

**16<sup>TH</sup> BIENNIAL REPORT FROM SCOSS**  
**The Standing Committee on Structural Safety**

**June 2007**

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This report has been downloaded from the SCOSS website at: [www.scoss.org.uk/publications.asp](http://www.scoss.org.uk/publications.asp)

ISBN 978-0-901297-47-1

**CONTENTS**

	<b>Page</b>
<b>FOREWORD</b>	<b>4</b>
<b>SUMMARY</b>	<b>5</b>
<b>1 INTRODUCTION</b>	<b>7</b>
Aims of SCOSS	
Introduction	
Actions arising from the 15th Biennial Report	
1 People	
2 Process	
3 Product	
Summary	
This report	
<b>2 LESSONS FROM FAILURE: REFLECTING ON THE WORK OF SCOSS OVER THE LAST 30 YEARS</b>	<b>11</b>
Introduction	
Subjects considered by SCOSS	
More recent failures	
Learning the lessons	
1 People	
2 Process	
3 Product	
<b>3 CONFIDENTIAL REPORTING ON STRUCTURAL SAFETY (CROSS)</b>	<b>18</b>
Background	
Reported matters of concern	
Analysis of reports to CROSS	
Specific successes	
The future	
<b>4 TOPICS DISCUSSED DURING THE PERIOD 2005-2007</b>	<b>24</b>
Independent review of structures	
Centre of construction safety excellence	
Robustness: disproportionate collapse	
Temporary structures (entertainment events industry)	
Other items	
1 Limestone aggregate	
2 Punching shear in flat slabs	
3 Liquid metal assisted cracking	
4 Eurocodes	

	<b>Page</b>
<b>5    LOOKING FORWARD</b>	<b>30</b>
People	
Process	
Product	
Conclusions	
 <b>APPENDICES</b>	
Appendix A    Independent review of structures: Guidance note	<b>33</b>
Appendix B    Centre of construction industry safety excellence	<b>38</b>
Appendix C    Structural submissions under the Building Regulations, Part A: Minimum competence standards and provision of information	<b>44</b>
Appendix D    Proposal for a ‘working engineer’s’ guide on structural robustness and disproportionate collapse	<b>48</b>
Appendix E    The assumptions behind the Eurocodes	<b>51</b>
Appendix F    Membership of the Committee	<b>59</b>
Appendix G    Schedule of topics discussed and other Committee actions during the period 2005-2007	<b>61</b>

## **FOREWORD**

This is the third Biennial Report that I have introduced, and the sixteenth overall, spanning the 30 years that the Committee has been in existence.

What has become apparent to me over the period I have been Chairman is the recurring nature of structural safety issues. The Committee has again categorised these under the three heads of **people, process and product**.

I urge everyone with an involvement in structural engineering to read the report; advice and comment occurs throughout its text. I hope that those in a position of influence will also do this, and that everyone will consider the lessons that emerge.

Structural failure is not confined to the small project, nor to the inexperienced team; it affects all types of construction and wreaks human and financial havoc.

Your successes as a structural engineering profession are to be applauded; however there is no room for complacency as the report demonstrates. Vigilance is required by all.

**Kate Priestley**  
**Chairman**

## SUMMARY

This is the 16th Biennial Report of the Standing Committee on Structural Safety (SCOSS).

The report describes the activities of the Committee over the last two years. It emphasises, as have all previous reports, that we cannot afford to become complacent about the need to ensure structural safety. Indeed it is demonstrated that failures continue to occur despite our increasing knowledge and ability, including where the root causes are well known phenomena. This report is able to draw upon the outputs from the Confidential Reporting on Structural Safety (CROSS) which reinforces this message.

The Committee has promoted some important initiatives with regard to, for example, independent reviews, building regulation matters, robustness and a Centre for Construction Safety Excellence. Details of these proposals are contained in the text and in the appendices.

As adopted for the 15th Report, we have utilised the ‘3Ps’ of **people, process and product** to describe and categorise the contributory factors which can lead to failure. These emphasise the wide range of influences and that ‘human factors’ are a key component.

