Research Focus

Issue No. 30 AUGUST 1997

PROMOTING THE APPLICATION OF RESEARCH IN BUILDING AND CIVIL ENGINEERING

IN THIS ISSUE

Research leads to new form of slim floor construction

Research at SCI, sponsored by British Steel, the Department of Trade & Industry and EPSRC under a LINK project, has led to the launch of a new slim floor constructions product, *Slimdek.*

Slim floor construction is the generic terminology for a steel beam contained within the depth of the floor slab. The original slim floor beam concept (trademark *Slimflor*) developed for use in the UK, consists of a Universal Column (UC) section with a plate welded to its bottom flange (see Figure 1). The deep deck sits on the bottom flange plate and spans between the beams. This acts as permanent formwork to the in-situ concrete slab and develops composite action with the concrete to resist the imposed loads.

The cross-section of the *Slimflor* beam was asymmetric in shape (Figure 1). Under the LINK project, British Steel and the SCI took the next logical step to develop a hot rolled Asymmetric *Slimflor* Beam (ASB) (see Figure 2). The resulting new product is called *Slimdek* (a registered trademark) and a British Steel patent defines a range of slim floor methods of construction which use deep deck composite slabs.

Initially, British Steel is producing a range of three ASB sections, two of which are 280 mm deep (with different flange and web thicknesses), and one 300 mm deep. All will be rolled using grade S355 steel.

Replacing the *Slimflor* beam with the ASB section gives the benefit of composite action between the beam and concrete without the use of shear stud connectors at the ultimate limit state. It also reduces steel weight, saves in fabrication costs and eliminates the possibility of plate distortion due to welding.

The composite action is enhanced by a raised rib pattern rolled into the top flange of the section. Composite action between the steel beam and concrete has been verified by full scale tests carried out at City University.

The *Slimdek* lightweight shallow floor system generally has 60 minutes' fire resistance. However, service voids can be included in the *Slimflor* beam and, where this is done, fire protection is required.

The RHS *Slimflor* edge beam has been developed as an alternative method for edge beam construction. It offers good torsional properties, an aesthetic appearance and is particularly well suited to edge beam applications (see Figure 3).

For use in conjunction with the ASB sections and RHS *Slimflor* edge beams, a new deep deck profile (designated SD 225) is being supplied by Precision Metal Forming. The new deep deck profile has improved features for construction and service fixings which are illustrated in Figures 2 and 3.

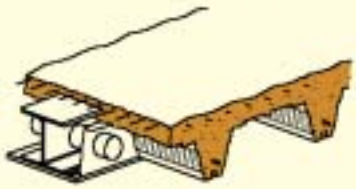

Fig 1. Conventional Slimflor *construction using deep decking*

Fig 2. Asymmetric beam in Slimdek *floor*

Fig 3. RHS edge beam in Slimdek *floor*

The SCI has prepared two design guides and software in 'Windows' format. The guides are available from the Institute Library (01344 872775) and the software via the British Steel Slimdek Team, Teesside (01642 404646).

For further information please contact: Derek Mullett at The Steel Construction Institute (01344 23345; fax: 01344 22944).

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, or if you would like additional copies for circulation within your organisation, 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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New help on roof drainage

Scientists at HR Wallingford have developed a new Manual, and a software package, to help architects and builders to design roof drainage systems. The Manual provides a background to current recommendations in the British Standard Code of Practice BS6367: 1983 for drainage of roofs and paved areas and shows how to carry out typical calculations. The work has been part-funded by the Department of the Environment.

Roof drainage systems help safeguard property worth many times the value of the drainage infrastructure itself. Two design approaches are possible. Simplified techniques can be used to devise rainwater systems capable of coping with almost all eventualities (leading to over-design in most cases); alternatively, design can be tailored to suit the requirements of individual buildings.

British Standard 6367 adopts the latter approach. 'BS6367 sets out the information needed to design conventional roof drainage systems, but the hydraulic principles it covers can be difficult for non-specialists to understand,' explains Richard May who leads the HR project. 'A new European Standard covering gravity drainage systems inside buildings has also been drafted** and, if accepted, will supersede existing British codes.'

May explains, 'We defined requirements for the manual and software package by talking with potential users within the building industry. We also reviewed BS6367 and the proposed European Standard. Initially, researchers aimed to tailor both the manual and the software to the European Standard but, because of the timescales involved, they eventually decided to base the manual on BS6367'. The software, in contrast, looks towards the proposed European Standard. 'We felt this would give designers an immediate practical guide, whilst new software would anticipate future changes,' says May.

The new manual describes the various stages in roof drainage design, referring the user to information and figures in BS6367. It is to be used alongside the Standard and does not replace it. Its chapters cover:

- rainfall data
- effective catchment area
- gutter capacity
- outlets and box-receivers
- flat roofs
- rainwater pipes *and*
- overflow weirs.

'Each chapter has two sections', explains May. 'The first provides background information while the second takes users through the calculations, step by step.' Unlike BS6367, where equations are set out in an Appendix, the new Manual incorporates formulae within the main body of the text for easy reference. Several well-attended training courses have already been organised to familiarise roof engineers with the Manual and further courses are planned around the UK.

The software (*HydroRoof*) has been designed to carry out calculations in accordance with proposed European Standards and requires the user to input information about roof shape, component size, length and type of gutter, outlet position and design rainfall intensity. It calculates design flow loads in each component and compares them against proposed standards. The software has been tested by a number of organisations to identify any areas for improvement. 'Users told us they wanted a relatively simple package that could be run on a PC, but there is scope to refine the interface during future research,' says May.

HR Wallingford is continuing experimental work on the performance of roof drainage systems and, with DoE support, is currently monitoring rainfall and flow rates from two buildings to compare actual behaviour with predictions from design standards. Studies such as these should help to foster amongst designers an improved understanding of the hydraulic processes involved in roof drainage as well as providing them with new tools for the job.

For further information please contact Richard May at HR Wallingford (01491 835381; fax 01491 832233).

** Comité Européen de Normalisation (CEN), Draft European Standard pr EN 12056-3, *Gravity drainage systems inside buildings – Part 3: Roof drainage, layout and calculation*, July 1995.

Monitoring equipment is being used to compare the actual performance of this roof drainage system with predictions.

