Structural Safety 1994–96
Review and recommendations

Eleventh Report of SCOSS
The Standing Committee on Structural Safety

January 1997

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SCOSS Constitution 1994–96

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Feedback invitation

Through SCOSS, engineers and others can express concern about trends adverse to structural safety. Confidentiality is a key feature of SCOSS day-to-day activity. Whatever the degree of concern or potential urgency of a structural safety problem, engineers and others are invited to refer it, on a confidential basis if they so wish, to SCOSS. Feedback on experiences where structural failure has occurred or where it has been prevented, i.e. 'near-misses', is especially valuable.

SCOSS invites comment on this Report.

Contact: Dr John Menzies (Secretary): Tel. 01923 675 106; Fax 01923 680 965, or Mr Nick Clarke (Technical Officer): Tel. 0171 235 4535; Fax 0171 235 4294; E-mail: istructe.lon@mail.bogo.co.uk. SCOSS, 11 Upper Belgrave Street, London SW1X 8BH; or any of the Committee members listed on page 2.

Acknowledgements

SCOSS is encouraged by the actions taken by the Institutions of Civil and of Structural Engineers, Government Departments and other bodies as a result of its enquiries and recommendations and is grateful for the information and help it has received from many engineers and others in the public and private sectors. Their cooperation has greatly helped SCOSS's work towards preventing disasters involving structural failures.
The biennial reports of the Standing Committee, of which this is the Eleventh, are written to summarise findings and to present recommendations that arise from recent interactions with the professions, industry and government.

The primary aims of the Committee and the Report are to give warnings where unacceptable risk is believed to exist and to encourage the maintenance of structural safety. An increasingly important secondary aim of the Report is to provide a source document of educational and professional development value to practising engineers, students and others. The present report therefore uses references to help readers towards further study.

During 1995 the Committee was delighted to establish, while maintaining its independence, closer working arrangements with the Health and Safety Executive. As a result, the Committee now has a stronger base from which to pursue its objectives. A wider range of work can be developed, in particular through joint projects in areas of common interest.

Structural safety is not an adjunct to construction projects but it is an integral part of a competitive industry. Safety is good business and should be a feature of the culture of construction. The Committee seeks therefore to encourage more positive attitudes towards safety in the construction industry and sees this Report as a contribution to that end.

Professor Anthony Kelly
Chairman
Executive summary

IMMEDIATE PRIORITY RECOMMENDATIONS

Recommendation 1: Inspection and appraisal of existing multi-storey car parks

Owners and operators of existing multi-storey car parks should commission periodic inspections and structural appraisals on the condition of their structures. Such inspections and appraisals should be made by engineers with appropriate experience following the principles adopted by bridge owners. Appraisal should extend beyond any areas of conspicuous deterioration, particularly where water with road salts may have penetrated, and should include a review of resistance to progressive collapse. (Section 5.1)

Recommendation 2: Adequacy of edge barriers in multi-storey car parks

Owners and operators of existing multi-storey car parks should:

- establish whether the strength of edge barriers is adequate to restrain vehicles,
- establish whether the height and design of edge barriers are appropriate to safeguard small children,
- modify, strengthen or replace inadequate edge barriers. (Section 5.1)

Recommendation 3: Guidance on assessment of barriers in multi-storey car parks

The Institutions of Civil and of Structural Engineers should urgently prepare guidance on assessment and strengthening of existing edge barriers in multi-storey car parks. (Section 5.1)

Recommendation 4: Pin connections in bridges and buildings – review of guidance

The Steel Construction Institute in collaboration with the British Standards Institution should review the guidance on the design, inspection and maintenance of pin connections in bridges and buildings. (Section 6.1) See also Recommendation 5.

Recommendation 5: Pin connections in bridges and buildings – design

The design of pin connections should be overseen by suitably experienced engineers who are responsible for design, detailing, installation, inspection and maintenance. (Section 6.1) See also Recommendation 4.

Recommendation 6: Fatigue in steel structures

The Institutions of Civil and of Structural Engineers, and the British Standards Institution should undertake a strategic review, from a safety standpoint, of standards and codes of practice relating to design against fatigue in steel structures as a basis for achieving convergence towards a compatible set of fatigue rules, taking into account the commitment to the development of the CEN Structural Eurocodes. (Section 6.4)

Recommendation 7: Disproportionate collapse

The Institutions of Civil and of Structural Engineers should prepare design guidance for engineers on structural concepts and forms which have a low sensitivity to damage and an appropriate capacity to resist disproportionate collapse. (Section 3.2)

Recommendation 8: Flood damage to bridges

A continuing collaboration between highway authorities, Railtrack and other owners of bridges over water, possibly under the aegis of the Institution of Civil Engineers, should be established to keep flood damage to bridges under review and to develop consistent best practice. (Section 5.5)

STRONGLY RECOMMENDED

Recommendation 9: Hazard identification and risk assessment in design

Starting at the design stage of projects, designers should apply an explicit risk management process, including the identification of hazards and assessment of risks, with the effort expended and sophistication of the assessment being directly related to the nature, size and importance of the structure. (Section 3.1)
Recommendation 10: Design and build: client-supplied data

 Bodies responsible for standard forms of contract for design and build should review their conditions of contract to ensure that the responsibility of the designer for investigations, checking and evaluating ground and other site conditions is clearly stated, and that there is protection against unjustified reliance on or over-optimistic interpretation of client-supplied data.

(Section 3.3)

Recommendation 11: Structural codes of practice

The British Standards Institution should give publicity to an overall policy for the development of codes of practice relating to structural design and should aim to achieve a single set of codes through positive coordination and support of their development.

(Section 2.4)

Recommendation 12: Air-supported structures – withdrawal of British Standard

The British Standards Institution should withdraw BS 6661: 1986 Guide for the design, construction and maintenance of single-skin air-supported structures.

(Section 6.3)

Recommendation 13: Guidance on air-supported and fabric structures

The Institutions of Civil and of Structural Engineers in collaboration with the industry should prepare guidance on the design, specification, construction and use of air-supported and fabric structures.

(Section 6.3)

EVENTS AND TRENDS

Over the past two years, the Standing Committee (SCOSS) has observed a very good record, with a few exceptions, of structural safety in the United Kingdom. Worldwide there have been structural collapses and failures arising from extreme natural disasters or man-made causes. These events provide a constant challenge for all who are concerned with structures of finding ways to avoid or minimise hazards to structures and to offset the risks.

Acceptable standards in structural safety can only be achieved through the constant vigilance of engineers and others who have responsibilities for safety. Effective communication in the construction industry, including the regulatory and standards bodies, professional and educational institutions and research organisations, is a major factor in maintaining vigilance and awareness of adverse trends and events affecting structural safety.

A challenge to effective communication has arisen in recent years from the fragmentation and commercialisation of the construction industry. Some organisations providing advice on good practice no longer exist or their output is diminished or less freely available. SCOSS has considered these and other trends and has noted some compensatory changes which have helped to maintain effective communications as the industry seeks greater competitiveness through innovation and increased efficiency:

• Important new legislation, particularly the Construction (Design and Management) Regulations 1994, provides a strong positive stimulus. The growing use of information technology helps to compensate for the effects of the fragmentation of the industry, the dispersion of reservoirs of knowledge and the trends towards lower permanency of employment and greater individual responsibility and mobility of professionals. There is danger however in placing too much reliance on information technology. This can be avoided by education and training and measures to ensure that good quality information reaches the right people.

• Codes of practice, standards and guidance documents play an important role in communicating information on safe practice. A plethora of such documents exists however making it very difficult for the busy practising engineer to keep up to date. The growing portfolio of codes of practice relating to structural design is introducing conflict and inconsistency in available guidance.

• Feedback of experience, both good and bad, can be a valuable influence towards maintaining structural safety. Feedback concerning hazards and risks in structural safety is not always distributed widely in the construction industry. The technical press plays an important role. Some other industries have confidential reporting systems for safety-related incidents. SCOSS aims to give warning where unacceptable risk is believed to exist.

• Effectiveness in maintaining structural safety may be lost during major organisational changes through, for example, dissipation of in-house experience or loss of records. The risk needs to be recognised and countered.

• Education and training are perhaps the most important communication processes. The study of recent experience of structural failures has an important role in raising awareness of hazards and risks. Educators have a valuable opportunity to instil a degree of caution and an appreciation of the need to guard against complacency and over-optimistic extrapolation from experience.

• Research provides the basis for the application of innovation and development in structures. Clients are currently demanding substantial improvements in the durability and quality of structures and yet expecting this at no extra cost. Innovation may assist the achievement of this objective. Continuing support for relevant research is needed to ensure that the industry response to the pressures for improvements maintains a high level of safety.
COMMENTS

The examination of the above trends and changes by SCOSS has led to the recommendations given above and the following comments on particular topics.

1: Trends in communications
Changes in the construction industry over recent years have had adverse effects on some traditional communication processes and routes. (Section 2.1)

2: Construction (Design and Management) Regulations 1994
The pressure of the CDM Regulations and the advice and guidance now available on complying with the spirit and formal requirements should assist safety. (Section 2.2)

3: Information technology
Information technology is providing greatly increased power to generate and transfer information between all the parties involved in construction and safeguards are needed to ensure competent use of generated material. (Section 2.3)

4: Codes of practice, standards and guidance documents
Practising engineers would be assisted substantially in ensuring structural safety if more positive action was taken by the Institutions of Civil and of Structural Engineers, the British Standards Institution and appropriate Government Departments at an early date to amend or replace codes of practice and other guidance documents in line with technological change and new guidance which becomes operational in Europe. (Section 2.4)

5: Feedback of experience
Systems for the feedback of experience relevant to the maintenance of structural safety are not as well developed in the construction industry as in some other industries. (Section 2.5)

6: Changes in national construction-related organisations
The potential loss of effectiveness in maintaining structural safety during major organisational changes is apparently being recognised and countered in some national construction-related organisations. (Section 2.6)

7: Education and training
All structural failures may have an educational value. Study of failures by students, and also by engineers throughout their careers, can make a valuable contribution towards avoidance of losses of structural safety. (Section 2.7)

8: Communicating research findings
In view of the trends in construction in response to pressures for innovation and greater industrial competitiveness, there is a continuing need for research on structural safety and for communicating the findings into practice. (Section 2.8)

9: Temporary demountable structures
Further incidents of loss of structural safety of temporary demountable structures have emphasised the need to implement the recently-published Institution of Structural Engineers’ Guide Temporary Demountable Structures: Guidance on Procurement, Design and Use. (Section 4.1)

10: Explosion damage to buildings
Attempting to protect buildings fully from damage by massive explosions is not realistic, but aiming to achieve robust structures, i.e. structures resistant to disproportionate collapse, may give some degree of explosion resistance. More robust glazing and cladding will reduce the risk of blast penetration. (Section 4.2)

11: Post-tensioned concrete bridges
A substantial programme of collaborative work by the concrete bridge industry and others has now established the principles for satisfactory construction of post-tensioned concrete bridges, including the improvement of the design concept, development of improved grouting materials, procedures and specifications, and use of the UK Certification Scheme for Reinforcing Steel (CARES) quality assurance system for post-tensioning operations. (Section 5.2)

12: Bridge assessment and strengthening
Road (and possibly rail) bridges in the United Kingdom will be required to carry increased loads in the near future. Current assessment rules are being reviewed by the Highways Agency against the requirement to maintain safety with the aim of avoiding as far as possible any unnecessary strengthening and repair. For rail bridges, better up-to-date standards, both high-level and detailed, are required for structural assessment. (Section 5.3)
13: Bridge strikes
Actions to reduce the risks of accidental impact on bridges in the United Kingdom are progressing but delays in introducing traffic management and other measures at some high-risk sites and in enacting the 'height-in-cabs' legislation are a matter of concern. (Section 5.4)

14: Feedback on use of new techniques in construction
The recent experience with the New Austrian Tunnelling Method (NATM) in the United Kingdom illustrates that gathering information on trends in the use of techniques in construction on a worldwide basis can provide valuable indications for safety. (Section 5.6)

15: Cladding and glazing
Few reports of unsatisfactory performance of claddings have been received over the past two years. Guidance prepared by the Institution of Structural Engineers should contribute towards a further improving record. (Section 6.2)

16: Hidden tension members
Continuing vigilance is needed to ensure that bridges and buildings with hidden tension members are known and remain safe. (Section 6.5)

17: Washwater systems
The questions raised in the Ninth SCOOD Report on the use of super-retarder treatments of washwater in concrete mixers have been satisfactorily answered. (Section 6.6)

18: Freestanding masonry walls
Guidance on the design and construction of freestanding masonry walls is now readily available and will encourage safer construction. (Section 6.7)

19: Seismic resistance of structures
Structures of modern seismic design have improved seismic resistance but more work is needed to mitigate the effects of earthquakes on communities. (Section 6.9)

FUTURE SCOSS PROGRAMME
Key items of work for SCOSS for the future are:
- liaise with relevant government departments, the Institutions of Civil and of Structural Engineers, the British Standards Institution and industry on matters relating to structural safety,
- gather and analyse information on structural safety,
- respond to concerns about safety and to structural failures/collapses as they arise,
- strengthen SCOSS database on collapses and structural safety topics.
Introduction

In the period since publication of the Tenth SCOSS Report in October 1994, civil and structural engineers worldwide have continued generally to provide safe and economic structures to serve their intended purposes. There have, however, been structural collapses and failures arising from extreme natural disasters or man-made causes including a few within the United Kingdom. These events provide a constant challenge to structural engineers and others with responsibilities for safety to find ways of avoiding or minimising hazards to structures and offsetting the risks. There is an ever-present potential for structural collapses. Acceptable standards of structural safety can be achieved only by the constant vigilance and awareness of all those concerned with structures.

