Structural appraisals of multi-storey car parks — have yours been done yet?

The sudden collapse of part of the top deck of a multi-storey car park at Pipers Row, Wolverhampton during the night of 20 March 1997 highlighted SC OSS concerns about the safety of car parks.

An area of reinforced concrete slab about 15 x 14 m collapsed onto a similar slab below which suffered local damage. No cars were parked on the slab. The car park was constructed in 1964/65 using a proprietary lift slab technique; design was based on standards current at the time. Investigations by Health and Safety Executive (HSE) and the owners identified significant factors in the collapse:

- quality of concrete
- repairs to the top of the concrete slab around the columns to below the top reinforcement
- presence of box-outs in the slab adjacent to a column head
- effects of differential temperatures in the top slab.

Similar lift slab car parks have since been inspected and appraised and other factors, particularly reinforcement corrosion, have been identified which may also impair their safety and serviceability. It seems that the collapse at Pipers Row was probably an isolated event due to a particular combination of circumstances associated with:

- comparative weakness inherent in pre-1972 lift slab construction (details around columns were improved from 1972)
- inadequate detailing and quality of construction
- inadequacy of repairs to the concrete slab
- exposure to severe weather conditions.

However, a similar combination of adverse circumstances could occur again. This emphasizes the need for planned structural appraisals by car park owners and operators as recommended in SC OSS Reports in 1994 and 1997.

A conference on Concrete Car Parks: Design and Maintenance Issues was run by the British Cement Association with support from SC OSS in September 1997. Professor Anthony Kelly, Chairman of SC OSS, chaired the morning session at which the keynote address was given by Dr John Menzies, Secretary of SC OSS. In a wide-ranging review of the past 40 years experience of concrete car parks, Dr Menzies summarised the challenges for the future as the need for owners and operators to improve quality by:

- designing new structures to be adequately safe, durable, repairable and maintainable
- making the users' environment more pleasant and safe
- appraising existing structures and edge barriers and, where necessary, making safer through repair and strengthening.

The range of factors identified as significant in the Piper's Row collapse indicates a need for up-to-date recommendations for inspection and appraisal of existing car parks and edge barriers, possibly with specific recommendations for system-built structures. The conference brought together extensive experience [1] from which new recommendations could be developed. The planned updating of the Institution of Structural Engineers' 1984 recommendations and extension to cover existing car park structures is urgently needed.


The top deck of the car park at Piper's Row, Wolverhampton, after the partial collapse on 20 March 1997. (Photo: Wolverhampton Express and Star)
IMPLEMENTATION UPDATE

Implementation of some recommendations of the Eleventh SCROSS Report is not yet complete. The progress made and related events are noted below.

MULTI-STOREY CAR PARKS

• Wide publicity given to SCROSS recommendations following partial collapse of car park, Wolverhampton, March 1997.
• BCASCROSS Conference on Concrete Car Parks, September 1997.

PIN CONNECTIONS

• Discussions underway between CIRIA, SCI, BSI and ICE on preparation of guidance.
• Verdict in Ramsgate trial: fines of £2 million.

FATIGUE IN STEEL STRUCTURES

• Slow progress in discussions with the Institutions and BSI.
• Highways Agency is preparing new advice.

DISPROPORTIONATE COLLAPSE

• ICE seminar on robustness, March 1997.
• Building Regulations Advisory Committee reviewing Part A of Building Regulations.
• IStructE plans to set up task group to prepare guidance.

FLOOD DAMAGE TO BRIDGES

• ICE to hold seminar in mid-1998.
• Highways Agency is preparing an Advice Note on scour.

STRUCTURAL CODES OF PRACTICE

• Discussions with BSI initiated, but concerns remain about coordination within BSI.
• BSI Committee B/2525 has been re-formed to oversee development of structural codes.

AIR-SUPPORTED STRUCTURES

• BSI has reviewed information provided by SCROSS and is to withdraw BS6661.

BRIDGE STRIKES

• Height in cais legislation enacted October 1997.

STRUCTURAL GLASS

• IStructE task group report due for completion in 1998.

SAFER COMPUTING

• IStructE task group due to report in 1998.

IMPLICATIONS FROM RAMSGATE

Concern about the use and detailing of pin connections led to a call in the Eleventh SCROSS Report for guidance on design, inspection and maintenance of pin connections to be reviewed. As a result, the Steel Construction Institute has prepared a proposal to undertake such a review.

Following the collapse in 1994 of the walkway at Ramsgate, Kent which incorporated pin connections, HSE brought criminal proceedings against the organisation involved in the design, construction and use of the walkway. These concluded in February 1997, when fines of nearly £2 million were imposed. The case was complex and there are lessons for designers, owners and constructors from the circumstances of the collapse:

• the stability, and thus safety, of a structure may depend upon the integrity or performance of a single element. This is a matter to be identified during design when fail-safe details should be developed;
• fatigue is an important consideration in structures subject to repetitive movement in service;
• welding relies on the skill of the operative and critical welds should be examined during preparation and after completion;
• proper maintenance of moving parts can be vital to safe operation.