LINK Transport Research: practical and exploitable

LINK transport programmes have now been providing funding for transport-related collaborative research for over 7 years, originally under the Transport Infrastructure & Operations Programme (TIO) and, since April 1996, under the Inland Surface Transport Programme (IST). Research funded in the early stages of the first programme (TIO) has already produced notable results, with many projects having delivered into the market new or enhanced products or working methods. By contrast, the more recent IST Programme is still open to new applications for support.

EPSRC

The main objectives of these two programmes have been and remain to stimulate good quality scientific research in transport and to contribute to UK wealth creation through commercial exploitation of the results. Government funding of up to 50% is provided for suitable pre-competitive collaborative research undertaken jointly by the science base and industry.

The Programmes have attracted applications involving a very wide range of topics and have encouraged a multi-disciplinary approach and the breaking-down of barriers between different areas of technology. Whilst many projects have been in the areas of civil, structural and mechanical engineering, topics studied have also commonly included electronics, IT, vision sciences and psychology. In particular, it has been encouraging to see applications based upon research which originated in fields as diverse as microbiology, astronomy and medicine.

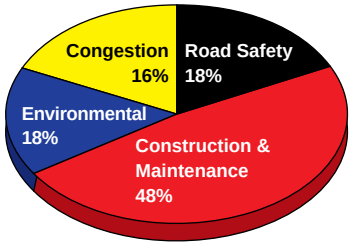
TRANSPORT INFRASTRUCTURE & OPERATIONS PROGRAMME

This programme had four main themes as indicated in the Pie chart. It attracted over two hundred applications across a wide range of topics and technologies, the Pie chart indicating the proportion of approved projects falling within each main theme area. In all, the TIO programme funded 44 projects with a value of over £10m, some of which are still running. Summaries of a selection of IST projects are given overleaf.

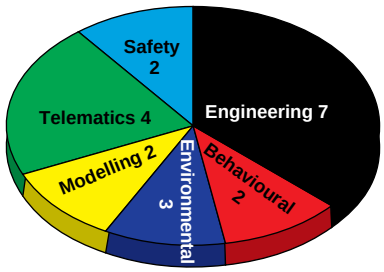
INLAND SURFACE TRANSPORT PROGRAMME

The IST programme has an even broader base than the TIO Programme. It is being funded by the Department of Transport, the Department of Trade & Industry, the Engineering and Physical Sciences Research Council and the Economic and Social Research Council who between them are providing £5.75m. The sponsors are able to fund a wide range of projects including civil, structural and mechanical engineering topics, transport modelling, economic studies, electronics, informatics and telematics, behavioural studies and other work in the field of social sciences across all transport modes.

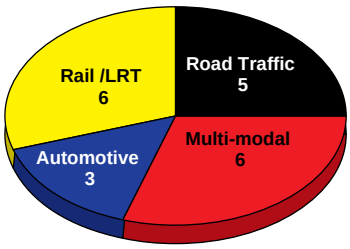
The programme does not have specific themes but has been framed to reflect the recommendations of the Technology Foresight Transport Panel. These have been summarised as:



Approved TIO projects by theme



Approved IST projects by topic area



Approved IST projects by mode

- **Understanding the transport system** – for example, modal change or interface issues, understanding and/or modifying traveller behaviour, and the use of informatics
- **Mode-specific technologies** – for example, improving safety and efficiency of individual modes of transport, mitigating environmental impact, and network management
- **Generic issues in transport** – for example, modelling and simulation, network and information management. Generic proposals are to focus on a specific commercial application.

These examples are for general guidance only. Proposals do not necessarily have to be presented under these headings, as long as they address the programme objectives. The programme also seeks to stimulate projects which have a strong environmental and/or safety theme. Projects on public transport and cycling are especially encouraged.

A particular strength of the IST programme is its cross-modal character, that is, its ability to deal with problems affecting or affected by different modes of transport. This not only encourages projects which address whole-journey requirements (eg passenger information systems) but should help to break down those barriers which still exist around specific transport modes and encourage a more generic approach in addressing transport needs.

To date, 20 projects have received technical approval and are expected to receive LINK funding of around £3m. The breakdown of the projects by topic and mode are shown in the IST Pie charts.

HOW TO APPLY FOR FUNDING UNDER THE IST PROGRAMME

There is a two-stage application process. Outline applications basically comprise a two page description of the proposal together with partnership details and an estimate of overall cost. Full applications involve a six-page case for support and detailed costs, together with a 'heads of agreement' which covers the partners' intellectual property rights.

Applications are assessed by peer review. External references are obtained from appropriate experts in the field and the applications are then considered by an independent advisory group comprising academic and industrial representatives which meets quarterly under the chairmanship of David Bayliss OBE, Planning Director of London Transport.

The next closing dates for outline applications are 20 August and 12 November 1997. Would-be applicants should contact the Programme Director, Howard Wyborn (0113 2672701; fax: 0113 281 7616) who will be pleased to discuss ideas for research proposals and give assistance in the preparation of applications.

What is LINK?

LINK is the name – not an acronym – of a Government scheme, set up around 10 years ago, to stimulate pre-competitive collaborative research and promote technology transfer from the science base into industry by giving financial support. There are now over 50 LINK programmes covering many areas of science and technology.

Example LINK Projects from the Transport Infrastructure & Operations Programme

EPSRC

IMPROVED GROUTING FOR POST-TENSIONED BRIDGES

One of the problems associated with the construction of post-tensioned bridges (like that shown in the photograph) is ensuring that the ducts which house the stressed tendons are fully grouted. A survey of grouting operations had shown that it was difficult to mix on site a grout which had consistent properties and met the requirements for volume change, shrinkage and flow.

To overcome this problem, TRL worked with a number of industrial partners to develop a pre-mixed grout having guaranteed properties, so that the variability which occurred with on-site mixing could be eliminated.

The results of this work were a contributory factor in the decision by the Highways Agency to lift its moratorium on the construction of cast-in-situ, post-tensioned concrete bridges with internally grouted tendons. This has widened the choice of construction options open to bridge engineers and has increased competition.

For further information please contact Richard Woodward at TRL (01344 770667; fax: 01344 770356; Email: richardw@b.trl.co.uk).

IN-CAR EQUIPMENT TO HELP DRIVERS AVOID ACCIDENTS

This project aimed to provide guidance to motor manufacturers about the types of equipment which are likely to be most effective in reducing accidents. In order to do this extensive samples of accidents were examined in order to determine their causes.

Two samples of over 1000 accidents were studied. One consisted of fatal accidents and the other of less serious accidents reported by drivers to their insurer. Seven major clusters of accident types were identified and the functionality required of in-car equipment which would help drivers to avoid these was specified. The possible accident reduction and the price that car owners might be prepared to pay were then assessed.