Valuable lessons for the future may be learned from the structural collapses that do occur. Some of the more notable structural engineering disasters over the last two years are listed below. More details of many of these events are given in the main body of the report. Such disasters often attract substantial coverage in the press, and this serves a valuable role in alerting structural engineers generally to causes and the potential for similar collapses elsewhere.

- Steel footbridge linking the ferry to the terminal collapsed, six passengers killed. Ramsgate, Kent, September 1994. (Section 6.1).
- Bridge span collapsed, 32 died. Songsu Bridge, Seoul, Korea, October 1994. (Section 6.1).
- Three-storey office building collapsed during alteration work, four building workers killed. Ashford, Middlesex, August 1995. (Section 3.2).
- Nearly 700 people died in the collapse of the Sampoong department store, Seoul, Korea, June 1995. (Section 3.2).
- A car broke through a barrier and plunged from the fourth storey of a multi-storey car park, seriously injuring the driver, Canterbury, Kent, January 1996. (Section 4.1).
- Terrorist bombs in London Docklands in February 1996 and central Manchester in June 1996, two killed in Docklands, widespread damage. (Section 4.2).
- Temporary grandstand seating 1200 collapsed at a pop concert in Earls Court, London, October 1994, more than 50 fans injured. (Section 4.1).
- Tunnel collapse during construction at Heathrow Airport, October 1994. (Section 5.6).

The topics that SCOSS has considered during the two years 1994–96 are reviewed in this Report. Where appropriate, actions taken in the light of previous SCOSS recommendations are noted, and instances of structural failures or potential problems are given to highlight SCOSS's concerns. To avoid repetition, full references to previous SCOSS reports are not repeated in every section. Topics which have been discussed in SCOSS Reports since 1976 are listed in Appendix 2.
Background information on SCOSS is included in Appendix 1.

In addition to its day-to-day interactions with the professions, industry and government, SCOSS maintains a close watch on the technical press for reports which may indicate early signs of adverse trends developing in a particular area, or examples of structural failures which may provide lessons that can be applied elsewhere.

Where possible, references are included throughout this Report to help further studies by engineers, students and other readers.

References, Introduction, Section 1

2 Communication

2.1 Communication processes
The generally good record of structural safety in the United Kingdom depends substantially on the effectiveness of communication processes which, for convenience, may be considered to be either direct or indirect.

Direct communication processes may be defined as those used explicitly by the owner, designer/specifier, contractor/subcontractor and operator/maintenance contractor with any associated regulatory control, in the procurement, management and maintenance of specific structures.

Indirect communication processes are those which support the direct ones. They include preparation of legislation, codes of practice, standards and guidance documents, research backup to innovation and development, and feedback of experience.

Good communications are essential to enable engineers to fulfil professional responsibilities for:

- using available up-to-date technical and other information,
- anticipating during the design and execution of construction projects all reasonable circumstances that may arise both during the work and subsequently when the built facility is in use,
- detailing the work to accepted current practice.

The success of direct communication processes depends largely on:

- an appropriate management system and control, including supervision and checking; increasingly, formalised quality systems are being applied to the design and construction processes,
- the use of good practice as defined in codes and other guidance documents,
- implementation by competent persons, i.e. appropriately trained and experienced personnel,
- cautious assessment in the application of innovation.

The effectiveness of communication within and between the processes listed above has been challenged over recent years by the fragmentation and commercialisation of the construction industry. A number of bodies providing advice on good practice no longer exist or their output is less freely available, e.g. Cement and Concrete Association, Property Services Agency, Building Research Establishment. The formal master–pupil relationship and role models have largely disappeared and much experience has been lost through contraction in the size of the industry. Compensatory changes are therefore needed to restore and maintain effective communications, especially since innovation in concepts, materials, organisational and work practices continues as the industry seeks greater competitiveness. It may be argued that the root cause of many of the losses of structural safety in the examples of structural failures described throughout this report was lack or ineffectiveness of communication. At the least, better communication would have averted catastrophe in some cases. (See also Section 2.6.)

Concluding comment:
Changes in the construction industry over recent years have had adverse effects on some traditional communication processes and routes.

2.2 Role of legislation
Some changes have occurred in recent years which will help to restore good communications and also to foster a safety culture in the construction industry. Important new legislation has come into effect, including the Management of Health and Safety at Work Regulations 1992 (2), the Construction (Design and Management) Regulations 1994 (3) (CDM Regulations) and the Construction (Health, Safety and Welfare) Regulations(4) (CHSW Regulations). The CHSW Regulations consolidate, modernise and simplify older health and safety regulations, and introduce some new provisions arising from the implementation of an EC Directive on construction. Guidance on the Regulations is also available(5, 6).

The CDM Regulations, which came into force on 31 March 1995, set out responsibilities for all parties involved in construction, and place duties on clients, designers, and contractors. For example, the client has to appoint a planning supervisor and principal contractor and to provide relevant information about the site. Designers are required to consider, in their design, health and safety during construction and cleaning work. They are required to provide adequate information about hazards and about the project, structures and materials to those carrying out the work. Contractors are required to provide the principal contractor with information about health and safety. A safety plan and safety file have to be produced and maintained throughout each project.

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These formal requirements of the CDM Regulations provide the framework for, most importantly, complying with the spirit of the Regulations. Whilst generally it can be seen that the Regulations should assist safety, it is also possible to envisage circumstances where structural integrity could actually be impaired by precedence being given to considerations of health and safety during construction. A hypothetical example would be a decision to change from driven piles to bored piles on account of noise, the piles then suffering from necking in soft clay strata. Such examples illustrate the need for a clear-thinking, logical and pragmatic approach alongside the formal requirements of the Regulations.

An Approved Code of Practice giving advice on compliance with the CDM Regulations was published by the Health and Safety Commission shortly before the Regulations came into force. Numerous other guidance documents and publications have been published to help the industry to plan and implement the new Regulations; see, for instance, references 6–11. Extensive discussion and debate are continuing on how to implement the Regulations effectively as experience is gained. For example, the Construction Industry Research and Information Association (CIRIA) is undertaking an extensive programme of research to assess the impact and benefits of the Regulations.

Concluding comment:

The pressure of the CDM Regulations and the advice and guidance now available on complying with the spirit and formal requirements should assist safety.

References, Section 2.2


2.3 Information technology

Computers are now widely used in civil and structural engineering projects, not only for structural analysis and design but also for information transfer. SCOSS concerns about their use were discussed in the Tenth SCOSS Report, and some valuable developments have since taken place. The Institution of Structural Engineers held a seminar on Safer computing – Managing technical risks in January 1996 and subsequently set up a task group to prepare guidelines on the topic for practising engineers. This will take account of the Guide to the validation and use of geotechnical software produced by the Association of Geotechnical and Geoenvironmental Specialists in 1994.

Misuse of computers was a concern of many engineers who responded to a survey carried out by the Institution of Structural Engineers' Informal Study Group on Computing in Structural Engineering in 1995. Respondents repeatedly commented on the danger of placing too great an emphasis on computer output, and on the importance of engineers retaining 'control' over the program, of sound engineering judgement, and a full understanding of engineering principles. The Study Group is planning a seminar on modelling of simple and complex structures for computer analysis, and intends to prepare guidance notes on the subject. The work of the Study Group was reviewed in 1996.

Cross-checking computer-generated solutions with other forms of analysis and ensuring that the computer operator has developed sound engineering judgement and a 'feel' for structural behaviour, derived from experience, are approaches that will minimise the risks in computer-aided structural analysis and design. Clear appreciation of the results expected in any computer-based design or analysis is essential, especially by younger engineers. The techniques of 'rules of thumb', basic physical and order-of-magnitude calculations, and of hand sketching must be retained.

Growing influences on communications within design and construction processes may be identified related to information technology. The developing use of IT is providing greatly increased power to transfer information between all the parties involved in construction. The 'paperless' project is not a figment of the imagination but a real prospect for projects generally in the near future. HyperText documents with links to background information are a potentially powerful means of enabling construction professionals to select optimum solutions and keep up to date. These forms of communication offer exciting prospects for achieving a more competitive construction industry. They do however require servicing through the indirect communication processes, mentioned in Section 2.1, and they have important implications for education and training.

Overall, the growing use of information technology may be seen as a contribution towards compensating for the fragmentation of the industry, the reduction and dispersion of reservoirs of knowledge and the trend towards
lower permanency of employment and greater individual responsibility and mobility of professionals. Placing too much reliance on information technology would be easy and a strong temptation which can only be avoided by education and training of those who use it. It would be even easier for the available information to be of poor quality. Software and databases can be out of date and incomplete and yet vigorously marketed. Safeguards are therefore needed to ensure that the functions and limitation of such systems are made explicit to users.

The remarkable growth in the use of the Internet and the World Wide Web provides an exciting opportunity for wide dissemination of information at relatively low cost. SCOSS hopes to make its report and other information available on the World Wide Web in 1997.

Concluding comment:

Information technology is providing greatly increased power to generate and transfer information between all the parties involved in construction and safeguards are needed to ensure competent use of generated material.

References, Section 2.3


2.4 Codes of practice, standards and guidance documents

Codes of practice, standards and guidance documents play an important role in communicating information on accepted practice in design and construction.

A plethora of such documents exists to help the direct processes of providing structural safety. The numbers grow as essential revisions and new subjects are introduced in response to advances in the business processes and technology of construction. Additional revisions and new documents are also arising from pressure to modify codes to a performance basis to facilitate competition within the Single European Market.

Those with direct responsibilities for ensuring structural safety face the continual challenge and cost of keeping up-to-date. For them a hazard to structural safety may exist in the guidance they are using. It may be out-of-date, not appropriate to the circumstances, limited in scope, or in error. It is recognised that standards can never be totally up-to-date in respect of technological advances. British Standards do however sometimes become substantially out-of-date because they do not embrace developments in technology within their scope, e.g. BS 6661(16), see Section 6.3. Although rare, errors in the advice given in authoritative guidance documents do arise, such as the advice on the structural use of high alumina cement concrete prior to 1975(19) and on the use of calcium chloride in concrete prior to 1977(20).

The risk associated with this form of hazard is generally kept small by the user making sure, as best he can, that the guidance being used is relevant and up-to-date. This task can be very difficult. It is often hard to find out about best practice documents with so many bodies covering their own specialist fields. For example, The CIRIA UK Construction Information Guide(21) lists over 800 organisations, a significant number of which produce guidance documents for their members. It can also be hard to know the status of a guide issued by a particular organisation. Where several codes and guidance documents cover the same area, the possibility of selecting the most advantageous sections from a range of different documents and combining them together into an inconsistent design approach exists. The use of documents in combination in this way should be avoided.

The classification of technical publications proposed by the Institution of Civil Engineers(22) is helpful and should be more widely used. This proposes that technical publications should be allocated descriptors under the headings: content, status, user and availability.

It is vitally necessary to reduce the number of essential reference documents so that a competent busy engineer can reasonably be expected to become properly acquainted with them. A more radical step would be to give such standards an automatic period of validity. At the end of the period, the issuing authority would either confirm validity for a further period or publish a new version for the next period preferably highlighting the changes made.

Concluding comment:

Practising engineers would be assisted substantially in ensuring structural safety if more positive action was taken by the Institutions of Civil and of Structural Engineers, the British Standards Institution and appropriate Government Departments at an early date to amend or replace codes of practice and other guidance documents in line with technological change and new guidance which becomes operational in Europe.

The growing portfolio of codes of practice relating to structural design (both British Standards and European Codes) needs review. Conflict and inconsistency of design guidance between these documents is increasing rapidly as European Codes, commonly referred to as the Structural Eurocodes, become available. SCOSS has noted, for example, that the amendment to the partial
safety factor for reinforcement in BS 8110 \(^{(23)}\), recently agreed by the British Standards Institution, diverges from the value accepted in Eurocode \(^{(24)}\). Such divergences may not be detrimental during the present 'voluntary' stage of the Eurocodes provided that they are made recognising an overall policy for codes of practice in the United Kingdom. SCOSS understands that present policy is to converge to a European basis involving the gradual withdrawal of British Standard codes. Since the Eurocodes will not be in place as European standards for some time, it is important that the transition to their use is positively managed, especially in view of the large number of interests involved, and that existing British Standards are maintained and updated until transition takes place.

**Recommendation:**

The British Standards Institution should give publicity to an overall policy for the development of codes of practice relating to structural design and should aim to achieve a single set of codes through positive coordination and support of their development.

The need for a review of standards and codes of practice relating to design against fatigue in steel structures is discussed in Section 6.4.

**References, Section 2.4**


**2.5 Feedback of experience**

Communication processes which feed back information from experience are of the greatest importance in view of the trends and changes referred to above. Two types of feedback process can be distinguished:

- the accumulation of knowledge and experience by those directly involved in all stages of procurement and use of structures,

- the gathering together and distillation of experience through consensus by professional institutions, standards bodies, trade associations, etc. and its feedback into education, training and current practice.

