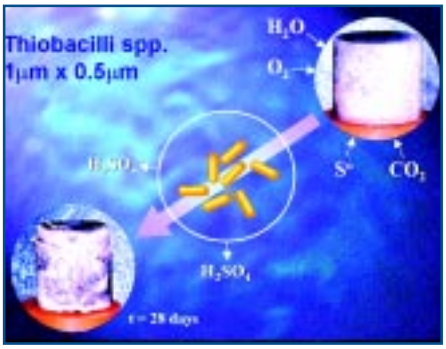
Bacterial corrosion of cement-solidified industrial wastes

At first sight, a concrete slab would not appear to be a welcoming environment for any form of life. Nevertheless, given the right conditions, many micro-organisms can thrive in this environment, with potentially dramatic effects on the material structural properties.

For example, the autotrophic thiobacilli group of bacteria can grow on a diet of little more than carbon dioxide and sulphur, producing corrosive sulphuric acid. In the Hamburg sewage system, the acid produced by thiobacilli was responsible for destroying concrete pipes in a matter of a few years, with disastrous consequences.

Whilst severe cases of microbial-induced degradation (MID) tend to be limited by the availability of a suitable energy source (reduced sulphur in the case of thiobacilli), the bacteria are fairly ubiquitous in the environment, and may affect a wide range of materials.
The perceived structural integrity and durability of cement has led to its widespread use in the treatment of radioactive and hazardous industrial wastes. In cement-based solidification of industrial wastes, cement is added to produce a low-grade concrete-like material. The assumption is that, under disposal conditions, the hazardous waste components are prevented from leaching for many years by the production of a high pH and low permeability monolith. For long-term environmental protection, the monolith must retain its physical and chemical integrity. However, under landfill conditions, such materials may be highly susceptible to the type of bacterial degradation observed in the Hamburg sewer.

Dr Robert Rogers (Idaho National Engineering Laboratories, USA) has isolated these bacteria at a number of real waste disposal sites and has shown the potential for significant structural breakdown and contaminant release as a consequence of their growth.



His expertise in this area was employed to develop microbial degradation test procedures for the US Nuclear Regulation Commission.

Under an EPSRC Visiting Fellowship Dr Rogers' expertise in this field is being brought to a 3-year research project at Imperial College. The programme combines field and laboratory studies to determine the extent of MID which has occurred in 10-year-old field samples. It will also investigate methods to control the properties of the solidified wastes to minimise susceptibility to microbial attack. By developing a model of the bacteriological and chemical processes, the findings of this project are expected to provide valuable information for waste managers and regulators on long-term environmental implications of further exploitation of this form of hazardous waste treatment in the UK.

For further information please contact Dr Chris Cheeseman at Imperial College of Science Technology and Medicine (0171-594 5971; fax: 0171-823 9401; Email: c.cheeseman@ic.ac.uk).

Update on CIRIA's environmental performance programme

Since 1991, CIRIA has been working on a wide range of collaborative research reports and arranging many informative events addressing the environmental performance for the construction industry. Much has been acheived in changing industry attitudes and in finding solutions to many environmental problems, and the programme is set to continue and develop further.

The continuing programme will draw upon:

- feedback obtained from the workshops organised by the Construction Industry Environmental Forum (CIEF);
- findings drawn from previous CIRIA research including the *Environmental handbooks for building and civil engineering projects and A Client's guide to greener construction;*
- current CIRIA research projects such as *Environmental issues in construction: a strategic review and Environmental management in construction.*

CURRENT RESEARCH

The strategic review of environmental issues affecting the construction industry will be completed this autumn, and openly published in the new year. The project team investigated the guidance currently available and established the views of industry. The main report will summarise the findings of the whole project, with three supporting documents available at the same time, with detailed results of the three stages of the project, namely:

- a desk study examining the progress made by the industry since 1993 on environmental issues;
- a questionnaire-based survey of industry views of the environmental issues they face, from which CIRIA received nearly 300 responses from construction practitioners;
- the development of Sustainability Indicators for civil engineering.

Amongst the findings of this research, CIRIA found that the construction industry felt that information on most environmental issues, including the idea of sustainable construction, is currently less than satisfactory, or is not known to much of the industry. Recommendations are therefore made for improvements in communication, plus consultation and information provision within and outside the industry on environmental issues. The industry also recognises the need to have some way of measuring their performance on the environmental issues identified and communicating this performance.

The CIRIA contact is Richard Lillywhite.

Work has recently began on a study of environmental management in construction, the objective being to provide guidance on the use and application of tools and techniques to manage and improve environmental performance. The research team will:

M&E natural ventilation on a sunny day, Anglia Polytechnic building, Chelmsford.
Courtesy of Ove Arup & Partners

- review published documentation and information on environmental management systems;
- consult the construction sector to identify experience and needs;
- identify relevant case studies;
- prepare a good practice guidance document to help those responsible for the implementation of environmental management systems for construction.

The CIRIA contact is Martin Hunt.

SUSTAINABLE CONSTRUCTION ACTIVITIES

In response to recent changes in policy emphasis, and increasing interest in what the principle of sustainable development means for construction, a sustainable construction programme has been developed, including projects on:

- the economic effects of environmental good practice;
- projects demonstrating environmental good practice;
- the social aspects of sustainable construction;
- improving consultation and communication with local communities during environmentally sensitive development projects.

In addition to these projects, the CIEF is developing a series of regional workshops, which will start in the autumn, to consider the implications of the revised national strategy for sustainable development.

The CIRIA contact for sustainable construction is Jon Bootland.

For further information on any of this work, please contact those named in the article at CIRIA (Tel: 0171 222 8891; Fax: 0171 222 1708; Email jon.bootland@ciria.org.uk)

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
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The Steel Construction Institute,
Silwood Park, Ascot, Berkshire, SL5 7QN
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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,
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