The immediate benefits have been to manufacturers developing advanced driver-support systems. Another benefit which could prove equally valuable is that the method for developed recording accident causation has subsequently been further developed for use by the police. Successful trials were carried out with eight police forces in 1996.

For further information please contact Dr J Broughton at TRL (01344 770897; fax: 01344 770356; Email: jeremyb@e.trl.co.uk).

ROAD CRACKING ANALYSIS

Measurements of cracking are an essential input to the economic appraisal of highway maintenance. The Highways Group in the University of Birmingham chose image analysis as the route for achieving automatic measurement of cracks and this led to a LINK TIO project in which the University was partnered by Cambridge Parallel Processing Ltd, the manufacturers of the Distributed Array of Processors (DAP) and by TRL. The aim was to see if the DAP could process images of road surfaces sufficiently quickly and effectively.

Processing in real time would eliminate the need for intermediate storage of thousands of images provided that cracks could be satisfactorily distinguished from the background surface texture.

The processing speeds finally achieved were tantalizingly close to real time. The exact time varied with the complexity of the image but average times of about one second were achieved without recourse to code optimisation, with 75% to 80% success in separating images into cracked/not cracked.

This performance was considered to be adequate for a practical system: development work is now needed in order to take the system forward into the commercial market.

For further information please contact Mr H T Tillotson at the University of Birmingham (0121-414 5146; fax: 0121-414 3675; Email: H.T.Tillotson@bham.ac.uk).

WHY CARRY OUT LINK COLLABORATIVE RESEARCH?

In many cases, research of the type being funded under LINK is seen as an essential pre-requisite when an idea conceived within an industrial organisation is to be developed into a viable product. Where the idea originates in an academic environment, active industrial collaboration is now generally recognised as a natural part of the research process.

However, industrial organisations frequently have doubts about the merits of collaborative research, especially when they see it as a potential impediment to reaching the market with a potential product at the earliest opportunity. In these cases it is important to recognise the advantages that LINK offers, especially in terms of the enhanced quality which the science base partner can bring to both research and development stages.

In the present highly competitive transport market this can be a crucial factor in both market penetration and subsequent sales. The research carried out in many LINK projects frequently leads to identification of further 'spin off' research, or even potential new products, which would not have come about but for the collaboration.

The direct involvement of end-users such as Local Authorities, user groups and other customer representatives in the research process should be a further incentive.

THE BITUTEST PROJECT

This project resulted in the development of practical test methods for bituminous materials used in pavement construction. It involved 9 companies and 14 Highway Authorities, the research being carried out by a team at the University of Nottingham headed by Professor Stephen Brown.

The equipment used for the tests, known as the Nottingham Asphalt Tester (NAT), was designed by Keith Cooper, a member of the research team and now of Cooper Research Technology.

The NAT (see photograph) is a practical, low-cost, pneumatically operated, computer-controlled experimental facility which allows the key mechanical properties of bituminous mixtures to be determined in the laboratory. The repeated-load, indirect-tensile-test mode is used to determine both the stiffness modulus, which relates to load-spreading ability, and the resistance to fatigue cracking of the mixture. A repeated-load compression test measures the resistance to accumulation of permanent deformation, this parameter relating to wheel-track rutting in pavements.

The team developed experimental protocols which were refined by use in the industrial and highway authorities' laboratories. These dealt with the mechanical property tests, and with the assessment of resistance to water damage and ageing, the two durability factors which can cause problems in the field. Several of the experimental procedures have been taken up by the British Standards Institution and are candidate tests for European standards.

Most leading contractors are now using the NAT routinely to assist with the process of introducing materials they have designed to meet end-product specifications. This allows them to compete more effectively in international markets as well as maximising their contributions to successful design/build/finance/operate work at home.

For further information please contact Professor S F Brown at the University of Nottingham (0115-951 3900; fax: 0115-951 3909; Email: stephen.brown@nottingham.ac.uk).

SECONDARY AGGREGATES AND BINDERS IN ROAD FOUNDATIONS

This project is examining the performance of foundations and sub-bases constructed with secondary materials including fly ash, china clay sand, slag, cement-kiln dust and gypsum.

The properties of mixes comprising a large proportion of secondary materials have been examined in laboratory trials. As a result, six selected mixes have now been laid as sub-bases in TRL's Pavement Test Facility (PTF), where their performance will be compared with that of two controlled sections.

The PTF trials will provide information on large-scale mixing, laying and performance of the mixes. The laboratory test and PTF trial results will enable a generic specification to be developed for sub-bases constructed with secondary materials. Specification trials may be required to confirm performance.

Benefits include less use of primary aggregates and more use of secondary aggregates, resulting in fewer disposal problems. The stiffer foundations produced by using these materials may lead to an overall thinning of the road base.

For further information please contact Val Atkinson at TRL (01344 770220; fax: 01344 770356; Email: vala@h.trl.co.uk).

CHLORIDE PENETRATION RESISTANCE OF SURFACE TREATED CONCRETE

Concrete highway bridges often suffer re-inforcement corrosion after only a fraction of their intended service life due to rapid penetration of chloride-based de-icing salts. Surface treatment of the concrete can be an effective means of countering this problem. In this project methods of assessing the chloride ion diffusion resistance of surface treated concrete were assessed and a new method was developed.

The new method – based on measuring frequency domain electrical impedance spectra – is non-destructive, very rapid and, showed good correlation with long-term test results. Unlike existing methods, it is able to isolate the individual contributions of concrete and surface treatment, allowing long-term monitoring of surface treatments.

The method was then used to assess commercial surface treatments and to assist in the development of novel systems.

The project was led by Dr Nick Buenfeld at Imperial College and industrial partners were Epichem Ltd and 5 members of FERFA, the Federation for the Repair and Protection of Structures.

For further information please contact Nick Buenfeld at Imperial College (0171-594 5955; fax: 0171 225 2716).

COMMERCIAL EXPLOITATION THROUGH LINK

A particular feature of LINK is the requirement that the research should lead to eventual commercial exploitation, bringing benefits to the industrial partners and assisting the UK's wealth creation. Projects should be based upon a partnership between one or more science base institutions (normally a university department or an approved research institution) and industrial organisations who will market the end product or process.