Immediate local experience stimulates a learning process which conditions the future actions of those involved. In this way structural safety may be affected beneficially or adversely depending on the nature of such experience and its interpretation. This process is more likely to be beneficial where it is tested against a body of wider experience, for example, within the parent organisation, through publication by a professional institution, or through discussion in a standards committee.

Professional institutions, standards bodies and trade associations have an important role in gathering together and distilling experience and its feedback into education and training. At present, the distillation and feedback of experience are concentrated almost entirely on defining current good practice. Little attention is given to increasing awareness of specific hazards and the associated risks to structural safety.

Unfortunately, rules on confidentiality in litigation and arbitration and the use of non-disclosure clauses in settlement agreements militate against experience being passed on. The results of technical studies by expert witnesses in preparation for potential litigation yield valuable lessons but do not generally reach the engineers who could benefit or may be so delayed that they are too late to help in countering adverse trends. A study of cases dealt with by expert witnesses was described in the Tenth SCOSS Report. Most cases reported could be attributed to fairly obvious errors often amounting to carelessness, ‘comer cutting’, incompetence in design or construction and of absence of supervision by experienced staff. In one case only did the possibility of shortfalls in the performance of new construction products appear to be a factor. This very limited short-term survey suggested, therefore, that the major causes of structural failures were associated with shortcomings in the management of design and construction. The hazards were not recognised in many cases and associated risks were not minimised.

Within the construction industry, the professional institutions provide guidance to their members about incidents where structural safety may be compromised\(^{(25-27)}\). SCOSS encourages engineers and members of the public to use its confidential route\(^{(28, 29)}\). Feedback is received about experiences where structural failure has occurred but rarely where it has been avoided, i.e. ‘near-misses’. There are now mandatory requirements for the reporting of accidents or dangerous occurrences to the Health and Safety Executive\(^{(30, 31)}\).

Confidential systems for reporting incidents relating to safety have, however, been developed in some other industries. Particularly noteworthy is the Confidential Human Factors Incident Reporting Programme (CHIRP) operated by the Institute of Aviation Medicine which allows aircrew and traffic controllers to report any personal experiences that might be detrimental to aircraft safety\(^{(32)}\). CHIRP receives confidential reports of about 200 incidents a year, and unattributed information is circulated in a newsletter to all licensed for flying and air
traffic control duties. The experience suggests a CHIRP-style procedure can succeed only when:

- anonymity is possible through many people being involved in the same activity,
- the confidential report comes direct and not through management.

Reporting within companies is unlikely to be successful even though ostensibly there might be a no-blame attitude by management. Blame is not the only significant criterion against which a decision to report is considered. Anonymity of individual reports preventing judgement by the peer group is of equal significance.

CHIRP provides a unique source of data that would otherwise be lost. CHIRP can recognise an urgent problem and has the status and lines of communication to be able to see that the problem is recognised and dealt with. It can identify long-term design and regulatory issues that may need research. It can influence the standards of equipment design and manufacture and all operating procedures.

CHIRP is not to be confused with the Civil Aviation Authority (CAA) mandatory incident-reporting procedure. Small aircraft are not subject to the same legal obligation as passenger and freight aircraft to report incidents, but the CAA also receives their reports on a voluntary basis. In total the CAA office receives approximately 5000 reports a year concerning United Kingdom aircraft throughout the world and all aircraft within UK airspace.

Feedback experience of this type has been sought in other industries; in shipping, railways and to some extent in road traffic management, there is a keen appreciation of the value of 'near miss' information.

Such feedback is valuable in the construction industry. Knowledge of potential dangers to structural safety can then be distributed widely to those in the industry who could benefit. SCROSS, through its reports and other means, aims to increase the feedback which it provides. Contact details for feedback to SCROSS are given on page 4.

Concluding comment:

Systems for the feedback of experience relevant to the maintenance of structural safety are not as well developed in the construction industry as in some other industries.

References, Section 2.5


2.6 Changes in national construction-related organisations

Changes in the business processes of construction were signalled in the 1995 report of the Technology Foresight Panel on construction(30). The report presented a vision of the construction industry with a future of lower costs, greater profitability and responsibility. The accompanying changes have a potential to undermine structural safety which should be recognised.

Organisations with control of a large stock of structures, such as Railtrack or the Highways Agency, have substantial inspection procedures to inform their maintenance programmes and hence an opportunity for refined risk assessment. These procedures, like those in the aircraft industry, have a key role in identifying hazards and reducing risks to structural safety. They depend on the systematic collection and interpretation of inspection data. Given stability of such organisations, they can be most effective in maintaining safety. However, the risk of loss of effectiveness may grow with organisational changes, such as the transfer of railway structures from British Rail to Railtrack or the breaking up of experienced teams in previously nationalised industries and local government. Although the risk of loss of safety is real and should be minimised, these concerns should not be overemphasised. Established organisations and experienced teams may have become stagnant and inefficient such that they gradually lose effectiveness.

The potential loss of effectiveness nationally in maintaining structural safety during major organisational changes, e.g. the transfer of Government research bodies to the private sector, should be recognised and countered. This is happening in some national construction-related organisations. Within the railway industry recognition of this problem followed as part of a major scrutiny of systems for managing safety in the wake of the tragic accidents at King's Cross in 1987 and at Clapham Junction in 1988. Until that time safety management was based largely on technical and rule-based systems which had evolved and been improved largely as a result of the lessons learnt from accidents. A fundamental review of safety management, which included the risk assessment techniques of other industries such as oil and chemicals, led to an approach based on adoption of targets of safety performance improvement(34). The approach became part of the guiding principles and framework used to plan the restructuring of the existing British Rail organisation.
A key element of the new framework was the adoption of the health and safety obligations under the Health and Safety at Work etc. Act. Fundamental to the approach is the principle of reasonable practicability of control measures and the use of upper and lower levels of risk for individuals, employees or members of the public affected by the activity, i.e. those that are beyond the 'upper limit of tolerability', and those that are 'broadly acceptable'. Between these boundaries lies the ALARP (As Low As Reasonably Practicable) region of risk, where the costs of risk control measures may be evaluated against the benefit of these measures. In this region there is an obligation on any organisation to seek all means to reduce risk towards the 'broadly acceptable' level provided the costs are not grossly disproportionate to the benefits gained. Cost-benefit analyses are used in conjunction with risk assessment for the required evaluations.

The Railways (Safety Case) Regulations 1994 introduced under the Act aim to establish procedures by which railway operators, whether they are engaged in the control of the infrastructure, or in the operation of trains or stations, can demonstrate that they have the will, capabilities, resources, organisations and systems to operate safely from the start and to continue to do so. Railtrack’s first Railway Safety Case under the Regulations was accepted by the Health and Safety Executive in March 1994.

Concluding comment:
The potential loss of effectiveness in maintaining structural safety during major organisational changes is apparently being recognised and countered in some national construction-related organisations.

References, Section 2.6

2.7 Education and training

Education and training are perhaps the most important communication processes of all. They transfer knowledge and experience from one generation of engineers and others to the next. For all those involved in the procurement and use of structures, education and training provide a basis for awareness and recognition of hazards and risks relating to structural safety and of measures to ensure safe structures. Before taking on responsibility for structures, young engineers, surveyors and architects need to assimilate the essential experience of their profession. Traditionally, young professionals have been given an all-round experience as a preparation for their future practice. It is important that this continues. While discussing the standards of their education and training is not appropriate here, it is certain that they need to develop an appreciation of structural safety and of the hazards which may jeopardise it. Students should at least be made 'safety-conscious' by making reference to hazards and safety an integral part of their courses. They should be taught systematically to consider possible modes of failure as part of the design process. They should also be taught how to manage risks and to know when to seek appropriate advice.

SCOSS commends the initiatives of the Joint Board of Moderators (the body responsible for accrediting civil engineering courses in United Kingdom universities) to develop a clear programme which identifies the importance of safety matters in undergraduate courses. For engineers entering the profession it may be appropriate for them to be required to demonstrate ability to handle safety issues.

For students and for engineers throughout their careers, the study of recent experience relating to structural safety is invaluable. All structural failures may have an educational value. Although thankfully infrequent, published details of reports of failure investigations provide a body of experience for learning about how to avoid loss of structural safety. Several recent publications provide valuable feedback on structural failures and industrial accidents more generally. The review of structural safety in this SCOSS Report is seen also as having an important role in this respect. SCOSS suggests that the findings in this and previous biennial SCOSS Reports should be discussed with engineering students on all appropriate academic courses.

SCOSS was pleased to note the way in which one university has successfully introduced investigations into the causes of disasters and a challenging series of mock planning and disaster enquiries into the undergraduate civil engineering course. Identified benefits to students have been the development of communication skills, a clearer appreciation of the professional responsibilities of engineers, and an opportunity to relate engineering principles to the practical implications of decisions.

Educators have a valuable opportunity to instil a degree of caution towards the over-optimistic extrapolation of experience, and complacency relating to structural safety. They can also play a valuable role in offsetting any tendency among engineers towards collective forgetfulness about previous structural failures or overconfidence in more powerful design tools. The education of engineers should instil some humility and appreciation of the fallibility of men, machines, mathematical models, etc. Petroski, based on research by Sibly and Walker, describes an apparent 30-year cycle of overconfidence among bridge engineers during the last 150 years.
He emphasises the benefit of the philosophical approach to design that realises the need to know and respect the lessons from failures. Increased standardisation means that design is delegated to less experienced engineers. Kletz, in relation to the process industries, identifies a cycle of corporate forgetfulness allowing errors and oversights previously identified to creep back in less than 10 years. He points to the phenomenon that memory is personal and experiences are not easily passed from one generation to the next.

Concluding comment:

All structural failures may have an educational value. Study of failures by students, and also by engineers throughout their careers, can make a valuable contribution towards avoidance of losses of structural safety.

References, Section 2.7


2.8 Communicating research findings

Research provides the basis for the application of innovation and development in structures. Communication of research findings to application in practice is a complex process. Research data pass through several stages from generation to distillation, comparison and interpretation before bringing about a change in practice.

The most immediate route occurs where research directly supports the assessment of an innovation for use in a particular construction project. Here, also, viewing this as a one-stage process is too simple. Criteria and guidelines for use need to be developed on the basis of analytical and technological work taking account of advances in materials science, fabrication processes and non-destructive testing. A good example of this process has been the recent introduction of steel castings in building structures.

Much valuable research relating to structural safety is undertaken in universities. The research is sometimes fundamental in character, e.g. development of a theory for structural vulnerability, and the results in the first instance will need to be tested and distilled by the research community to help transformation into techniques for use in construction practice. However, such research can generally benefit from input from construction professionals. Other structural engineering research in universities is more closely aligned to solving immediate problems in practice or to developing an improved product. This type of research is only likely to be successful if it is undertaken in collaboration with industry. It is notable that this is often the case although the industry collaboration is not always well publicised.

In relation to research relating to structural safety, SC OSS welcomes the emphasis now being placed by the Engineering and Physical Sciences Research Council (EPSRC) on supporting research serving the needs of industry. The EPSRC Built Environment Programme is especially important particularly since society seeks greater health and safety and since the research contribution in this area made by government research bodies has decreased.

For research sponsored by the Construction Sponsorship Directorate of the Department of the Environment, in particular in its Partners in Technology programme, stages are being introduced into the proposal system to ensure that the research teams put suitable emphasis on disseminating the results of their research. This is to be done both at proposal stage by means of a project impact statement and when the work is completed through an application and implementation plan.

While there are public and legislative pressures for greater health and safety, clients are currently demanding substantial improvements in quality and costs. These demands may lead to an adverse trend in structural safety. It is important for the construction industry response to the pressures to be balanced and sound. Continuing support by the Engineering and Physical Sciences Research Council (EPSRC) and relevant government departments and official agencies, e.g. Department of the Environment (DOE), Health and Safety Executive (HSE), Department of Transport (DOT) and Highways Agency (HA), for research on structural safety is needed so that industry can achieve acceptable safety and structural performance at economic cost.

Concluding comment:

In view of the trends in construction in response to pressures for innovation and greater industrial competitiveness, there is a continuing need for research on structural safety and for communicating the findings into practice.

References, Section 2.8

3 Safety concepts, design and control

3.1 Assessment of safety and risk at the design stage

The Construction (Design and Management) Regulations 1994 came into force on 1 March 1995. These Regulations require the consideration of hazards and risks arising during design, construction, cleaning and demolition processes. The requirements are compatible with the suggestion, made in the Tenth SCOSS Report, for assessment of hazard and risk to be an explicit procedure at the design stage of permanent works.

The first reaction of a few engineers to this suggestion has been that it imposes a requirement on designers for yet more (unnecessary) work and that in any case structures are currently designed/refurbished successfully without it. This view is not correct. Assessment of hazard and risk is already a part of design development of structural concept although for many structures it is largely an implicit process which is not formalised.

However, in some well-founded building and civil engineering practices an explicit procedure of hazard identification and risk assessment is a part of the development of the design concept and the definition of design situations, especially for large civil engineering or multiple use structures. The procedure enables the designer to fulfil the requirement for anticipating all reasonable circumstances which may affect the safety of the structure being designed, thereby ensuring the essential quality of robustness.