Some general thoughts ‘looking forward’ are given in Chapter 5, together with conclusions arising from the Committee’s 30 years of operation.

The key recommendations of this report are:

- 1 That *influencers* of our industry as well as *practitioners of our industry* need to consider the issues arising from the report, but specifically:
  - i) the lessons to be learnt from failure as outlined in Section 2.8 and the emerging issues from CROSS (see Section 3.7 and associated table)
  - ii) the promotion and adoption of independent reviews (Appendix A) where appropriate
  - iii) the issues surrounding Part A of the Building Regulations, as outlined in Chapter 3 and Appendix C.
  - iv) the issues associated with robustness and specifically the ‘deemed to satisfy routes’ as outlined in Chapter 4, noting also the proposed guide to robustness (Appendix D).
  - v) the implications of the conclusions of 30 years of operation of SCOSS, given in Section 5.14.
- 2 That *influencers* actively consider how they might assist SCOSS in the establishment of a Centre for Construction Safety Excellence (Appendix B).
- 3 That *influencers* as well as *practitioners* seek to support and engage with the Confidential Reporting of Structural Safety (CROSS). This has the potential to provide important feedback and identify emerging trends but will only do so if supported by industry.
- 4 That *practitioners* seek to actively familiarise themselves with, and embed the principles behind the Eurocodes into their work (Appendix E). In the main, these principles apply equally to current code of practice.

- 5 That *influencers* and *practitioners* take time to consider the remaining items described and discussed in the report, all of which impinge upon structural safety.

# 1 INTRODUCTION

## Aims of SCOSS

- 1.1 The formal aims and objectives of SCOSS are set out on the website. In brief terms however, the Committee is charged by its sponsors, the Institution of Civil Engineers, the Institution of Structural Engineers and the Health and Safety Executive, with investigating and then if appropriate disseminating advice to the industry on matters concerning structural safety that are considered of sufficient importance to warrant action. The Committee is concerned with trends and practices rather than one-off events. A list of topics considered over the last two years is to be found in Appendix G, and the website contains downloadable files of all previous reports and other documents issued by the Committee.
- 1.2 The Committee considers a wide range of subjects. In each case it seeks to identify what action should be taken. Some matters can be directly followed up with the relevant party or by publishing an alert; others provide evidence of the need for awareness and education or regulation in areas such as competency, codes of practice and processes. In these more general areas SCOSS seeks to formulate proposals that can be taken up by the sponsors or government departments, or which at least stimulate debate.
- 1.3 The Committee celebrated its 30th anniversary in 2006. Chapter 2 gives a résumé of the Committee's work over this period.

## Introduction

- 1.4 This is the 16th Biennial Report produced by the Committee, since it was formed in 1976. As was the case for the 14th and 15th Reports, published in 2003 and 2005, it has been produced in electronic format and placed on the SCOSS website thus allowing immediate and easy access for practitioners, those able to influence the manner of structural engineering, researchers and industry historians.
- 1.5 An Executive Summary has also been produced, in hard copy, and issued to those who are in a position to influence others and bring about change.
- 1.6 The general aim of this report is to summarise subjects discussed by the Committee over the last two years and to indicate how, in the Committee's view, matters may be improved. Further details on some of these topics may be found in specific papers on the website. The subjects raised in the report have been commented on under the three generic heads of **people**, **process** and **product** (the approach used in the 15th Report) thus emphasising the wide sources and influences of structural risk.
- 1.7 The Committee has directed the recommendations specifically at either 'practitioners', anticipated to be the majority readership, or 'influencers', i.e. those who are able to influence the manner in which the industry works. This influence might be by contribution to Institution or Government deliberations, or by bringing influence to bear in a more general way via the workplace or standing in the profession.

- 1.8 The Committee has, over the years, been effective in raising awareness of issues, resulting in the establishment of guidance and best practice methodologies, changes to standards, and other benefits to the industry. The Committee is pleased to note that action has been taken on a number of the recommendations from the 15th Report, as noted below under 'Actions arising from the 15th Biennial Report'.
- 1.9 However, those who take some time to review past concerns and matters of discussion will soon identify that there is much yet to be done. Many of the points raised by the Committee over the years recur; either in a slightly different format, or because no action has been taken.