The judge, Mr Justice Clarke, included two noteworthy quotes from the prosecution evidence in his summing up:

“the client is required to make an assessment of risks – that follows directly from the Health and Safety at Work Act – and is required to identify the risks and make sure that those risks are properly managed.”


BRIDGE SAFETY

Structural safety of bridges is a significant current interest of SCROSS. Media attention has helped alert engineers to important developments. The UK’s ageing stock of about 150,000 bridges is owned and managed by relatively few organisations, mainly central and local government, Railtrack, London Underground and British Waterways. Considerable expertise and resources are needed to assess the condition, load-carrying capacity and maintenance requirements of bridges in view of their diversity of ages, forms of construction, materials, and loading. Maximum permitted lorry weights are due to be increased from 1999 but the substantial programme of highway bridge assessment and strengthening to accommodate the increased loading has fallen behind schedule. Concern has been expressed in many quarters about this, not least in the House of Commons Transport Committee enquiry into Road and Bridge Maintenance which reported in February 1997[3]. SCROSS submitted evidence to that enquiry.

SCROSS has recently discussed the issues with the Highways Agency and has been pleased to note actions being taken by the Agency in response to recommendations in the Eleventh SCROSS Report. During the coming months SCROSS will be examining further issues relating to safety of UK bridges.


Renovation of M6 Thelwall Viaduct near Manchester: some concrete piers and all the deck have been replaced following chloride damage. (Client: Highways Agency; Designer: Pell Frischmann; Main contractor: AMEC Civil Engineering; Photo: Highways Agency)
ISO 9001 AND DESIGN CONTROL

Does your structural design organisation operate an ISO 9001 quality assurance scheme? If so, you may be able to help SC OSS investigate an apparent anomaly. The ISO 9000 series of quality system standards was developed mainly for manufacturing where a single organisation usually has overall responsibility for design and production. ISO 9001 is accordingly described as ‘Model for quality assurance in design, development, production, installation and servicing’, for use by such organisations. Clause 4.4 specifies powerful procedures for design control.

ISO 9001, as the only model specification referring to design, is also applied in design-only organisations such as structural engineers. But due to a possible narrow interpretation of the word ‘product’ in Sub-Clause 4.4.1, it is understood that some design-only organisations do not apply Clause 4.4 to all their design activities. If you are a design-only organisation, operating an ISO 9001 quality system, SC OSS would be interested to hear whether or not all your design activities are subject to design control procedures responding to ISO 9001 Clause 4.4.

MOVING STRUCTURES

Moving large, heavy structures, such as bridges, for installation and demolition, has developed in recent years, using plant and techniques developed for offshore platform modules. SC OSS has been concerned over the possible failure of the transport system, the structure being moved, or other structures along the route. Failure of the structure being lifted is a particular problem as lifting is not usually at the primary bearing points, differential movements may occur during lifting or transporting, and exceptional hogging or warping may be induced. To enable views to be exchanged, ICE held a seminar in May 1997 on transportation of structures. SC OSS recommends proper assessment of the structure to be lifted, and the roadways and structures along the route, and employment of experienced, capable transportation contractors.

DEMOLITION

Instances of unplanned collapses during alteration and demolition work continue to occur from time to time. Demolition and structural alterations are much easier, safer and less costly if accurate structural records and drawings are available. SC OSS is pleased to note that some of those commissioning such work appear to be recognising their responsibilities for providing accurate information as a requirement of the CDM Regulations: in due course, the CDM health and safety file should form a good basis for developing operational manuals with detailed information on structures.

Valuable practical guidance, such as the NFDC Guidance for deconstruction of tower blocks over ten storeys, is becoming more widely available. The new edition of the BS Code of Practice on Demolition, issued for public comment during 1997, will also help, when it is published in its final form.


SAFETY CONCERNS OVER ADJUDICATION

SC OSS has expressed concern to the Department of the Environment, Transport and the Regions (DETR) over potential effects of Part II of the Housing Grants, Construction and Regeneration Act 1996 (not, early 1998, brought into force) and the draft supporting Scheme for Construction Contracts.

Unsafe structures or site operations could result from the draft Scheme and Part II of the Act, SC OSS warns. First, Section 108 of the Act provides a right to require any dispute under a construction contract to be referred for immediate, speedy adjudication, which is binding, at least on an interim basis. The adjudicator’s decision could affect what is constructed or the construction methods, and so could have safety implications, but the Act and Scheme do not include any regard to safety in selecting an adjudicator, the time and resources allowed, or the basis of the decision. Second, Section 112 provides a right to suspend performance of obligations in the event of non-payment. Such suspension could introduce risks to safety, but these are not addressed in the Act.