These industrial partners can range from sole traders to large companies, as well as local authorities. Some can also fulfil a further need, which is for end users to be included in the partnership to give a practical input to the research from a customer's perspective.

Overall, many TIO projects have resulted in benefits to industry, such as:

- construction and local authority highway engineers have benefited from the identification of more cost-effective methods of building and maintaining pavements and structures;
- the industrial partners of the advanced composite materials projects were provided with a competitive new design for street lighting columns
- the vehicle telematics project provided guidance on systems which would have the greatest effect on road accidents whilst being commercially viable

Spin-off benefits also arose. For example, the vehicle telematics project produced a new approach to accident reporting and analysis which is being trialled by the Department of Transport and police.

Bridge detailing: good practice guide

Following its projects on Bridges: design for improved buildability and The use of standardisation and preassembly to provide better value for money, CIRIA is now preparing a Bridge Detailing Guide for the Bridges Engineering Division of the Highways Agency.

The guide, for use in the design both of steel and concrete bridges (like that shown in the photograph), will contain advice on current good practice for the components and materials involved, and provide a comprehensive set of standardised examples of good detailing practice. Accompanying explanatory notes will:

- promote good detailing practice as a result of which the buildability and durability of bridges will be improved, leading to reductions in capital and whole life costs;
- enable good detailing of special cases to be developed, by adapting the standard details;
- emphasise ease of construction, durability, and inspection and maintenance requirements.

The standardised examples will be illustrated in sufficient detail to enable them to be readily included in design solutions. The explanatory notes will highlight key features and important considerations regarding durability and buildability. The details will be illustrated in the report, but will also be available in CAD form.

Fundamental to the project's success is feedback from practitioners on good and bad practice. Anyone able to provide such input to the project is encouraged to contact CIRIA, to maximise the potential benefits to users of the guide.

To provide appropriate input and/or for further information please contact Barry Staynes at CIRIA (0171-222 8891; fax: 0171-222 1708; E-mail:bws@ciria.org.uk).

Photo Courtesy of The Highways Agency

Spreadsheets for concrete design

This project, funded through the DOE Partners in Technology initiative, aims to present reinforced concrete design in computer spreadsheet files that will be issued with publications covering their use, model designs and a commentary. Two issues are envisaged: one to British Standard BS8110, *Structural use of concrete*, and one to Eurocode 2, *Design of Concrete Structures*, Part 1.

The design of concrete structures is often described as time consuming and costly. Computer programs are used extensively but designers are often reluctant to rely on 'black box' technology over which they have little knowledge or control.

Computer spreadsheets, on the other hand, are user-friendly, completely transparent, very powerful and becoming increasingly common in structural engineering. They have powerful graphical presentation facilities and established links with other software. They suit concrete design ideally, in that they can be set up to carry out a series of mathematical calculations, and, as in design, to check whether certain criteria are met. Spreadsheets are also an ideal medium to show the intricacies of design, an area where the project aims to help overcome a major problem for the concrete industry – teaching young engineers and graduates the intricacies of contemporary, commercial concrete design.

The work will be directed at practising design engineers and educational establishments, the main outputs envisaged being:

- a publication and issue of disks, with spreadsheet files to BS8110, with an accompanying document covering their use, model designs and commentary;
- as above but in accordance with Eurocode 2;
- seminars to coincide with publication.

Thus, undergraduates and young engineers will have copies of model calculations on which to base their understanding and their designs. They will be able to gain experience by doing their own 'what if' studies, and all engineers will be able to produce optimised designs quickly.

Standardised, or at least rationalised, designs will make the checking process easier and quicker. Other benefits include quicker and more accurate reinforcement estimates and the possibilities for electronic data interchange. The already-widespread and still-increasing availability of spreadsheets and the need to get Eurocode 2 used more widely in the UK make the timing of this project appropriate.

The project is managed by the Reinforced Concrete Council guided by an advisory group of interested parties, including consulting engineers and software houses. The elements currently being developed into spreadsheets are: one-way slabs, two-way slabs, flat slabs, beams, columns, pad foundations, basement and retaining walls. Others are due to follow.

The spreadsheets – a sample of which is shown on the next page – are being developed using the most popular spreadsheet packages such as Excel, Lotus 1-2-3 and Quattro Pro. One major problem to be tackled is the transportability between the packages. Other issues being addressed include validation and security, for example, using spreadsheet emulators versus open files to allow users to develop the spreadsheets for their own purposes.

Work on the BS8110 version will carry on during 1997 with publication in 1998. Feedback will be incorporated to maximise the acceptability and usefulness of the Eurocode 2 versions which will follow a year later.

For further information please contact Charles Goodchild at the Reinforced Concrete Council, at BCA's address. (01344 725736; fax: 01344 761214; E-mail: cgoodchild@bca.org.uk).

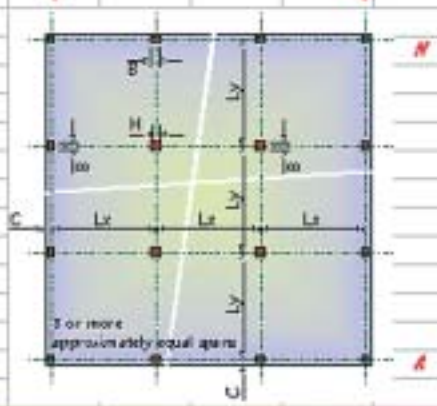
Project:	Trial layout for comment	NG NEER & PARTNERS	
Location	Floor 16	Made by: RMW	Date: 02-Jun-97
SIMPLIFIED DESIGN OF FLAT SLAB TO BS 8110 CLAUSE 3.7.2.7			Page: 1
Using TWOWAY 02, a spreadsheet to design Flat Slabs to BS8110 (Table 3.13)		Checked: AHO	Revision: Job No: 2091
© 1997 Reinforced Concrete Council, Century House, Telford Avenue, Crowthorne, Berks			

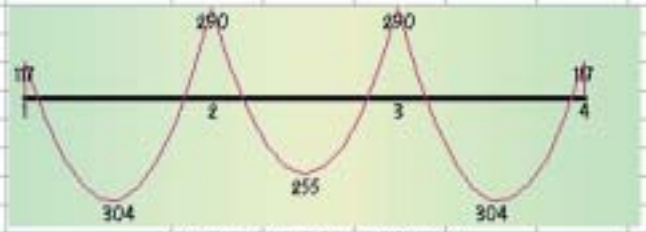
INPUT — **STATUS** VALID DESIGN

LOCATION											
NS Grids on lines			1	2	3	4					
EW Grids on lines			A	B	C	D	E	F	H		
									COLS	Internal	Edge	Corner
DIMENSIONS	X	Y							H	500	300	300 mm
N° of spans	3	6	N°	slab depth, h		225	mm		B	500	500	300 mm
Span, L	6.200	6.750	m	Top cover		20	mm		T			4
Edge dist, C	350	250	mm	Btm cover		25	mm					