### **Actions arising from the 15th Biennial Report**

- 1.10 The Committee is pleased to note that a number of the issues raised in the 15th Report have been considered and actioned by others, albeit to varying degrees, viz:

#### ***People***

##### *Competence:*

The report covered a wide range of issues within this topic area and it remains an on-going item of discussion and concern. However, the revised CDM Regulations, which came into force in April 2007, will bring corporate and individual competence to the fore. SCOSS is pleased to note that the Institutions are responding to this by reviewing their own procedures and life-long learning requirements and have signed-up to a 'health and safety strategy' as a vehicle for implementation. However, there remains a need for expeditious action.

#### ***Process***

##### *Risk Management:*

Partly at the suggestion of SCOSS, IStructE is producing a guide on risk management as it relates to structural engineers. It will cover the risks that occur throughout the lifecycle of a building or structure, the philosophy and principles of risk management and the tools and techniques for managing risk within a structural engineering context (due for publication in 2008). Notwithstanding, this subject is likely to continue to be a 'standing item' of discussion as it is central to engineering activity.

##### *Certification and other matters:*

The Committee had previously expressed concern that EU certification procedures in particular were not fully understood. The Committee is pleased to note that BRE has taken up the suggestion that a guide be produced to explain the background to EU certification procedures. This is an area which will be unfamiliar to much of the industry and hence guidance and explanation, at least in the short term, will be useful. This is due for publication in 2007.

##### *Eurocodes:*

This topic is being considered by others, e.g. the Standing Committee on Implementation of Eurocodes. Nonetheless, SCOSS has produced a paper highlighting the assumptions behind the Eurocodes, as set out in EN1990, and giving practical example of how these may be satisfied in practice (Appendix E).



*BSI Committees:*

Both the 14th and 15th Reports expressed concern over the increasing difficulty of obtaining adequate representation on BSI technical committees. The ICE has taken action on this matter by instigating a joint survey with BSI to determine the current situation on this, and other aspects of BSI Committee functioning. BSI's involvement is particularly welcome. The survey results indicated less concern than might have been supposed although there remain a number of areas where significant concerns do exist, viz:

- The amount of academic support has dropped off from historic levels and contractor involvement is low.
- The majority (83%) of those involved in BSI committees are in the age group >45. Of the remainder 4% are 35 or less. This should be a concern to the future viability of the voluntary committee structure and the maintenance of the knowledge that lies behind the codes.
- A significant number (48%) are only present for 50% to 75% of meetings. Workload pressure was a major factor affecting attendance, but cost was not.
- Levels of financial support for attendance at committee meetings was a concern to a sizeable minority (some 48%), which considered lack of payment to be a barrier.

*Dams and similar impounding structures:*

The Committee had argued that the relevant legislation should be risk based, rather than threshold based, as at present. SCOSS has been advised that not all members of the British Dam Society (BDS) agree that the assessment of reservoirs should be risk based in this respect. However, the BDS is liaising with Defra on the subject.

The Committee had drawn attention to a concern regarding the ability of Panel Engineers to obtain competitive PI cover. The BDS reports that has not identified any trend amongst its membership of Panel Engineers withdrawing from the system, other than as a result of retirement, age or completion of the term of appointment. It would appear that PI insurance cover is readily available. BDS is not aware of any case where Panel Engineers are uninsured or inadequately insured. BDS point out that the inspection regime envisaged by the Reservoirs Act does not appear to be in jeopardy, as can be seen by the virtually 100% compliance in supervision and inspection since the hand over of enforcement to the Environment Agency. The Committee welcomes this situation.