ROBUSTNESS AND DISPROPORTIONATE COLLAPSE

The long-standing dialogue between SC OSS and DETR Building Regulations Division has not yet been concluded. SC OSS has recommended that the fundamental property of resistance to disproportionate collapse should be required by regulations for all building structures and that guidance should be prepared on structural concepts and forms with low sensitivity to damage.

ICE and IStructE arranged a well-supported meeting in March 1997 to allow wider discussion of the topic. A lively discussion took place which was seen as a useful input to DETR in its review of Part A of the Building Regulations, Structure. SC OSS recognises the need for research into basic understanding of the connectivity of structural form and its effect on robustness and vulnerability. The Building Regulations Advisory Committee, and the DETR Robustness Committee which is assisting the review, have accepted the need for guidance on meeting requirements for robustness and resistance to disproportionate collapse to support Part A of the Regulations. DETR has undertaken to commission the preparation of such guidance, and IStructE also plans to set up a task group to prepare guidance.

THE CDM HEALTH AND SAFETY FILE AND GLASS

SC OSS has recently examined the structural use of glass and its safety during the lifetime of a building. SC OSS concern is that the glass and its fixings, when used structurally, should be inspected periodically.

Replacing the River Exe Railbridge, which was specifically designed for rolling during construction using steel balls and hydraulic rams. (Photo: Cass Hayward & Partners and Hochtief)
The existing regulatory framework does not provide an obvious means of ensuring that such inspections are carried out. One SCROSS suggestion is that the requirement for inspection should be stated in the CDM health and safety file, which the approved Code of Practice states may include "maintenance procedures and requirements for the structure". An alternative is that the requirement should be stated in building regulations made under Section 2 of the Building Act 1984, which enables building regulations to impose continuing requirements on owners and occupiers of buildings.

The Institution of Structural Engineers is preparing a guidance document on structural glazing which will provide a valuable basis for confident design of glass structures.

SAFER COMPUTING

Discussion at the IStructE seminar "Safer computing: managing technical risks", held in January 1996, supported the need for concise guidelines aimed at both large and small engineering practices, as recommended in the Tenth SCROSS Report. A task group of the Institution plans to publish such guidelines during 1998.

SCROSS continues to note potential shortfalls in safety arising from inappropriate use of computers. The ASCE Forensic Engineering Congress in Minneapolis in October 1997[5] included two sessions on computer misuse.


NEW BOOKS


The second edition of Jacob Feld's classic work contains much new information and case studies of structural collapse and failure around the world. There is much to learn from this comprehensive review.


This book, in English, is a much-needed text on a subject with which many practising engineers are not yet familiar. Intended for both students and practising engineers, it explains concepts and procedures by simple examples. It includes clear descriptions of hazard and risk and an approach for dealing with hazards through the use of hazard scenarios and a safety plan. The approach is akin to the process for assessment of safety and risk advocated in the Eleventh SCROSS Report.

NEW SCROSS CHAIRMAN

Professor Anthony Kelly FEng FRS will be handing over the chairmanship of SCROSS to Lord Lewis of Newnham during 1998. Jack Lewis FRS has been Warden of Robinson College Cambridge since 1975, and was Professor of Chemistry at the University 1970-95. He has served on many commissions and boards, and received numerous honours and awards.

INTERNATIONAL LINKS

SCROSS interactions with structural engineers overseas are growing steadily. Structural Engineering International and Civil Engineer International included summaries of the Eleventh SCROSS Report in 1997, bringing SCROSS findings to a worldwide audience.

Two SCROSS members have recently outlined our work at international meetings: Professor Kenneth L. Carper of Washington State University, a former TCFE chairman. TCFE, a close analogue to SCROSS, develops practices and procedures to reduce failures in engineered facilities; disseminates information on failures; provides guidelines on their investigation; and encourages ethical conduct in forensic engineering. SCROSS members Brian Neale and Gordon Millington attended the First Forensic Engineering Congress (mentioned earlier), held in conjunction with the ASCE 1997 National Convention in Minneapolis. The Eleventh Report was reviewed in the August 1997 issue of the ASCE Journal of Performance of Constructed Facilities. This journal provides valuable reports of experience and is a feature of the considerable activity within ASCE on forensic engineering.

THE ELEVENTH SCROSS REPORT

The Eleventh SCROSS Report, Structural Safety 1994-96: Review and recommendations, SETO Ltd, price £25.00, ISBN 1 874266 31 X, may be ordered from:

• Institution of Structural Engineers, 11 Upper Belgrave Street, London SW1X 8BH. Tel 0171-235 4533, Fax 0171-235 4294.
• Thomas Telford Bookshop, 1 Great George Street, London SW1P 3AZ. Tel 0171-665 2019.