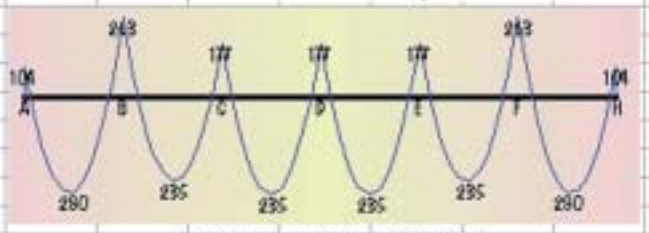
MATERIALS							
fcu	35	N/mm²	h agg	20	mm	Nominal middle strip	
fy	460	N/mm²	Density	23.6	kN/m³	top steel in spans ?	
fyv	250	N/mm²	(Normal weight concrete)			Y	

LOADING						
Self Wt	6.31	kN/m²	Perimeter			
+ Dead	2.80	kN/m²	Load		Lex =	5.866 m
Imposed qk	5.00	kN/m²	8.50		Ley =	5.416 m
Total Dead, gk	8.11	kN/m²	kN/m		F =	690.0 kN
n =	19.36	kN/m²				





Bending Moments kNm - X Direction



Bending Moments kNm - Y Direction

MAIN STEEL	Internal Column Strips		Middle Strips		Perimeter Column Strips	
X (short) DIRECTION	b	REBAR	b	REBAR	b	REBAR
END SUPPORTS	1.000	6T20@160T1	6.200	20T10@260T1	0.875	4T20@210T1
END SPANS	2.875	13T16@220B1	3.325	18T12@180B1	1.688	8T20@210B1
PENULTIMATE SUPPORTS	2.875	15T16@140+280T1	3.325	13T10@250T1	1.688	11T16@110+230T1
INTERIOR SPANS	2.875	10T16@280B1	3.325	14T12@230B1	1.688	9T16@180B1
Y (long) DIRECTION						
END SUPPORTS	0.900	6T20@150T2	4.850	19T10@250T2	0.925	4T20@230T2
END SPANS	2.875	15T16@190B2	2.875	12T16@230B2	1.788	11T20@160B2
PENULTIMATE SUPPORTS	2.875	15T16@140+280T2	2.875	12T10@230T2	1.788	11T16@120+240T2
INTERIOR SPANS	2.875	10T16@280B2	2.875	15T12@190B2	1.788	7T20@250B2
INTERIOR SUPPORTS	2.875	17T12@120+250T2	2.875	11T10@260T2	1.788	13T12@100+200T2

REACTIONS	ditimate	Axial kN	Total Col M (kNm) Mx	My		LINKS	Link Zone Arrangement	Width H x Breadth B	
Internal	Norm	689.97	0.00	0.00					
Penultimate	C2 ult	758.97	93.09	0.00	<< >>		R6 @ 140 EW	1760	1760
Penultimate	Norm	758.97	0.00	86.96					
Double Penult	B2 ult	827.96	93.09	86.96	<< >>		R6 @ 140 EW	1800	1800
Side Internal	Norm	424.78	0.00	104.25					
Side Internal	C1 ult	421.16	116.67	0.00	<< >>		R6 @ 140 EW	1040	1320
Penult side	A2 ult	467.24	60.66	104.25	<< >>		R6 @ 140 EW	1030	1410
Penult side	B1 ult	463.28	116.67	86.35	<< >>		R6 @ 130 EW	1100	1380
Corner	A1 ult	257.37	82.52	76.03	<< >>		R6 @ 130 EW	1070	970

CHECKS	BAR Ø > COVER	SINGLY REINFORCED	BAR SPACING	DEFLECTION	SHEAR LINKS	GLOBAL STATUS
	OK	OK	OK	OK	OK	VALID DESIGN

Detecting voids under highways

The presence of voids and areas of sub-standard foundation beneath highways cause problems for road operators and users alike. Weak areas of the highway and collapse of material into voids have led to concern for maintenance and repair costs and for the safety of vehicles. There are obvious advantages in being able to locate areas of the highway requiring immediate attention, and areas where maintenance can be planned. Research at TRL, with assistance from Surrey University, is assessing the applicability and accuracy of geophysical techniques in defining the size and extent of voids beneath highways, and also in determining road subgrade strength.

To simulate a highway in which voids have developed, a trial concrete road has been constructed at the TRL Crowthorne site (see picture), into which a number of air filled voids were incorporated. The voids lie in the road subgrade and have a range of sizes. Using currently available technology, some will be easily detected, some should lie on the limit of detectability and others should not be detectable. Steel reinforcement extends along half the length of the road, so that a comparison can be made between the effectiveness of geophysical equipment for reinforced and non-reinforced concrete pavements. A second trial road, with a variety of subgrade materials and strengths, will shortly be constructed. The effectiveness of various geophysical and non-destructive testing methods in determining the subgrade strength will be assessed.

Initial work using ground probing radar (GPR) for void detection has yielded promising results. Subsequent investigations will include further use of GPR, as well as other commercially available geophysical techniques such as seismic methods (spectral analysis of surface waves), microgravity surveys, and non-destructive test methods using deflection equipment (such as the falling weight deflectometer).

The speed and ease of using each technique is also being assessed, especially related to practical use of the equipment being able to cause minimum disruption to traffic flow. The work is being carried out so that the methods and survey techniques are refined and optimised as the research progresses, to determine which are the most suitable and accurate methods for void location and subgrade strength determination.

For further information please contact Rob Evans at TRL (01344 770562; fax 01344 770748; E-mail: roberte@b.trl.co.uk)

Trial road at TRL under construction

BUILDINGS

ICBEST '97 – combining research and practice on building envelopes

ICBEST'97 – the second International Conference on Building Envelope Systems and Technology – was organised by the Centre for Window & Cladding Technology (CWCT) and brought together equal numbers of people from the construction industry and the research community to enhance the practice of building envelope design and construction.