**Product***Large Panel Structures:*

Concern was expressed in the 15th Report (Section 5.2) at the unauthorised use of LPG in high-rise blocks of flats. ODPM (as it was then; now DCLG) indicated that further advice to local authorities would await the outcome of research by BRE into more accurate assessment techniques. Unfortunately, the BRE commission is not yet complete and hence no progress has been made in this regard. This must remain a concern and as such the Committee intends to remind the Minister of the concerns

expressed in earlier correspondence. In the meantime, and where possible, local authorities should continue the prohibition of the use of LPG in such buildings.

## Summary

- 1.11 The primary subject matter chosen for both the 14th and 15th Reports, i.e. Risk Management, Education, and Eurocodes, has remained central to current concerns. The items discussed in those reports remain germane to practising engineers, academics, and those responsible for influencing the manner in which the industry moves forward; it is for this reason that they appear again throughout this report.
- 1.12 As reported in the 15th Report, failures have continued to occur at an unacceptable rate, across a wide range of countries and structural types, and for a variety of reasons. Whatever the causes, and some are not yet formally declared, many have a human cost, and all have a financial consequence. Some examples and the issues arising are discussed in Chapter 2.
- 1.13 The issue of timely release of information relating to failures is of fundamental importance; it was the subject of comments in the 15th Report and most recently in a presidential address by David Shillito [1]. Although this Report is able to give one example of the timely release of information, most incidents suffer from a slow and partial release of data thus frustrating the dissemination of lessons to the wider industry.

## This Report

- 1.14 This report discusses a number of matters considered by the Committee to be central to improving levels of structural safety, some of which overlap with the above. In this respect:

**Chapter 2** looks at the lessons to be learnt from past failures, the role of SCOSS over the last 30 years and contemporary failures.

**Chapter 3** analyses the items which have featured in the CROSS Newsletters

**Chapter 4** considers the issues reviewed by the Committee since the last report.

**Chapter 5** looks ahead and makes recommendations under the headings of people, process and product.

The Report recommendations are contained in the **Summary**.

**Appendices A-E** contain discussion papers relating to the key items considered by the Committee since the last report. **Appendix F** lists members of the Committee over the period, and **Appendix G** schedules the topics discussed and other actions taken.

## References

1. *Accident Investigation from the inside*. Presidential address to the UK chapter of the Conseil National des Ingénieurs et Scientifiques de France in January 2007 at the ICE

## 2 LESSONS FROM FAILURE: REFLECTING ON THE WORK OF SCOSS OVER THE LAST 30 YEARS

### Introduction

- 2.1 Structural failure continues to be a matter of great concern: within the last two years we have witnessed the collapse of the Gerrards Cross tunnel, the Milton Keynes scaffolding, the Montreal highway bridge and a number of construction cranes. The Buncefield explosion and fire at Hemel Hempstead in December of 2005, although not a 'structural engineering failure' in the first instance, does nonetheless raise a number of lessons for us all. How is it that, with an abundance of experience, quality codes of practice, and the lessons of previous failures to draw upon, these events continue?

### Subjects considered by SCOSS

- 2.2 The wide range of subjects covered by the 15 previous Biennial Reports, over a 30 year period, can be seen from the reports themselves and the subject schedule on the SCOSS website. In particular, bridge structures have featured strongly over the years covering concerns relating to scour, collisions, assessments and post-tensioning. Structural elements such as purlins, parapets and hidden members have also featured. What is clear from a review of these issues is that the influences on safety are wide ranging and include not only technical issues but also the 'soft' management issues. It can be argued that many structural failures are caused by human failings.
- 2.3 This Chapter initially reflects on past Committee considerations as a way of setting the scene, and then considers more recent experiences. Some of the text is taken from a forthcoming paper<sup>1</sup>.
- 2.4 Key subject areas considered in the past have included:

#### *Actions<sup>2</sup>*

There is an essential need for designers to recognise that codes of practice do not necessarily include all the actions that might apply. As from December 2004 Class 3 buildings - as defined by Approved Document A of the Building Regulations for England and Wales - require the designers to assess for themselves what actions should be included, although formal guidance is currently lacking in this respect. The new Eurocodes include a section on 'accidental actions' (EN 1991-1-7).