The nature and sophistication of the procedure clearly should be simplest for small structures and those where the consequences of failure would be minimal. For large projects, especially those where the consequences of failure would be particularly onerous, a more sophisticated procedure would be appropriate. Overall the procedure should be a part of the quality system applied to the design and construction processes.

A consensus on what is the appropriate procedure for particular projects does not appear to exist although guidance exists in some other European countries. It does however appear to be a necessary approach for building and civil engineering projects in general.

Risk assessment techniques are commonly used for safety critical systems and where codes of practice are not available. In conventional structural engineering, design is generally based on codes of practice. These do not address identification of risks to structural safety except in very general terms. The task is left largely to the imagination of the engineer. To identify and take account of significant risks may be of great importance. Risk assessment should be a part of the overall process of assessing the safety of structures.

Recommendation:

Starting at the design stage of projects, designers should apply an explicit risk management process including the identification of hazards and assessment of risks, with the effort expended and sophistication of the assessment being directly related to the nature, size and importance of the structure.

References, Section 3.1


3.2 Resistance to disproportionate collapse

New structures

The SCOSS Tenth Report recommended that:

The fundamental property of resistance to disproportionate damage (robustness) should be required by regulations for all building structures.

Robustness is a desirable attribute of all structures, but has not yet been embraced wholly in Part A of the Building Regulations. It is perhaps implicit in Regulation A1 but is now only an explicit requirement in Regulation A3 for buildings of five or more storeys in height. The arguments in support of the recommendation were given in the Tenth Report and have been expanded upon elsewhere. SCOSS remains concerned that this recommendation has not been implemented. Feedback indicates an adverse trend amongst some structural designers which is leading to structures whose ability to resist accident or exceptional circumstances may be insufficient.
The Building Regulations Division of the Department of the Environment is reviewing Part A of the Building Regulations. This review will take account of the SCOSS recommendation. A joint half-day meeting of the Institutions of Civil and Structural Engineers on robustness is planned for March 1997.

While accepting that there should be a minimum of regulation controlling structural safety, the minimum should include both fundamental performance requirements relating to safety, i.e. safety in normal use and resistance to disproportionate damage in the event of accident, misuse or exceptional circumstance. SCOSS considers that the force of regulation is necessary to offset the tendency in the construction industry towards collective forgetfulness concerning previous failures or overconfidence in more powerful design tools driven by pressure to reduce the cost of construction.

A difficulty perceived by some in implementing the recommendation is that rules whereby the robustness requirement can be met are difficult to formulate. No engineering theory is available which can be used as a basis. Although research is in progress in several universities, it seems unlikely that it will yield a useable theory in the immediate future. However, a lack of theory does not prevent engineers from applying as far as reasonably possible, relevant measures, such as:

- Avoid, eliminate or reduce the hazards to which the structure may be exposed.
- Select a structural form which has low sensitivity to the hazards considered with conscious emphasis on the influence of structural continuity.
- Provide adequate ductility of the structure for energy absorption.
- Made due allowances during design for the effects of construction tolerances, e.g. in positions of piles.

Application of these measures results from the assessment of hazards and risks during the early stages of design. A helpful element within the thought processes is consideration of how easily the structure could be collapsed with a minimum of effort were it applied most effectively. At present, such assessment is often more implicit than explicit during the structural design process. British codes of practice, as discussed in the Tenth SCOSS Report, give various guidance on design measures which implicitly introduce a degree of robustness. Generally, the resulting designs are satisfactory in this respect. Nevertheless, SCOSS is concerned by the adverse trend identified above.

Selection of structural form with low sensitivity to relevant hazards and provision of adequate ductility is sometimes interpreted solely as a requirement for structural redundancy. The presence of alternative load paths in a structure so that it will not collapse catastrophically if a single element fails, is certainly desirable, but it is not a characteristic which should be insisted on in all circumstances – see also the discussion on pin connections in Section 6.1. For some structures the functional concept makes it necessary for them to be statically determinate. In other cases, static determinacy may be a desirable feature, e.g. multi-span viaducts on ground liable to settlement. Of course, where the structural form is not redundant, using a robust design for critical elements and supports is then especially necessary. Sometimes safeguarding features can be introduced, e.g. at supports, which will limit the consequences of damage or disturbance at a critical point. SCOSS believes that helpful guidance including illustrative examples could be prepared for engineers and to assist the education of students and young engineers.

Recommendation:

The Institutions of Civil and of Structural Engineers should prepare guidance for engineers on structural concepts and forms which have a low sensitivity to damage and an appropriate capacity to resist disproportionate collapse.

Alterations to structures

The assessment of hazards and risks is also necessary as part of the basis for the design of alterations to structures. The total collapses of two building structures, one in the United Kingdom and one in Korea, are extreme cases which illustrate graphically the consequences of failure to recognise the inability of a structure to withstand alteration and additional loads safely.

- At Ashford, Middlesex, UK, a three-storey office building collapsed in August 1995 during alteration work, killing four building workers. The building was constructed in 1969 with steel beams supporting precast concrete floors, supported on brick piers, with lightweight blockwork panels below windows between the piers. Additional steel columns on new foundations were to be inserted between the brick piers to stiffen the structure. As the structure was opened up to allow for the new members to be inserted, the stability of the whole structure was disturbed and collapse followed immediately.

The building was not constructed according to the original plans. The building was originally designed and built as a single storey block with a flat roof, but a two-storey extension was added subsequently. The brick columns in this extension were placed on top of the lightweight concrete block parapet, and overhung the weaker parapet blocks. This additional work was done under a design certificate, and structural details were not made available to the local authority.

- In a second case, nearly 700 people died in the total collapse of the Sampoong department store in Seoul, Korea in June 1995. The building was constructed in 1989, with four basement levels and five upper floors of reinforced concrete slabs and columns. The plan area of the building was 61.6 × 50.4 m. Three air-conditioning water-cooling towers each weighing more than 30 tons had recently been placed on the roof, positioned in the centre of the 10.8-m spans.
This overloading resulted in a punching shear failure at a column head, and adjacent columns failed, which led to collapse of the roof slab, which in turn led to progressive collapse of all the lower floors. Signs had been apparent that the structure was in distress but no action had been taken.

The official enquiry identified numerous factors in the design, construction and maintenance of the building which contributed to the failure. These included underestimating the load from the roof slab, undersized columns and bearings, and inadequate slab thicknesses for bending moments and punching shear. Reinforcement was often wrongly positioned or missing, with mixtures of bar sizes, and anchorage lengths of only 150 mm instead of the 640 mm required by the design. The roof space had been converted into a restaurant, increasing the loading by about 3.5 kN/m², and the cooling towers added a further 4 kN/m².

References, Section 3.2


3.3 Design and build

SCOSS has considered whether some forms of design and build contract might introduce safety loopholes not normally experienced with more traditional forms of contract.

A client can choose a variety of methods to commission a project but these differ in their operation essentially by whether or not the contractor is responsible to the client for the development and detailing of the design. The design work could be undertaken by the same people in either case but their relationships could be different and their post construction responsibilities could be different.

In common practice the client will appoint his advisors to interpret his requirements and produce sufficient documentation to enable competitive tenders to be obtained from contractors. The client will be guided by his advisors as to the adequacy of those tenders and the contractor's commitments will be defined by the contract he signs with the client. The contractor is bound to construct in conformity with the agreed specification which is usually prescriptive in its terms. Product conformity may be demonstrated by the adoption of a quality management system or by quality control applied by the client.

Raising adverse criticism of the completed project in respect of quality, appropriateness or safety will require examination of the roles of the client, his advisors and the contractor in defining and requiring demonstration of achievement of their respective responsibilities. Appportioning blame may not be easy.

When the client appoints a contractor to provide an integrated design and build project, the contractor is solely accountable for the satisfactory performance of that project since he will have agreed to meet the requirements set out and agreed between them. These requirements are usually defined in performance terms. In arriving at his proposals the contractor will select appropriately experienced and often familiar designers and specialist sub-contractors to supplement his in-house resources. He will propose features of the design which enable him to apply his construction plant, staff and operatives in the most effective manner. He will usually have been appointed by a competitive process and be committed to economy of price and period for design and construction. The contractor will be conscious of the responsibility to produce a finished project which demonstrably satisfies the client. Use of a quality management system enables this demonstration of product conformity.

The client and his project are clearly at risk if he does not appoint competent and appropriately experienced organisations and staff to act for him. The client's definition of his requirements should sufficiently explain his functional expectations of the finished project for these to be expressed in appropriate construction specifications. Competent design organisations and contractors are equally able to help in the preparation of such a brief. When the design organisation does so they need to ensure that proper expression of it passes to the contractor through the tender enquiry and contract award stages. In contrast, a contractor offering design and build services receives the briefing direct from his client. In design and build projects the client selects a contractor and his team in a single operation whereas the appointment of a design organisation as advisor will be followed later by a second selection of a contractor. Advantages claimed by contractors are that using design and build is not only quicker but also that it provides a technical team who have elected to work together on the project. Clearly all technical requirements of the product should be adequately covered by the team and there should be no gaps in competent technical expertise needed to deliver the product.

When contractors are working on design and build, they undoubtedly seek to economise within the specification to which they are committed for cost and time reasons. Transmitting instructions within the design and build team and reaching agreements over matters of debate can be easier, provided management control is exercised properly. The contractor should not lose sight of the need to demonstrate, when the product is ready for handover to his client, conformity to the agreed specifications as well as to the requirements of regulations and other
definitions of recognised good construction practice. In the case of a dispute he has to resolve the matter with his client and not through an intermediary who may or may not be responsible.

In design and build, the contractor and his designer need to work closely, responding to each other's concerns and pressures. Unless they have mutual respect and exchange ideas and concerns, the resulting working design will not integrate their ideas to advantage and much of the potential advantages of this method will not be attained. The client can benefit from having an easier relationship with those working for him and especially if a target form of contract is operated which enables all parties to share in cost savings which are compatible with the client's agreed requirements.

These considerations suggest that design and build contracts which are competently operated and managed have no greater risk of resulting in unsafe or inadequate quality construction than traditional forms of contract. The requirements of the new CDM Regulations point to the need to designate and employ competent and appropriately experienced persons for each project. It is clearly of paramount importance that, for each project, there should be an identified, appropriately experienced designer with responsibility for all design aspects and the provision of clear and appropriate records

Despite this generally reassuring analysis, several aspects of concern remain:

- Designers have been restricted by their terms of employment from investigation of associated areas of concern which they would consider to be necessarily their normal responsibility under an Association of Consulting Engineers' non-design and build appointment. There is a danger, for example, that design and build contracts may be interpreted to mean that the designer is entitled to treat the design merely as an exercise to satisfy, at least cost, the most optimistic version of the information provided by the client. In contrast, it is normally accepted that the designer takes full professional responsibility for the adequacy of the data, e.g. on ground conditions, on which he bases his design. Designers in design and build contracts are often restricted in site visits, and in involvement in disputes over the quality of the constructed work. They are sometimes restricted to the design of parts of the works through sub-letting procedures, although this is not clear to the client.

- These restrictions might not be unreasonable provided the contractor is undertaking the missing items from the design brief with competent staff. Should there be unreasonable economies or incompetence in such work, there is fear for safety during construction or for the adequacy of the final structure. Responsibility for unsafe circumstances might not be clearly defined. Should this occur, designers nominally excluded by the restrictions to their brief may, in the client's eyes, become implicated.

- There is potentially a safety issue if there is any bar to free communications between a designer and the design and build contractor's staff or other designer interpreting and executing the design.

- There have been reported instances of the contractor instructing the designer to accept the use of specialist construction methods or products without the designer being provided with, or having an opportunity to assess whether, the proposed design and application of the method or product are appropriate for use in the particular situation. Should it be found that the method or product is inappropriate or its application misinterpreted then who is responsible? The contract between the contractor and his designer should contain provisions for the designer to properly examine changes brought about by the introduction of specialist construction methods or other circumstances.

- As design and build is increasingly applied to public sector works and linked to temporary or permanent ownership and maintenance (i.e. Design, Build, Fund and Operate contracts), a progressive loss of technical expertise in the management staff of the public sector can be foreseen, e.g. local authorities. As a result, a gulf is developing between those who have to operate and maintain the works and those who competitively perform its design and construction to a series of project briefs. This could lead to public sector works without the traditional adaptability and robustness which has, in the past, enabled many of these works to be adapted readily to changing society demands. SCOSS is concerned that subsequent changes in usage might occur without sufficient regard for essential safety-relevant features of design. Where such conditions are likely to occur, project records and use/maintenance documents referring to design concepts as well as actual construction should be integrally provided.

Any of these circumstances may lead to shortcomings in structural serviceability more often than to loss of safety.

Recommendation:

Bodies responsible for standard forms of contract for design and build should review their conditions of contract to ensure that the responsibility of the designer for investigation, checking and evaluating ground and other site conditions is clearly stated, and that there is protection against unjustified reliance on or over-optimistic interpretation of client-supplied data.