The International Committee on Building Envelope Systems and Technology exists to further understanding of the construction and performance of building envelopes. It particularly aims to look at the design of walls and roofs as a holistic exercise having full regard for the different roles of wall in buildings:

- moderating the internal building climate;
- providing the architectural appearance of the building;
- having integrity to perform safely;
- having durability to perform throughout the life of the building.

Research in these different areas is often carried out without due regard to the implications of applying the research as part of a complex engineering solution. Within a zone some 400-600mm deep around a building, facade engineers have to resolve many, often conflicting, performance requirements. In these circumstances it is important that researchers talk to practitioners and that designers have access to the best available technical knowledge.

Held at Bath University from 15-17 April 1997, the second International Conference on Building Envelope Systems and Technology brought together experts on all aspects of the building envelope under three themes:

- Construction
- Integrity, and
- Building physics.

In keeping with their own aims, CWCT as organisers sought to involve all those involved in the design, manufacture and construction of facades. Papers were presented ranging from world-leading research to case studies of major buildings and from new technology to re-engineering the construction process.

The papers have been published by the CWCT and will be of great use to those unable to attend the conference. As one attendee said, 'There is so little other information available for engineers and architects in this field'.

For further information please contact Stephen Ledbetter at CWCT (01225 826541; fax 01225 826556).

Testing for moisture in building elements

Moisture is involved in a large percentage of problems with buildings and, if not detected early, can cause considerable damage and possible failure. Traditional methods (flood testing, core sampling) of detecting moisture are imprecise, costly and destructive; since 1956 a wide range of non-destructive methods have become available which can accurately identify, locate and, in some cases, measure moisture present in building elements. However, there is no comprehensive, independent guidance on these new methods, their basis of operation, appropriate use and limitations, interpretation of the results and overall efficacy, and many design professionals are unaware of the range and potential use of the techniques currently available.

Traditionally, the use of testing for moisture in building elements has been mainly reactive, for detecting and diagnosing defects. Now, with the responsibilities and liabilities imposed by the CDM regulations and greater emphasis on quality control, there is an increasing need for pro-active certification, such as proof of correct moisture content or watertightness, and continuous in-use monitoring to ensure problem-free, long-term performance. The use of non-destructive testing for moisture is therefore likely to increase significantly.

A new CIRIA project, supported by the Department of the Environment under the Partners in Technology Scheme, will review the different test methods available, particularly non-destructive techniques, for detecting, identifying, locating and measuring moisture in the elements of the building envelope (roofs, walls, floors and basements).

A Launch Workshop for the project at the beginning of March was attended by consultants, equipment manufacturers and academics undertaking research in this field. Two introductory papers setting out the problems associated with moisture ingress were given by Keith Roberts of Rollinson Glanville Consultants and John Fidler of English Heritage. The presentation on the project was followed by an open discussion, during which delegates strongly endorsed the need for the project.

Courtesy of Rollinson Glanville Consultants

Between 8 and 12 methods will be reviewed, selected from the following by the Steering Group:

- Electrical conductivity/resistance
- Electrical capacitance/dielectrometry
- Earth leak detection
- Infra-red thermography
- Carbide measuring method
- Humidity probes
- Hygroscopic core
- Impulse radar
- Nuclear Magnetic Resonance (NMR)
- Neutron absorption
- Ultrasound.

For each method, the collection and distillation of information, and the report on the method, is to be written in accordance with an agreed standard format and, it is proposed, will be undertaken by an appropriate individual or organisation as an in-kind contribution to the project.

A Research Contractor, appointed by competitive tender, will be responsible for preparing the review pro-forma, co-ordinating and editing the in-kind contributions and writing the introduction and overview section for the report. Authors will be invited to present their paper at a Seminar prior to the preparation of the final report.

CIRIA would like to hear from anyone interested in contributing to the project. When complete, the project will result in a report providing clear, independent, authoritative guidance for designers, building surveyors, contractors and building owners on the appropriate use, effectiveness, and the correct interpretation of the results for each technique.

For further information please contact Ann Alderson at CIRIA (0171-222 8891; fax: 0171-222 1708; E-mail: aa@ciria.org.uk).

Exports project seeks input

As part of its Technology for Exports Project (see *Research Focus* Issue 29 for details), the ICE wants to identify areas of new technology with which the UK can support future civil engineering activities throughout the world. It is seeking help from its members and others in this challenging task.

It would therefore be most helpful to the Project Team if any Research Focus readers with export experience could spare a few minutes to respond to the questions below and write, fax or email their response, with your full address, telephone, fax and email numbers, to Dr John Bennett at the ICE at the address below.

1 Which of the following market areas are relevant to your experience and/or activity?
- Transportation planning and infra-structure
- Water & wastewater engineering
- Coastal and river engineering
- Infrastructure for urban development and megacities
- Environmental improvement, remedi-ation and sustainable development
- Other – please specify.

2 Please list the issues, technologies and strategies which you believe are critical to success in civil engineering and where further research & development could be of major benefit.

Your suggestions may relate to any aspect of civil engineering or supporting technologies. Some examples are listed below but do not be constrained by them:
- information technology and remote sensing
- dry waste-treatment processes
- component standardisation
- improved/more efficient desalination techniques
- more cost-effective sources of renewable energy
- flood control and protection
- alleviating road traffic congestion
- improved urban transportation.

Please send your responses by post, fax or email to Dr John Bennett, Assistant Director of Engineering, The Institution of Civil Engineers, 1 Great George Street, London SW1P 3AA (Fax: 0171-799 1325, Email: bennett_j@ice.org.uk).

For further information about the project, please contact the Project Manager Roger Venables, Venables Consultancy, 12 Cranes Drive, Surbiton, Surrey, KT5 8AL (0181-399 4389; fax 0181-390 9368; E-mail: 01722.374@compuserve.com).

THE INSTITUTION OF CIVIL ENGINEERS

Is a tunnel fire worse in compressed air?

The Health and Safety Executive recently began a major research project to study fire in compressed air tunnels. Tunnel fires are thankfully very rare, and fires in tunnels where compressed air is being used during construction are even rarer. Both, however, have the potential to be major disasters. Until now, little scientific research has been done on fire growth, burning rates and products of combustion in a hyperbaric environment.

On behalf of HSE, the Health and Safety Laboratory has recently installed a pair of bulkheads in the Dust Explosion Gallery at its Buxton site to enable a range of fire tests to be carried out to investigate a number of aspects of fire in compressed air tunnels. This facility is believed to be unique in a fire research laboratory.