References, Section 3.3


4 Structures where large numbers of people congregate

4.1 Temporary stands and stage structures
The Institution of Structural Engineers published guidance on procurement, design and use of temporary demountable structures in 1995[61]. This was intended to supersede the existing general guidance on temporary demountable structures[62,63]. It was prepared by a Task Group which took account of recommendations in the Ninth and Tenth SCOSS Reports. These arose from examination of the safety of these types of structure and of reported collapses and disturbing sway movements.

A Monitoring Group was set up by the Institution in March 1996 with a wide range of representation[64]. The Group will review the guidance in the light of comments made, identify difficulties in its implementation, and prepare additional guidance as necessary. It will identify areas where further research and information are needed.

Several further incidents of loss of structural safety of temporary demountable structures have been reported in the last two years.

- In October 1994, more than 50 fans were injured at Earls Court, London, when a temporary grandstand seating 1200 collapsed at the start of a pop concert[65]. Non-standard additions of scaffold tubes had been made to the proprietary seating system.
- Nine children were injured when a stage extension collapsed at Rotherham Civic Theatre, December 1995.

These incidents emphasise the need to implement the guidance given by the Institution. The establishment of the Monitoring Group is therefore a welcome initiative. There remains a need for better information on components of such structures, particularly barriers and railings, and further research in these areas is desirable.

Concluding comment:
Further incidents of loss of structural safety of temporary demountable structures have emphasised the need to implement the recently-published guidance given by the Institution of Structural Engineers.

References, Section 4.1
64. Temporary demountable structures: Implementation Monitoring Group. The Structural Engineer, Vol. 74, No. 8, 16 April 1996. p. A4

More than 50 people were injured at a pop concert at Earls Court in October 1994, when a temporary grandstand collapsed. (Photo: Times Newspapers)
4.2 Explosion damage to buildings and other structures

Worldwide, but excluding acts of open war, explosions within or external to buildings and other structures occur from time to time either due to accident or terrorism. The behaviour of structures, cladding and finishes can vary markedly from building to building even in one incident, depending on the orientation and proximity to the seat of the explosion. Three of the explosions during the period under review illustrated this wide range of effects:

- A terrorist bomb was detonated in London Docklands in February 1996. Two people were killed. Office buildings and nearby homes were extensively damaged. The composite concrete–steel viaduct of the Docklands Light Railway also suffered significant damage to peripheral items such as parapets, but the box girder closest to the blast suffered little structural damage. The effects of the explosion on adjacent buildings were markedly different, and, as with similar events, damage to cladding, internal fittings and services was extremely disruptive(66), even for buildings where the main structure was not greatly affected.

- In central Manchester, a bomb in June 1996 caused widespread damage in the city centre, many injuries being caused by flying glass.

- A massive bomb adjacent to the Federal Building, in Oklahoma City, USA in April 1995 killed 169 people and damaged more than 300 buildings(87). It was estimated that at least 80% of the deaths were caused by the progressive collapse of the building itself rather than the blast.

Damage by earlier bombs in the City of London (St Mary Axe in April 1992, and Bishopsgate in April 1993) was similarly extensive. Repair of most buildings has now nearly been completed. A small number of buildings have been completely rebuilt, while many others have been refurbished.

An accidental gas explosion occurred within Ronan Point, a high-rise block of flats in East London, in 1968, causing partial collapse of the structure. As a result, a requirement was introduced in the Building Regulations and rules given in some codes of practice in the United Kingdom to enable provision of structural resistance to disproportionate collapse. The requirement, which is discussed in Section 3.2, was not envisaged to apply to accidental detonation or deliberate attack by detonation of high explosive. However, since large-scale detonations have been observed to cause extensive damage at considerable distances from recent explosions, building owners have become aware of the need for assessment and protection of structures against explosions in general.

Where deliberate detonation of explosives is a significant risk, measures to prevent the placing of an explosive device near to or within the structure can do much to reduce the risk and the severity of damage to a load-bearing structure. Though protection from the effects of explosions generally cannot be complete, the risk of gas explosions may be minimised, for example, by correct installation and the supply positioned externally or through a ventilated duct, and potential effects may be mitigated by structural design or remedial measures. Structural design to resist disproportionate collapse, as recommended by SCOSS for all structures (see Section 3.2), generally also confers some resistance against explosion damage. For buildings which are significantly at risk, the effects of blast can be mitigated by appropriate design(66). The use of laminated glass or anti-shatter film bonded to the inside face of existing ordinary glass is beneficial in reducing injuries caused by flying glass. Flying glass is often the major danger beyond the immediate explosion scene. The provision of relatively safe internal evacuation areas may be an appropriate part of emergency planning in some cases.

Although explosions often cause substantial damage to glazing, cladding and internal fittings, the structures of modern buildings are usually able to survive with relatively localised damage needing repair. However, assessment of bomb damage to cladding on buildings in London after the incidents in 1992, 1993 and 1996 confirmed on a larger scale that damage to fixings and over-stressing of cladding components would not always be readily visible.

Factors that affect the ability of buildings to resist blast damage are structural continuity, the presence of alternative load paths, the ability to arch or act in catenary, and permeability to blast(66). Of these, the last is particularly significant at some distance from the blast since, if cladding and glazing remain intact, damage to the interior is likely to be eliminated.

The Institution of Structural Engineers has recently published guidance to help engineers to assess damage due to explosions and to determine investigation measures and enhanced design(70,71). See also Reference 72.

Concluding comment:

Attempting to protect buildings fully from damage by massive explosions is not realistic, but aiming to achieve robust structures, i.e. structures resistant to disproportionate collapse, generally also gives some degree of explosion resistance. More robust glazing and cladding will reduce the risk of blast penetration.

References, Section 4.2


4.3 Structural safety in fire

The subject of fire safety engineering continues to develop and SCOSS has noted a number of recent developments.

A state-of-the-art guide Design principles of fire safety\(^{73}\) a British Standard Draft for Development Fire safety engineering in buildings\(^{76}\) have been published. The Draft for Development is more sophisticated than any other current guidance document and will enable calculations of fire development and evacuation of people to be made so that life safety can be assessed. It will deal with growing as well as steady state fires. Work on ISO standards on fire safety engineering is also continuing and, within the European Standards Organisation (CEN), several Structural Eurocodes for structural design for the accidental situation of fire are now available; see, for example, references 75–77.

The programme of large-scale fire tests at the BRE Large Building Test Facility at Cardington, Bedford is providing useful information on overall structural stability in fire conditions. The results are being used to validate the Structural Eurocodes. The equations in the Eurocodes dealing with the ‘equivalent time of exposure’ have been found generally satisfactory, but in some situations, such as large compartments with large ventilation openings, they may give unsafe predictions. The Department of the Environment is undertaking a review of Part B of the Building Regulations.

Recent fires have highlighted unexpected structural behaviour of composite sandwich panels used as ceilings and internal walls\(^{78}\). Sudden delamination and collapse resulted in the death of fire fighters in a fire in a food processing plant. Research by the Fire Research Station has been commissioned by the Department of the Environment and the Home Office on this form of construction.

An Institution of Structural Engineers’ Informal Study Group on fire engineering has been formed.

In the educational field, there are now five chairs in fire safety or fire engineering in the United Kingdom. Graduates from the recently established fire engineering degree courses at South Bank University, the University of Central Lancashire and Leeds University are completing their courses, and master’s programmes are becoming established elsewhere.

References, Section 4.3

78. Cooke, G. The structural behaviour of sandwich panels exposed to fire. Fire Safety Engineering. In press.
5 Structures associated with the transport infrastructure

5.1 Multi-storey car park structures and edge barriers

The Tenth SCOSS Report in October 1994 expressed concern about the structural integrity and safety of multi-storey car parks. The concern has grown substantially in the wake of an accident in Canterbury in January 1996. A car plunged 20 m from the fourth storey of the Watling Street Car Park, seriously injuring the driver. The barrier intended to restrain cars from falling over the edge failed. Following the accident, which is the second of this type known, SCOSS urged the Secretary of State for the Environment to act. Action proposed was to assist the public safety of multi-storey car parks by encouraging car park owners collectively to establish standards for maintaining safety or possibly by licensing and/or the provision of powers of inspection and enforcement to an appropriate agency. The Health and Safety Executive has undertaken an investigation of the accident.

For new multi-storey car park construction, Part K of the current Building Regulations(81) includes structural requirements for edge barriers. These do not apply to existing car parks, of which more than 4000 are estimated to be in use. For these structures, there are relevant provisions in the Health and Safety at Work etc. Act 1974(82) and the Occupiers Liability Act 1957(83).

The Health and Safety at Work etc. Act 1974(82) is concerned principally with people at work, and has an absolute requirement to ensure "the safety of various groups of persons regardless". Further, car park operators are obligated to their employees by virtue of Section 2 of the Act and to any person who is not their employee by virtue of Section 3. The former states that "it shall be the duty of every employer to ensure so far as is reasonably practicable, the health, safety and welfare at work of all his employees" and the latter states that "it shall be the duty of every employer to conduct his undertaking in such a way as to ensure so far as is reasonably practicable that persons not in his employment are not thereby exposed to risks to their health and safety".

In addition to the Health and Safety at Work etc. Act 1974, all premises are subject to the Occupiers Liability Act, 1957(83). Under the provisions of this Act, the occupier of premises has placed upon them a duty of care to ensure that the premises are reasonably safe for use by lawful visitors for the purpose for which they are permitted to enter the premises.

The Building Act 1984(84) is potentially relevant. Under this Act, a Local Authority has power to intervene under Section 76 if the premises are in a defective state or, under Section 77, if the building is in a dangerous condition or is used to carry such loads as to be dangerous. It seems doubtful, however, in the absence of legislative clarification, that either Section could be used in regard to edge barriers of an existing structure that might fail under accidental impact loadings.

In summary, it appears that car park owners and operators are obligated under law to provide and maintain car parks that are safe for their employees and users. However, SCOSS cannot be certain that there is no gap in the regulatory framework relating to the safety of existing multi-storey car park structures and suggests that the framework be reviewed.

While life-threatening accidents involving multi-storey car parks may be considered to be acceptably rare, the frequency and severity of accidents involving structural inadequacy will increase unless action is taken. The primary focus for action should be car park owners and operators.

The accident at Canterbury alerted SCOSS to the fact that many car park owners had not acted upon the recommendations in the Tenth SCOSS Report. They are therefore repeated here in modified form:

Recommendation:

Owners and operators of existing multi-storey car parks should commission inspections and structural appraisals of their structures by engineers with appropriate experience before carrying out repairs. Appraisal should extend beyond the areas of conspicuous deterioration, particularly where water with road salt may have penetrated. Such appraisals should be made periodically following the principles adopted by bridge owners. Structural appraisal should include a review of resistance to progressive collapse.

Recommendation:

Owners and operators of existing multi-storey car parks should:

- establish whether the strength of edge barriers is adequate to restrain vehicles,
- establish whether the height and design of edge barriers are appropriate to safeguard small children,
- modify, strengthen or replace inadequate edge barriers.
SCOSS welcomes the initiative by the Institution of Structural Engineers to revise the report Design recommendations for multi-storey and underground car parks (85).

For evaluation of existing edge barriers, criteria and methods need to be established and agreed, and options for remedial action defined quickly. Some forms of metal edge barrier are susceptible to brittle failure on impact and need to be replaced or strengthened to ensure a ductile mode of failure at a higher load. The fixings can be particularly vulnerable.

Recommendation:

The Institutions of Civil and of Structural Engineers should urgently prepare guidance on assessment and strengthening of existing edge barriers in multi-storey car parks.

References, Section 5.1


5.2 Post-tensioned concrete bridges

Since 1979, most biennial SCOSS reports have expressed concern about the safety and durability of post-tensioned concrete bridges. Initially, in 1979, SCOSS concluded that, though there was doubt about the effectiveness of injected cement grout to provide bond between the tendons and the structure and to inhibit tendon corrosion, the complete filling of ducts with grout, although desirable, was not essential. In the post-tensioned bridges considered, the risk of sufficient tendons failing by corrosion at any time to cause sudden collapse was considered small. It was recommended that work to improve grouting materials and techniques and to develop non-destructive and other forms of test for monitoring purposes should be undertaken.

As more evidence accumulated, it gradually became apparent that the 1979 conclusions were optimistic. A number of bridges, e.g. Angel Road Bridge on the North Circular Road in London (1980), Taf Fawr Bridges in Methyr Tydfil (1982), Folly New Bridge in Oxfordshire (1988), Blackburn Road Bridge on the M1 in Sheffield (1990), and Botley Road Flyover in Oxfordshire (1992), were found to have tendons corroded or broken following corrosion. Abroad, similar conditions were found, and the Melle bridge, constructed in Belgium during the 1950s, collapsed in 1992 due to failure of post-tensioned tie-down members following tendon corrosion. The collapse without warning of the Ynys-y-Gwas road bridge in West Glamorgan in 1985 due to corrosion of the tendons at the segmental joints, in particular, led to increased concern about the risk of tendon corrosion, the adverse effects of chlorides and the need to improve methods of detecting corrosion and to provide effective methods of corrosion prevention.