The Gallery, which was also used for work on potential fires in the Channel Tunnel, was built in the early 1960s to allow detailed experimental work on coal dust explosions for the mining industry and was designed to withstand transient explosion pressures of up to 20 bar. Unlike other large scale tunnel explosion facilities, the Buxton Gallery is a heavily reinforced concrete structure built above ground. This allows ready access through the walls for a wealth of instrumentation which would otherwise be difficult or impossible to use in fire, explosions or similar research work.

The gallery is approximately 2.5m in diameter and 366m long. The bulkheads have been set 35m apart near one end of the gallery giving an experimental pressure chamber of around 200m3. Air is supplied from a standard, 7-bar compressor through ports in the gallery wall, and the facility currently has a working gauge pressure of 3.5 bar.

Two series of tests are planned. In the first, standard wood crib and oil fires will be used to determine how the behaviour of fires, whose properties at atmospheric pressure are well known, varies with pressure. The effects of pressure on flame spread rates will also be monitored.

In the second series of tests, materials commonly found in tunnelling will be burned in compressed air at a pressure of 2 bar. These tests will cover the range of flammable materials commonly found in tunnels such as heavy timber sections, straw, oily clothing, cable, conveyor belting, hydraulic oil, and plastic and paper rubbish.

In all of the tests, temperature, flame length, the intensity of the fire, the extent and nature of the products of combustion formed by the fire, and other parameters will all be monitored. Tests will also be carried out to determine how much more easily these materials can be ignited under pressure.

It is also hoped to determine the efficiency of various extinguishants in compressed air and to test the effectiveness of water spray curtains in containing the spread of smoke in the tunnel.

Extensive photographic records and video recordings of the fires will be made and it is hoped to make a compilation video of the tests available to the tunnelling industry for training purposes.

For further information, please contact Donald Lamont at The Health and Safety Executive, Magdalen House, Stanley Precinct, Bootle, Merseyside, L20 3QZ (0151-951 4818; fax: 0151-922 7918; E-mail: donald.lamont@hse.gov.uk).

The pressurised fire test facility under construction at the Health & Safety Laboratory in Buxton, Derbyshire.

Testing of light steel demonstration building begins

Construction of the innovative, light-steel-framed demonstration building at Oxford Brookes University has been completed, and monitoring and testing of the structure has begun. The building forms part of SCI's and British Steel's involvement in European MegaProject 5, a large multi-partner project that has addressed the use of steel in housing, refurbishment and temporary structures.

The Oxford building uses British Steel's SureBuild light-steel framing system to great effect, and draws upon the findings of an intensive testing and development programme. It provides three storeys of accommodation, and includes a 4-bedroom family house, three student suites and a two-person flat.

The main technical features included are:

- open, habitable roof spaces based upon light steel attic trusses and purlin solutions;
- suspended ground floors constructed using composite steel decking
- high standards of thermal and acoustic insulation.

The building is being monitored using a sophisticated, purpose-designed, building-monitoring system. It will provide large amounts of data that will greatly advance understanding of the durability, energy characteristics and as-built performance of this form of construction.

For further information please contact Dr Raymond Ogden at The Steel Construction Institute, (01344 23345; fax: 01344 22944).

(Above) *Structure under construction.* (Below) *Front elevation of completed building.*

Concrete frames will show the way ahead

Experts within the concrete frame industry have long believed that their products can be designed and built more efficiently. They are now to have the chance to prove it, with the start of a ten-year programme of concrete research, based around full-scale frames at the BRE's Large Building Test Facility at Cardington.

The brainchild of the concrete industry, the research programme is being led by BRE working with academic institutions to determine best practice across the entire design and construction process. Professor Haig Gulvanessian, head of BRE's structural design division, is managing the research programme.

The research programme will eventually involve the construction of four concrete frames at Cardington: a seven storey in-situ frame with flat-slab floors; a five storey innovative precast frame with flat-slab construction; and a five storey hybrid building using composite in-situ and precast techniques; and, finally, a pre-cast frame. The first to be built, at the end of this year, will be the in-situ building.

The first project was recently awarded funding of £480,000 from the Government's Partners in Technology scheme, specifically for research into re-engineering the business process on in-situ concrete frame construction. Research is to be centred on three areas, all of which have input from every side of the concrete industry: innovative design features, process re-engineering, and structural performance.

Designers and concrete contractors alike have long believed that traditional design codes are far too conservative and, because they are based on individual elements, do not take account of the inherent strength of the building as a whole. The in-situ building will be used to test those theories. Although it is being designed to a 'fairly standard' architect's brief for a town centre office, which assumes it is to be built on a 1,200 sq m plot in central Bedford, it will be designed to the absolute limits of Eurocode 2. Features such as thin plate floors, unobstructed soffits with no edge upstands, and pre-manufactured steel cross bracing and shear heads will be included. It is three bays by four in plan and has 7.5m square bays, with outline design to BS8110, but detailed design to Eurocodes 1 and 2.

Once the frame is built, it will be put through a series of performance-related tests to find out how it behaves as a whole. This will be the first chance anywhere in the world for the industry to put its theories about the behaviour of concrete frames to the test. Of particular interest will be the deflection of the thin slabs which are integral to the design philosophy of this building, as well as evaluation of the innovative column slab connections and shear reinforcement.

The building will also be subjected to fire tests and gas explosions. All the data collected from the tests will be fed back into design software to create a more accurate method of modelling in the future – based on the real behaviour of a whole building, rather than individual elements.

Foundation for new demonstration buildings under construction.

For further information please contact Professor Haig Gulvanessian at BRE (01923 664233; fax: 01923 664096; E-mail: Gulvanessian@bre.co.uk).

The impact of the Okehampton bypass

Bypasses have become a controversial part of the UK national roads programme of which they form a major element. Whilst they are often strongly supported by local residents, opposition from environmental groups can be significant. The debate on bypasses is becoming heated and adversarial, as demonstrated recently during the construction of the Newbury bypass, with protagonists on both sides often stating matters of opinion as if they were matters of demonstrable scientific fact.

Of all the factors that are associated with the design and construction of a new bypass, the anticipated changes to the environment probably generate the most controversy. Unfortunately few studies have ever been carried out once a bypass is opened, either to examine the accuracy of the environmental predictions that were made, or to ask the population of the bypassed town their views on the road they have to live with.

The RAC Foundation for Motoring and the Environment commissioned the Transport Research Laboratory to undertake a post-construction case study of the existing Okehampton bypass in Devon which was opened in 1989. Few disagreed that a bypass to relieve Okehampton was required but the two main route options were equally controversial. The northern route passed through locally valuable farmland and required visually intrusive engineering solutions such as viaducts. The southern route – the one that was eventually built – ran through the Dartmoor National Park and raised many important environmental questions.

The study examined the published literature on both the human and environmental impact of bypasses and placed the Okehampton case study within the overall context of the wider debate on roads and the environment.

A survey of 200 local residents conducted as part of the research project sought to gain the views of the town on the success or failure of the bypass. Eighty percent of those interviewed still regarded the bypass as being of real benefit to the town. Many thought, however, that the levels of traffic in the town, particularly heavy goods vehicles, were still too high. It was found that, despite a comprehensive traffic management and environmental improvement scheme having being drawn up for Okehampton, this had not been implemented. It is suggested that many of the town's residual traffic problems could be solved by the implementation of such a scheme.

Finally the study examined the predicted environmental impacts of the bypass, determined by reference to evidence presented at the Public Inquiry, and compared these to the current environmental indicators along the route. It was found that, in nearly all circumstances, the environmental predictions stood up well to re-examination.

For further information please contact Gordon Mudge at TRL (01344 770079; fax: 01344 770918; E-mail: gordonm@e.trl.co.uk)

Encouraging partnering for public sector construction

Partnering – a set of principles rather than a single technique – has yet to be widely adopted in the public sector. A recent DOE-sponsored project undertaken by the European Construction Institute (ECI) has developed a form of partnering that should enable greater take-up in future.

In their Report on post-award, project-specific partnering*, ECI describe Partnering as 'a range of principles and practices designed to promote more co-operative working between contracting parties'. In encouraging more collaborative working practices, ECI seeks a move away from the adversarial approach with which many areas of the industry are more familiar.

Partnering arrangements in the USA, benchmarked by the Construction Industry Institute (CII), produced cost savings of up to 10%. Greater efficiency, a reduction in accidents and higher job satisfaction were also identified. Yet the CII concluded that the full benefits had yet to be realised.

Closer to home the process of 'alliancing' in the North Sea has produced even more impressive results. One project, involving equipment for the Andrews Field, produced outturn costs 45% lower than the client's original estimate, amounting to total savings of some £80m. The project was also completed months ahead of schedule. This and other partnering successes have not only produced cost and efficiency savings in the short term, but extended the economic lives of North Sea oil and gas fields which would otherwise have proved uneconomical.

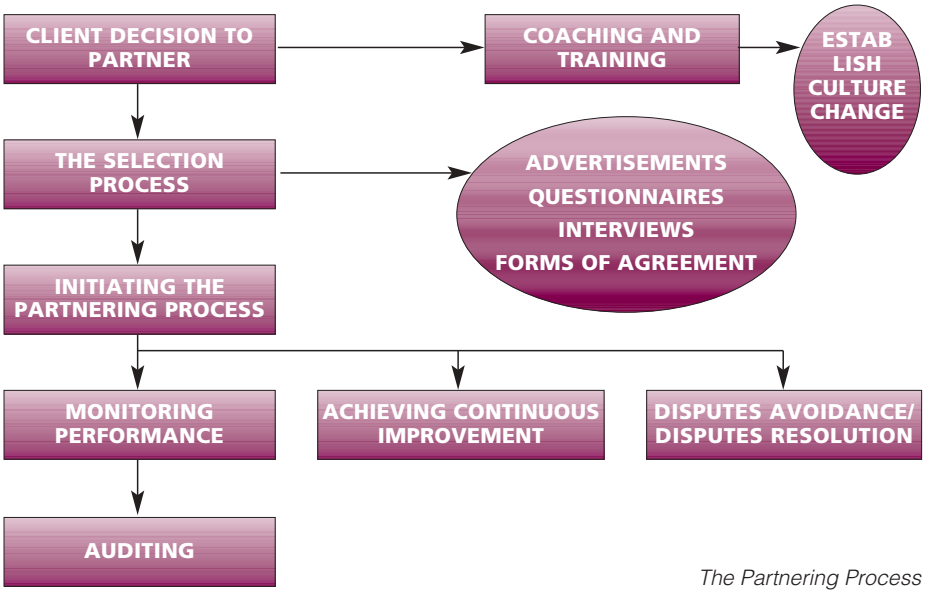
The Latham Report recommended that private sector partnering principles should be considered more for public sector construction. Part of the answer perhaps lies with the nature of work in the public sector: arguably there is less freedom to innovate in procurement and the need to ensure full transparency in spending taxpayers' money is more onerous than constraints on the private sector.

The ECI report addresses all of these issues, the form of partnering proposed being an arrangement arrived at after contracts have been awarded. It sets out the working relationship to be established within the contractual framework where the partnering arrangement supplements, not supersedes, the contract. It is not legally binding unless the partners agree that it should be.

Partnering is neither a panacea nor a soft option. Care has to be taken that effective techniques for teambuilding, motivation and communication are fully incorporated into the process – see the figure below. Nevertheless, post-award, project-specific partnering is already being adopted in the US, Canada and Australia with 9% cost reductions and 8% time savings so far reported compared with non-partnered projects. There would appear to be considerable scope for the UK public sector to develop and benefit from partnership arrangements in the future.

For further information please contact Ivor Williams at the European Construction Institute, (01509 263171; fax: 01509 260118; E-mail: d.a.weston@lboro.ac.uk; World Wide Web address for further information: http://info.lut.ac.uk/departments/cv/eci)

* The full title is *Partnering in the Public Sector: A toolkit for the imple-mentation of post award project specific partnering on construction projects.*



The Partnering Process

SPONSORING ORGANISATIONS

GOVERNMENT

Department of the Environment, Transport & the Regions,
Eland House, Bressenden Place, London SW1E 5DU
(0171 890 5689, fax 0171 890 5759)

RESEARCH ORGANISATIONS

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

Building Research Establishment,
Garston, Watford, Hertfordshire, WD2 7JR
(01923 894040, 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 23345, fax 01344 22944)

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 23355, fax 01344 23467)

Institution of Civil Engineers,
1 Great George Street, Westminster, London, SW1P 3AA (0171 222 7722, fax 0171 222 7500)

Institution of Structural Engineers,
11 Upper Belgrave Street, London SW1X 8BH
(0171 235 4535, fax 0171 235 4294)

INDUSTRY

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