The lack of warning of reduced safety due to tendon corrosion was perhaps the most disturbing feature of this experience. SCOSS noted in 1992 that, despite substantial efforts by the Transport Research Laboratory (TRL) with the support of the Department of Transport, the problems of achieving effective grouting and of determining the condition of tendons in existing post-tensioned construction had not been overcome. A recommendation was made that alternative stressing methods which avoided the need for grouting tendons should be investigated. Attention was drawn to the potential contribution that developments of non-ferrous tendons and of optical fibres and ‘smart’ structures might be able to make. The Department of Transport temporarily ceased to commission the construction of grouted post-tensioned concrete bridges at about the same time (86). The Department encouraged the use of external unbonded tendons and published design recommendations for this form of construction (87).

In 1992, SCOSS did not rule out improvement of the existing technology, but believed this did not appear to be a promising route for the future. Two features of the existing technology led to this view. The first was the perceived difficulty of improving the technique so that protection of the steel tendons would be reliably achieved by full grouting of voids. Experimental work showed that a way had not been found to achieve the desired reliability. Indeed the evidence suggested that the technology current at the time was quite resistant to giving the desired result. Modifications usually did not bring improvement and, in addition, the process appeared to be very sensitive to small deviations from specification of materials and process.

The second feature concerned the methods available to check that the tendon protection (grouting) was totally so at 9958. The concerns of such a system were that the tendons were not deteriorating sound when construction had been completed and, subsequently, that the tendons were not deteriorating from local corrosion. Success in developing such methods with the required level of discrimination and reliability had been elusive. It was felt that, without such methods, it was not possible to provide the required assurance of tendon and grouting integrity and thus of the safety of the structure at the construction stage and later during the service life.

Taking the conclusions on these two features together led to SCOSS’s view that the necessary improvement to the reliability of internal grouted post-tensioned construction had yet to be achieved.
A full-scale post-tensioned concrete bridge beam 60 m long was constructed for grouting trials which formed the basis of new guidance. (Photo: Transport Research Laboratory)

The United Kingdom concrete bridge industry responded to this challenge while recognising that improvements were necessary in design, materials and construction. A working party was set up jointly by The Concrete Society and Concrete Bridge Development Group to tackle the problem. An Interim Technical Report was published in 1995 and a Final Report was published in September 1996 following four years of research, full-scale trials, and development work on novel test equipment to measure the efficacy of grouting. A 'multi-layer protection' approach has been recommended by the working party that embodies design concept and detail and improved material specifications, including a switch to plastic materials for ducts and the development of a special pre-packed grout. Particular attention was given to operations on site and a third party certification scheme was developed, with the emphasis on method statements and operative training. The core recommendations are intended to be followed as a total quality package but to allow for future developments, especially of test methods.

SCOSS recommended in 1992 the introduction of a stringent regime of inspection of existing post-tensioned concrete structures. The Highways Agency issued advice and held a series of seminars in 1994/95 on inspection procedures for post-tensioned bridges, which were attended by approximately 1000 engineers. A substantial programme of special inspections has followed. A complex picture of the condition of tendons and overall structural condition is building up. It is too early yet to draw general conclusions but it can be noted that the post-tensioning in about 75% of the bridges inspected so far has been found to be in good condition and significant defects have been found only in a small number of these bridges. Further seminars are planned by the Highways Agency to disseminate information gathered during this programme of special bridge inspections.

SCOSS is pleased to note the whole-hearted response of the Highways Agency, local authorities, the concrete bridge industry and others to its concerns. The new standards and practices for grouted post-tensioned bridges represent a substantial improvement on past practice and have led to removal of the ban on this form of construction by the Highways Agency. Their implementation, under controlled conditions as a quality system, should allow greater confidence in future in this form of construction and provide a platform for further developments in the sealing of ducts and anchorages and in the refinement of test methods which have been developed by the working party.

Concluding comment:

A substantial programme of collaborative work by the concrete bridge industry and others has now established the principles for satisfactory construction of post-tensioned concrete bridges, including improvement of the design concept, development of improved grouting materials, procedures and specifications, and use of the UK Certification Scheme for Reinforcing Steel (CARES) quality assurance system for post-tensioning operations.

References, Section 5.2


5.3 Bridge assessment and strengthening

Highway bridges

The 15-year Bridge Rehabilitation Programme for trunk roads in the United Kingdom, launched in 1988, has continued[89]. Highway bridge assessment and strengthening are taking account of the predicted effects of increased maximum permitted lorry weights from 1999 under new EU Directives for international transport. By March 1995 more than 420 bridges had been strengthened, leaving a further 812 to be upgraded, according to the survey reported by the National Audit Office in March 1996[94]. Concern was expressed in the report that the programme is going more slowly than planned, and that road bridges are deteriorating faster than maintenance work is restoring their condition. SC OSS is concerned that, if this situation is allowed to continue, an unacceptable risk to structural safety will arise.

SC OSS has noted that the Highways Agency has put in place an extensive programme of research and development to review assessment rules in order to avoid as far as possible any unnecessary strengthening or repair of bridges[93].

Concerns of owners and operators of major bridges that advice on the use of bridge access gantries was diffuse with adverse implications for safety has led to the preparation of a guide by a Task Group of the Institution of Structural Engineers[95].

Rail bridges

Public concern about the condition of the Forth Rail Bridge during 1995 led to the Health and Safety Executive requiring Railtrack to carry out a rigorous assessment of its structural integrity[96]. SC OSS noted that the assessment method included the use a British Standard for the design of new bridges, a draft Department of Transport standard and techniques introduced by the main consultant, no comprehensive guidance for the assessment of existing rail bridges being available. The report of the assessment revealed deterioration of parts of the bridge but concluded that it was safe in its current condition to carry the present loading and that its structural integrity had not been compromised. The deterioration which had been allowed to occur had led to corroded and damaged steel sections and malfunctioning bearings. The bridge is over 100 years old and its continuing performance in the face of this deterioration is a tribute to the robustness of the original design. SC OSS is pleased to note that the deterioration of this historic structure is to be rectified by targeted restoration, repair and maintenance and through monitoring of condition. It is especially important that early access to the whole structure is achieved so that inspection and maintenance are facilitated.

The strategic objectives of the 1995/96 Railway Group Safety Plan[97] included the reform of Railway Group Standards to produce a minimum number of high-level risk-based standards of greatly reduced prescriptive content. The 1996/97 Plan[98] reported the intention of reducing the number of standards to 500 by April 1996, with many existing detailed standards devolved to the line management. Both the high-level and detailed standards have a role in the achievement of structural safety.

Railtrack is required to adopt the relevant high level standards for railway bridges and other structures. Railway Group Standards, the high-level standards, are produced by the Safety and Standards Directorate of Railtrack and are subject to a consultation process with the railway industry and the Health and Safety Executive's Railway Inspectorate[99]. The Standards are listed in a published catalogue[100] and copies may be purchased including those relating to design and assessment of rail bridges and other structures. They are therefore readily available for comparison with standards in related fields and for open peer review. The detailed standards, however, do not appear to be defined in the same way leaving scope for individual Railtrack zones to use different standards with a possibility, as a result, of using out-of-date or inconsistent detailed safety assessment methods.

Current standards for structural design and structural assessment have been derived from earlier documents originating from British Rail. It is important that these standards, both high-level and detailed, are up-to-date. The design standard used by Railtrack requires compliance with current British Standards and other guidance, but its assessment standard is based on permissible stresses rather than a modern limit state basis. Railtrack has commissioned an in-depth critique of this assessment standard and is now considering further action which may be needed to improve its assessment methods. Privatisation of British Rail increases the possibility of demand for higher rail traffic loadings. It is essential that up-to-date assessment standards for existing railway structures are available to enable evaluation of safe load-carrying capacity.
Concluding comment on highway and rail bridges:
Road (and possibly rail) bridges in the United Kingdom will be required to carry increased loads in the near future. Current assessment rules for highway bridges are being reviewed by the Highways Agency against the requirement to maintain safety with the aim of avoiding as far as possible any unnecessary strengthening and repair. For rail bridges, better up-to-date standards, both high-level and detailed, are required for structural assessment.

References, Section 5.3
95. Institution of Structural Engineers. The operation and maintenance of bridge access gantries and runways. London, September 1996. 54 pp.

5.4 Bridge strikes
Bridge strikes, i.e. accidental impacts of road vehicles (often called 'bridge bashing'), are the commonest form of accidental impact on bridges. Other forms of bridge strike which arise from time to time are impacts from trains or ships101. Worldwide, accidental impact is one of the major causes of bridge collapse, the other being scour and flood damage102 – see Section 5.5.

Road vehicle strikes on rail bridges are reported to have increased steadily over recent years. This trend is believed to be due to increased public awareness following publicity campaigns by the Department of Transport, Railtrack and the Associations of County Councils and of District Councils since the numbers of serious or potentially serious strikes has remained about constant over the last ten years.

A working party of the relevant organisations – Department of Transport, Railtrack, HSE's Railway Inspectorate, London Underground, the Associations of County Councils and of District Councils and industry associations – has continued to pursue actions to reduce the risks of bridge strikes:
• A quantified risk assessment system is now available which is reported to show the risks to be less than previously thought. This finding arises primarily because bridges on high speed lines tend to be more robust and heavier while the more easily dislodged bridges are on lightly used or low speed lines.

• A bridge strike impact detector has been developed and a prototype is undergoing trials on a bridge in service.

• The effectiveness of road signs and markings in giving warning of low headroom available at a bridge is being evaluated. Factors being assessed include type, positioning, shape and colour of signs.

• The most frequently struck bridges have been identified and, during 1996/97, a study of them is proposed to investigate further the reasons for strikes.

• Further publicity has been given to bridge strikes. A new edition of the Automobile Association Trucker’s Atlas, a new leaflet Commercial Vehicle Drivers – Know Your Traffic Signs and a booklet Know your Traffic Signs have been published. All these publications include sections on low bridges and bridge strikes.

These positive steps to reduce the risks are welcomed. However, the revision of the Roads Vehicles (Construction and Use) Regulations requiring ‘in-cab’ signs has not been enacted and it is reported that lack of local authority finance is preventing the introduction of traffic management and other measures at some sites of high risk. The resulting delays are a matter of concern.

Concluding comment:

Actions to reduce the risks of accidental impact on bridges in the United Kingdom are progressing but delays in introducing traffic management or other measures at some high-risk sites and in enacting the ‘height-in-cab’ legislation are a matter of concern.

References, Section 5.4

101. Larsen O. D. Ship collision with bridges, the interaction between vessel traffic and bridge structures. Zurich, International Association for Bridge and Structural Engineering, 1993. 132 pp.


104. Commercial Vehicle Drivers – Know Your Traffic Signs.


5.5 Scour and flood damage to bridges

The most common cause of highway bridge failure is reported to be due to adverse hydraulic action. Damage may result from scour of foundations, bank erosion, hydraulic forces on piers or bridge deck, debris built up against the bridge structure or ice forces.

Among these hazards, scour is perhaps the most difficult to predict and guard against. A scour risk assessment technique is now in use by Railtrack for rail bridges which is being further developed to enable critical aspects to be identified.

A key element in gaining warning of an increasing risk is knowledge of conditions under water. For this purpose, Railtrack requirements for routine examination of bridge structures with underwater parts have been strengthened, following the recommendation in the Tenth SCOSS Report, to include logging of any changes in the local regime. At the same time sonar gauges have been installed on some 30 bridges to evaluate their effectiveness for detecting increasing scour. In addition, at each bridge site considered at risk, local instructions are now in place defining action to be taken when certain predetermined criteria are met. The use of impulse sub-surface radar to detect the presence of scour holes in river beds is showing promise and the Highways Agency is supporting continuing research to evaluate the technique.

A task group of the Institution of Structural Engineers is preparing guidance on underwater inspection of structures, which will include advice relevant to some aspects of the problem.

For highway bridges, the Highways Agency has issued an Advice Note for design of highway bridges for hydraulic action and is preparing further advice on the management of bridges subjected to scour.

Recommendation:

A continuing collaboration between the Highways Agency, Railtrack, and other owners of bridges over water, possibly under the aegis of the Institution of Civil Engineers, should be established to keep flood damage to bridges under review and to develop consistent best practice.

References, Section 5.5


5.6 Tunnels during construction

Collapses of tunnels being constructed using tunnel boring machines were reported from Los Angeles\(^{(110)}\) and Athens\(^{(111)}\).

Within the United Kingdom, a serious tunnel collapse occurred at Heathrow Airport on 20 October 1994\(^{(112)}\) where the Heathrow Express rail station tunnel was being constructed using a sprayed concrete tunnel construction technique known as the New Austrian Tunnelling Method (NATM). This incident prompted close scrutiny of tunnelling work in progress at that time on the Jubilee Line underground extension in central London, which was using the same construction method. After investigation, work resumed on these tunnels. Another collapse of a NATM tunnel occurred in Munich at about the same time\(^{(113)}\).

As a result of the collapse at Heathrow, the Health and Safety Executive published a report on the safety of NATM tunnels\(^{(114)}\), which revealed that over 100 incidents had occurred during tunnel construction in the 30 years that the technique has been used, with more collapses known to have occurred but not to have been reported. SC OSS believes that an earlier collation of this worldwide experience might have led to the prevention of the Heathrow and other recent collapses.

Numerous detailed technical recommendations were made in the HSE Report with the aim of defining procedures for safe design and construction using the technique. Other reports were produced by HSE\(^{(115)}\) and by the Institution of Civil Engineers\(^{(116)}\) as a result of the collapse, which will help to provide a stronger basis for future safe use of the technique.

Concluding comment:

The recent experience with the New Austrian Tunnelling Method in the United Kingdom illustrates that gathering information on trends in the use of techniques in construction on a worldwide basis can provide valuable indicators for safety.

References, Section 5.6

6 Other structures, components and materials

6.1 Pin connections in bridges and building structures

Pin connections have, for many years, been a structural feature sometimes used to implement the concept of steel bridges. Such connections are being used increasingly today in building structures particularly in roof structures, e.g. sports stadia. Articulating structures using pins are also common, e.g. link spans to berthed ships. Arrangements of rods, cables and turnbuckles to support building elements are often a feature of modern architecture and use a similar concept of pin connection. These arrangements however, may have no articulation function and no rotation may be required at connections.

Experience of the use of pin connections is perhaps greatest in machinery, particularly cranes, excavators and other construction plant, where substantial articulation at the connections is a requirement of the function of the machine. Movable bridges and RO-RO linkspans also use pin connections to permit articulation at main pivot and counterbalance pivot joints. Apart from lifting bridges, pin connections in bridges and buildings are often required only to allow limited rotation. They provide a convenient means of joining members. An additional function is to enable the transfer of direct forces normal to the pin axis but not moment through the connection about the pin axis. Suspension and cable-stayed bridge structures have pin connections at the ends of the hangers or stays to prevent moments being induced at the ends. Lifting beams used during construction of bridges and buildings are often attached to lifting slings and shackles through pins, again to ensure moments are not induced during lifting at points in the beam where they have not been allowed for. Pins are sometimes used to locate bearings and transmit shear.

A number of collapses have occurred in recent years of structures incorporating pin connections. Notable examples are:

- Queenhill Bridge, Tewkesbury, February 1992. Failure in hanger at pins[118].
- Ramsgate, Kent, September 1994. A steel pedestrian bridge connecting the ferry terminal building to the ferry collapsed, killing six passengers. Failure of a single connection incorporating a pin led to the collapse of the 35-m span weighing 60 tona[119].
- Songsu Bridge, Seoul, Korea, October 1994. A 48-m span of the bridge collapsed during the morning rush hour and 32 people died, many of whom were in a bus on the bridge at the time[120]. The 1062-m span bridge was constructed in 1979 with a reinforced concrete deck supported on a series of steel lattice girder trusses. Cantilever trusses supported central spans, suspended from the cantilevers which were supported on reinforced concrete piers at 120-m centres. Fatigue loading had not been considered in its design. Doubts had been expressed about the safety of the bridge and possible problems had been identified. Actual traffic loading was much higher.

A ferry links pan at Ramsgate, Kent collapsed in September 1994, killing six passengers. (Photo: Institution of Civil Engineers)
than in the original design, and the weight limit of 32 tons was often exceeded, with 60-ton lorries known to be using the bridge. More than 130,000 vehicles crossed the bridge daily. Failure was due to fatigue of the connecting members between the cantilevers and the suspended span. Inadequate detailing of welded connections and welding defects also contributed.

- Holyhead, Anglesey, October 1995. A 500-ton roll-on, roll-off ramp collapsed during construction when temporary ties restraining the 35-m ramp gave way, and a buoyancy tank overturned before pins were inserted.\(^{121}\)

Recently concerns among engineers have come to light relating to the use and detailing of pins in bridges and buildings. Aspects that are reported often not to be considered adequately during detailing include:

- The effect of corrosion and the facilities provided for lubrication. Although not typical of steel structures generally, the adverse effects on pin joints and bearings of the Forth Rail Bridge arising from lack of maintenance and facilities for lubrication have recently been described.\(^{122}\)
- The facilities provided to stop the pin working loose axially.
- Bending moments induced in the pin. This has been a problem in some suspension bridges and still causes adverse effects such as fatigue of coatings leading to water penetration and corrosion of the component.
- The facilities provided to allow the pins to be removed and inspected/replaced and checked for condition – especially where the pin has a change in section or a keyway.
- The design of pin plates and the transfer of forces into the structure is sometimes not correctly carried out.

Guidance on the design of pin connections in steel structures is given in BS 5400, BS 5950 and Eurocode 3.\(^{125}\) The guidance concentrates on the design of the pin and the immediate steel geometry of the connection itself. For connections requiring rotation, Eurocode 3 is in general more conservative than BS 5400 and BS 5950. For connections not requiring rotation, Eurocode 3 results in pin plates of different dimensions compared to design to BS 5950.

While these documents are different in detail and consistency of their rules is desirable, both give guidance for the strength design of pin connections against potential failure modes of shear or bending of the pin or of tension or bearing in the connected member. However, available guidance is considered deficient in relation to design against fatigue and pins becoming disengaged. In addition, guidance on provisions for inspection, maintenance including lubrication and repair is insufficient. Practice in these respects is well established for articulating pin connections in machinery but a comparable situation does not obtain in the structural engineering of bridges and buildings. For roll-on/roll-off ramps and ship to shore links, the British Standards Institution has recently agreed to start preparation of a new code of practice on design, maintenance and safety. This code, which will become a part of BS6349: Maritime Structures, may help to establish sound practice in this area.

Inadequate design sometimes arises also because detailing around the pin hole and of the pin and its means of inspection and retention are not completed by a suitably qualified and experienced person. Inappropriate delegation of responsibility for the design of the connection can lead to inadequate design expertise being brought to bear.

Pin connections in articulating structures such as RO-RO link spans and in many other structures are generally crucial to the safety of the structure. No redundancy or alternative load path is available should the connection or the structure immediately around it fail. At design concept stage the performance requirement of the structure should be examined to see whether the hazard of collapse following pin connection failure could be avoided entirely by providing a structural arrangement with alternative load paths. This is not always possible. Very careful attention is then necessary to the design, detailing, installation and inspection/maintenance provisions of the pin connection.

Recommendation:
The Steel Construction Institute in collaboration with the British Standards Institution should review guidance on the design, inspection and maintenance of pin connections in bridges and buildings.

Recommendation:
The design of pin connections should be overseen by suitably experienced engineers who are responsible for design, detailing, installation, inspection and maintenance.

References, Section 6.1

121. Retrieval under way for collapsed linkspan. New Civil Engineer, 12 October 1995; Stena orders review of linkspan design. ibid. 16 November 1995.
6.2 Cladding and glazing
Since 1977 SC OSS reports have noted a history of cladding failures and have drawn attention to aspects of the structural safety of cladding:

- Designs of cladding systems have not always received sufficient structural engineering input.
- Cladding systems have often been made with insufficient provision for movement.
- The quality of cladding and fixings has not always been adequately inspected during construction or maintained in service.
- Fixings concealed during erection have often been subject to premature deterioration due to an aggressive environment for which they were not suited.

In 1992, SC OSS recommended monitoring of innovative cladding systems and in 1994, periodical checking of cladding relying solely on adhesive systems for structural support and resistance against wind and thermal action was also recommended. This was to enable early identification of any loss of safety of fixings and feedback of information to help eliminate structural and serviceability problems in the future. The extension of the Building Regulations(127) to control the structural safety of wall cladding was welcomed. Further extension to include major structural repairs/replacement to building cladding was recommended. New guidance on aspects of cladding has been prepared by a Task Group set up by the Institution of Structural Engineers. Their report Aspects of cladding was published in October 1995(128). The Institution of Civil Engineers held an informal discussion on design of cladding systems based on this report in November 1995 and the Institution of Structural Engineers is planning a seminar on structural aspects of cladding in March 1997.

SC OSS has received few reports of unsatisfactory performance of claddings during the last two years. It is hoped that the incidence of unsatisfactory performance of cladding due, for example, to specification of components and materials which cannot be assembled satisfactorily and lack of dimensional surveys of the structure before installation, is diminishing as a result of a growing awareness of the importance of the physical and contractual interactions in facade engineering.

Following a recommendation made in the Tenth SC OSS Report in 1994, a task group of the Institution of Structural Engineers has been set up to prepare guidance on the structural design of glass facade and roof systems. This is part funded by the Department of the Environment under the Partners in Technology scheme. Of related interest are the paper by Sedlacek et al.129 and the English edition of the book Structural Glass by Peter Rice and Hugh Dutton(130).

Following the bombs in the City of London in 1992 and 1993 and London Docklands in 1996, which caused extensive damage to claddings, rebuilding and repair has involved the replacement of cladding systems in several cases. No difficulty has been reported in controlling this replacement work under Part A of the Building Regulations. Clearly so much repair and replacement work was required that control as for the erection of a new building was accepted. This situation is in contrast to the concerns expressed in the Ninth SC OSS Report relating to the structurally inadequate replacement or refixing of cladding and the recommendation that major structural repairs of cladding should be subject to control.

The requirements for the control of design and installation of cladding on tall buildings are wider in some other countries than those in the United Kingdom. For example, in New York specific rules and regulations exist for the design and installation of curtain wall and panel wall (non-loadbearing external wall) systems which extend more than 40 ft above the ground. These regulations include controls on alterations to existing wall systems. There are also requirements for periodic inspection of exterior walls and appurtenances at least once every five years where the buildings are more than 25 feet high. The inspections are part of preventive action required to maintain safe conditions.

Concluding comment:
Few reports of unsatisfactory performance of claddings have been received over the past two years. Guidance prepared by the Institution of Structural Engineers should contribute towards a further improving record.

References, Section 6.2

6.3 Air-supported and fabric structures
The construction of air-supported structures is a very small industry in the United Kingdom. They are subject to control under Building Regulations in Scotland(131) and Northern Ireland(132). However, in England and in Wales(133), local authority policies differ over whether or not they should be regarded as a form of temporary
structure. This variation in their treatment can lead to confusion and a coherent policy is desirable.

Guidance on design, construction and maintenance of single-skin air-supported structure is contained in British Standard BS 6661:1986(135). The withdrawal of this British Standard was recommended in both the Ninth and Tenth SCOSS Reports because it is known to give misleading results in some respects relating to structural design. In the light of this knowledge SCOSS remains concerned that BS 6661 remains on sale and available to engineers and designers who may not be aware of its shortcomings. BSI has expressed a view that a replacement should exist before BS 6661 is withdrawn, but no organisations have been willing to undertake the preparation of a replacement. Although the problems with the existing standard are well-known(135) there is no consensus on the scope of a new standard. SCOSS considers that the present standard should be withdrawn even if a replacement is not yet available.

Recommendation:
The British Standards Institution should withdraw BS 6661: 1986 Guide for the design, construction and maintenance of single-skin air-supported structures.

A standard on air-supported structures has been prepared by the American Society of Civil Engineers(136) but it is not easily applicable in the United Kingdom. A German standard, DIN 4134(137), exists but this too is not easily applicable, and some aspects are not considered entirely satisfactory. For tents and marquees some general guidance may be found in a recent report published by the Institution of Structural Engineers(138). There is therefore no up-to-date detailed guidance on the design, construction and maintenance of air-supported and fabric structures generally in the United Kingdom or Europe as a whole. Consequently, local authority building control and fire officers have difficulty in applying consistent standards in their assessment of proposed structures. In view of the previously reported failures and the potential risks to life, practical guidance is needed. The guidance should be European in character as the design, manufacture and construction of these structures often involves international collaboration.

Recommendation:
The Institutions of Civil and of Structural Engineers in collaboration with industry should prepare guidance on the design, specification, construction and use of air-supported and fabric structures.

References, Section 6.3
137. DIN 4134. Air-supported structures: structural design, construction and operation. 1983. (In German.)

6.4 Design against fatigue in steel structures
Several different standards and codes of practice exist for design against fatigue in steel structures. These include:

- BS 2573, Rules for the design of cranes(139)
- BS 5400: Part 10, Code of practice for design of bridge bearings(140)
- BS 7608, Code of practice for fatigue design and assessment of steel structures(141)
- BS 6235, Code of practice for fixed offshore structures (now withdrawn)(142)
- Offshore Installations Guidance, Offshore structures (Department of Energy: 1990)(143)
- Offshore Installations Guidance, Offshore structures (Health & Safety Executive: amendment No. 3: 1995)(144)
- ECCS No. 43, 1985, Recommendations for the fatigue design of steel structures(148)

BS 2573(139), and the 1972 edition of BS 153 (Specification for steel girder bridges – now withdrawn, but still used for the assessment of rail bridges)(149) were both based on test results for relatively small specimens. More recent work, using larger specimens and therefore containing more realistic residual stresses, provided the basis for the continuing development of the later codes.

As a result two quite different methods of design are currently in use and they usually give different answers. In BS 2573(139) the maximum allowable fatigue stress for a defined number of stress cycles (life) depends upon the detail class and the ratio between the minimum and maximum stress levels in the cycle. In other codes, however, fatigue strength is defined by the allowable stress range for the detail class and required life, regardless of the stress ratio. This is a result of taking the presence of welding residual stresses into account.
BS 5400\(^{(140)}\) gives rules which are coupled with the relevant fatigue loading for bridges.

BS 7608\(^{(41)}\) is a general code that can be applied to any type of steel structure. It could be used to design bridges since the two sets of rules are virtually identical although first, it would be necessary to define separately the loading rules incorporated within BS 5400 and derive the requisite load spectra for fatigue design.

The emerging Eurocodes also give fatigue load and design rules. Eurocode 1: Part 3\(^{(46)}\) provides fatigue load models of vertical forces produced by road and rail traffic on bridges for use in design to rules in Eurocodes 2 to 4. Eurocode 3: Part 2\(^{(47)}\), now being drafted, will provide rules for design against fatigue in steel bridges.

Bridges, cranes and offshore structures are by no means the only types of structure which are liable to suffer fatigue failure. Historically there has been a tendency in the United Kingdom to use BS 153 bridge fatigue rules for designing this range of structures although BS 5400 is now used for bridges. BS 7608 could also be used instead. BS 7608 appears to be an appropriate code for design against fatigue in general, although it lacks information on the fatigue behaviour of tubular joints and corrosion fatigue.

SCOSS questions, as part of the concern already discussed in Section 1.4, the need for so many codes covering the fatigue of steel structures. The plethora of code documents covering this subject but yielding different results could conceivably lead to confusion and possibly impaired safety. A strategy is needed for convergence towards one compatible set of fatigue design rules and the withdrawal of out-of-date or competing codes. The development of European standardisation, particularly Eurocode 1: Basis of design and actions on structures, and Eurocode 3: Design of steel structures, offers the best way forward. This view recognises the continuing dedicated effort that will be needed to influence the present Eurocode drafts towards providing practical rules which do not give overconservative designs.

**Recommendation:**

The Institutions of Civil and of Structural Engineers and the British Standards Institution should undertake a review, from a safety standpoint, of standards and codes of practice relating to design against fatigue in steel structures as a basis for achieving convergence towards a compatible set of fatigue rules, taking into account the commitment to the development of the CEN Structural Eurocodes.

**References, Section 6.4**


**6.5 Hidden tension members**

The potential for hidden tension members in bridges and buildings to present an increasing risk to safety over time was highlighted in the Tenth SCOSS Report. For existing highway bridges, Highways Agency advice\(^{(150)}\) automatically requires bridges with post-tensioned tie-down supports to be assigned the highest priority rating irrespective of the amount of traffic carried.

The number of structures with hidden tension members is relatively small and includes portal structures tied below ground level. It is vital for these structures that their reliance on hidden tension members is recorded and remains known to those with responsibility for their structural safety. This should happen more readily in the future for new structures as the CDM Regulations require that drawings are lodged in the health and safety file for the structure.

**Concluding comment:**

Continuing vigilance is needed to ensure that bridges and buildings with hidden tension members remain safe.

**References, Section 6.5**


**6.6 Washwater systems**

The Ninth SCOSS Report questioned the growing use of washwater systems for washing the drums of concrete mixers and suggested use should not continue until the results of research is known. The results of research by the British Board of Agrément became known during 1994 and led to the issue of Agrément certificates for two particular washwater systems. SCOSS is pleased to note that the questions it raised have been satisfactorily answered for washwater systems with current Agrément certificates. A CEN standard for mixing water and for
reuse of washwater is in preparation that should give further assurance in the use of this technology\(^{(151)}\).

**Concluding comment:**

The questions raised in the Ninth SCOSS Report on the use of super-retarder treatments of washwater in concrete mixers have been satisfactorily answered.

**References, Section 6.6**


**6.7 Freestanding masonry walls**

Freestanding masonry walls were discussed in the Ninth SCOSS Report in 1992. Recommendations were made that such walls should be included in the brief of building surveys when properties change hands, and failures should be monitored to assess whether BRE guidance published in 1992\(^{(152)}\) had improved performance. Since then, BRE has extended its guidance on freestanding walls by publishing two further Good Building Guides on repairs to cappings and copings, and on building reinforced diaphragm walls\(^{(154, 155)}\). A related publication on domestic earth-retaining structures is due for publication\(^{(156)}\).

The Department of the Environment has decided not to bring freestanding walls within the scope of the Building Regulations. The Brick Development Association guidance on freestanding walls continues to provide detailed guidance on the subject\(^{(157, 158)}\) and a leaflet\(^{(159)}\) giving simple guidance on the assessment of existing walls has been made widely available through libraries, citizens' advice bureaux and DIY retailers.

Since July 1993, the National House Building Council's technical performance standards for the design of freestanding walls have recognised the BDA Design Guides as meeting the required standards. Work is underway to revise the BDA Design Guide to take account of changes in the new building regulations, materials specifications and the wind loading code BS 6399: Part 2\(^{(160)}\). Wind design pressures for freestanding walls have generally increased in the new code over those in CP3 which it replaces. A new United Kingdom wind zoning map to allow simplified design guidance to take account of the new code may be needed.

It can be seen that clear guidance is now readily available on designing and building freestanding walls. Yet incidences of collapses have continued to occur especially where walls have not been structurally designed, but where they have been built by local builders or householders, often with excessive height to thickness proportions and without adequate piers, buttressing or reinforcing. Of particular concern is the danger to children of small under-designed walls close to housing. Children tend to play around, climb on and impact on walls. Often a simple tie from a dwarf wall to an adjacent house wall would prevent a serious injury or tragic death from collapsing masonry. Such events are fairly rare but claim one or two lives each year.

The Building Research Establishment collects information on failures of freestanding walls. The details recorded include date of incident, location and wall dimensions and age. This data relates to reported accidents and does not allow estimation of the effects on the incidence of failures due to the availability of guidance. Nevertheless, it gives a valuable indication of trends in the safety of freestanding walls.

**Concluding comment:**

Guidance on the design and construction of freestanding walls is now readily available and will encourage safer construction.

**References, Section 6.7**


**6.8 Structural use of adhesives**

SCOSS is pleased to note that, following the recommendations in its Tenth Report, the Institution of Structural Engineers has set up a Task Group to produce a best practice guide to the structural use of adhesives. This will cover their use both in repair and in new construction. The work is partly funded by the Department of the Environment under the Partners in Technology scheme. The Task Group members are drawn from the professions, the Health and Safety Executive and the Building Research Establishment.
6.9 Seismic resistance of structures

The severity of earthquakes in the United Kingdom is generally less than in some other parts of the world, e.g. California, and design specifically for earthquake resistance is not necessary for most structures. It is, however, a requirement for the design of some major and special structures.

Earthquakes provide information on the behaviour of large numbers of full-sized structures under extreme conditions which cannot be obtained by any other means. The work of groups such as the Earthquake Engineering Field Investigation Team (EEFIT) and the Earthquake Field Training Unit (EFTU) are valuable in gathering and disseminating first-hand practical information on the effects of particular earthquakes.

Two major earthquakes occurred during the period under review, at Northridge, California, in January 1994, and Kobe, Japan, in January 1995. These tragic events indicated that steel buildings are more vulnerable to seismic action than had been previously assumed.

- At Northridge, 61 people were killed in the earthquake which had a magnitude of 6.7. The cost of the damage to property and freeways has been estimated as 20 billion dollars. In more than 100 steel moment frame buildings, cracks occurred in the beam–column connections, and subsequently, the standard connection detail, used in California since the 1970s, was shown to be unsatisfactory

- At Kobe, more than 5500 people died in the earthquake which had a magnitude of 7.2, and large areas of the city were devastated. Many older low-rise buildings collapsed. Sections of the Hanshin Expressway, an elevated highway constructed of a line of reinforced concrete columns supporting a concrete deck, tipped over. More recent structures generally performed well but, as at Northridge, fractures occurred in a number of modern steel structures.

Considerable debate between researchers and designers in different parts of the world continues about the most effective approaches to seismic-resistant design and different philosophies are adopted in the light of local tradition. The level of damage in the Northridge and Kobe earthquakes had a strong positive correlation with date of construction showing that modern seismic design is heading in the right direction.

Among other developments, the European prestandard Eurocode 8, Design provisions for earthquake resistance of structures, has been issued. Development of new techniques is continuing, including isolating structures from the effects of earthquakes.

Concluding comment:

Structures of modern seismic design have improved seismic resistance but more work is needed to mitigate the effects of earthquakes on communities.

References, Section 6.9


6.10 Cranes

SCROSS is pleased to note that, following the recommendations in its Ninth and Tenth Reports, a guide on stability of cranes on site has been prepared by the Construction Industry Research and Information Association (CIRIA). 169

References, Section 6.10

The SCOSS 1996/97 business plan, which is used to improve targeting of effort onto priorities and to assist in the more effective use of limited resources, identifies the following key items of work and new initiatives:

**Output**
- Publish other papers relating to topics in Eleventh Report as effort is available.

**Other output**
- Maintain regular liaison with the Institutions of Civil and of Structural Engineers, HSE, DOE, DOT, Highways Agency and industry.

**Information gathering and analysis**
- Maintain up-to-date information on areas and topics already examined (Appendix 2) and newly identified, including:
  - air-supported structures
  - bridge strikes
  - cladding
  - cranes
  - education and training
  - explosion damage to buildings
  - flood damage to bridges
  - fatigue in steel structures
  - glazing
  - hidden tension members
  - multi-storey car park structures
  - post-tensioned concrete bridges
  - positive/adverse effects of regulations on structural safety
  - pin connections
  - publication of safety-related information
  - resistance to disproportionate damage
  - structural assessment of railway and highway bridges
  - temporary stands and staging structures
  - transport of structures
  - use of computing systems

**Topics arising at short notice**
- Respond to reported concerns and structural failures/collapses appropriately as they occur.

**New initiatives**
- Strengthen the SCOSS information base on collapses and structural safety topics through a database project in collaboration with the Health and Safety Executive.
- Establish more international contacts to obtain better information on structural safety events worldwide.
- Make information on SCOSS available through the Internet.
- Seek to increase awareness among practising engineers and others of current topics of concern through issue of leaflets and occasional publications.
- Explore a project in collaboration with the Health and Safety Executive to prepare a framework of guidance for engineers on risk management techniques.
Appendix 1  SCOSS: origin, role and terms of reference

SCOSS – the Standing Committee on Structural Safety—is an independent body established by the Institutions of Civil and of Structural Engineers and others in 1976 to maintain a continuing review of building and civil engineering matters affecting the safety of structures.

The prime function of SCOSS is to identify in advance those trends and developments which might contribute to an increasing risk of structural unsafety. To that end, SCOSS interacts with the professions, industry and government on all matters concerned with design, construction and use of building and civil engineering structures.

SCOSS reports directly to the Presidents of the Institutions and liaises with the Directors of Engineering of the two Institutions. Its Reports are published biennially. The Reports are available from both Institutions and are sent to key representatives of organisations with responsibility to contribute to structural safety. Papers are also published from time to time to draw attention to SCOSS’s recommendations and to encourage the collection and dissemination of experiences likely to foster the avoidance of structural failures and a greater measure of structural reliability.

Whilst concentrating on matters relating to the United Kingdom, SCOSS maintains an awareness and contact with construction events worldwide. In so far as its resources enable it to do so, it seeks to obtain information from overseas experience by appropriate contacts with the International Association for Bridge and Structural Engineering and other international associations.

Topics for consideration by SCOSS arise from many sources, relying upon information derived mainly from the experience of others. SCOSS seeks information on how structures actually perform in practice. It identifies where risks are thought likely to be unacceptable and then seeks changes of practice which will maintain safety. It is itself a feedback mechanism and encourages other, more comprehensive, modes. Feedback is received through the day-to-day interaction of SCOSS members with the professions, industry and government. Feedback on topics which are considered particularly relevant is actively sought by the Secretary and Technical Officer. SCOSS receives presentations on specific topics from relevant experts. More than a hundred topics have been closely studied at some time in the last 20 years, see Appendix 2. Many of these topics are, by their nature, fundamental and ongoing and of a general nature. Others are relatively detailed and result from incidents reported to SCOSS as potential problems. Not all topics drawn to the attention of SCOSS are necessarily pursued. Once a topic has been addressed, SCOSS aims to leave the matter unless it decides that there are ongoing structural safety issues which are not being adequately addressed elsewhere.

Confidentiality is an essential feature of SCOSS’s procedure. This helps to encourage those who have doubts, fears or experiences of potential problems to share them with SCOSS. It also means that ideas, materials or techniques under discussion are not seen to be unnecessarily blighted by suspicions.

Administrative and secretariat support are funded by the two Institutions with some additional financial assistance to these support services from the Health and Safety Executive commencing in November 1995. The Institution of Structural Engineers provides the secretarial services.

Terms of reference

The terms of reference of SCOSS are to:

- Consider both current practice and likely development from the standpoint of structural safety.
- Be aware of trends and innovations in design, construction and maintenance from the standpoint of safety.
- Consider whether unacceptable risk exists or might arise in the future and, if believed so, to give warning to relevant bodies.
- Consider whether further research and development appears desirable from the standpoint of structural safety.
- Disseminate the findings of the Committee by a biennial published report and by other appropriate means.
- Avoid duplicating the work of the Health & Safety Executive, of the Institution of Civil Engineers and of the Institution of Structural Engineers.
- Report to the Presidents of the Institutions of Civil and of Structural Engineers annually and from time to time on specific issues.

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Appendix 2 Cumulative index to topics considered by SCOSS since 1976

The Ninth, Tenth and Eleventh SCOSS Reports can be purchased from SETO, 11 Upper Belgrave Street, London SW1X 8BH. Photocopies of earlier Reports may be obtained from the SCOSS Secretariat, at the same address.

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