#### *Legal and associated procedural issues*

SCOSS has considered legal and procedural issues in three key respects: the direct obligations affecting the design process, the question of 'certification' as it relates to Building Regulations and other works and materials, and the duty to warn others of matters of concern.

It is suspected that most engineers have their contractual obligations foremost in their mind. This is understandable: however the statutory duty should not be forgotten.

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<sup>1</sup> due to appear in ICE Civil Engineering journal: August 2007.

<sup>2</sup> the term used in the Eurocodes to denote loads and other effects such as thermal expansion.

SCOSS has argued for a simplified system of safety regulation in the built environment particularly for buildings in use [1], but without any success to date.

The possibility of introducing some form of ‘self-certification’ to the Building Regulation process has been mooted by others on a number of occasions. It was tried in Scotland and found not to function with sufficient certainty [2]. History shows us [3, 4, 5] that in order to ensure compliance there needs to be independent assessment and supervision. SCOSS is pleased to note the progression of proposals by the ICE and IStructE for a ‘Scheme for Certification of Plans’ to apply in England and Wales, which would complement a similar scheme already running in Scotland.

The duty to warn, embedded in professional responsibilities, and the common law duty of care, has been the subject of considered opinion, particularly via the Engineering Council [6] and the Royal Academy of Engineering [7]. It is anticipated that the recently promoted pilot scheme for the confidential reporting of matters of structural safety (CROSS), will provide the industry with valuable information on adverse trends and practices. The limited data received to date confirms that there are a number of areas requiring attention [8] but has also reinforced the concern that the profession are generally reluctant to participate in this knowledge sharing scheme. However the content of the reports submitted is the type of information anticipated and confirms the potential effectiveness of CROSS. An initiative has been taken by the ICE president to involve contractors, which is welcomed. This scheme is discussed in Chapter 3.

#### *Risk Management*

The Committee has discussed this subject in eight of the fifteen biennial reports; it remains central to good engineering. Although much technical risk is controlled through design codes, SCOSS has recommended that:

*‘starting at the design stage of projects, designers should apply an explicit risk management process including 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’.* [9]

A holistic, whole-life approach, utilising the statutory framework to consider hazard and risk, will bring commensurate benefits to projects and the community.

#### *Structure and materials*

SCOSS welcomes the advances made in both the sophisticated structural forms now possible as a result of powerful analysis tools, and also in materials. The Committee is concerned however that the profession keeps alert to the dangers inherent in such progress. The issues surrounding the use of software have been well aired [10, 11]. The advancement of analysis techniques, in parallel with the use of sophisticated integrated software packages, means that in some cases the ability of the designer to maintain intellectual control is severely tested. This is exacerbated when, as is often the case, the designer and modeller are different people. Specification, and then validation of the software model, and verification of the output are essential processes in order to maintain control and to safeguard the design.

Although the materials used in the industry are generally quality assured the Committee has had cause for concern that some well established problems are not taken account of by all designers; for example stress corrosion cracking potential in stainless steel used in swimming pool buildings [12] together with less well known phenomena, such as

liquid metal assisted cracking [13] which can occasionally occur in galvanised steelwork. Concerns relating to the effect of aggregate type on the shear strength of reinforced concrete have also been discussed and are outlined in Section 4.25.

### More recent failures

- 2.5 As noted in the introduction to this Report (and in Chapter 6 of the 15th Report), it is an unfortunate fact that structural failures continue to occur. What is noticeable, from a study over the years, is that these include large and prestigious projects often associated with high profile companies, as well as small projects. Significant examples since the last report include:

Gerrards Cross tunnel	The collapse occurred during construction and is thought to be due to asymmetric filling against the pre-cast concrete arch tunnel segments. HSE's investigation is on-going. This collapse had the potential for causing a major incident. Fortunately, no deaths or injuries resulted but there were trains in the vicinity. The consequential costs are significant.
External TV screen in Birmingham	Wind induced collapse of a temporary, but very substantial, TV screen structure, erected to allow public viewing of the football World Cup. Temporary structures, used specifically in the entertainments industry, are discussed in Section 4.21-4.24.
Temporary grandstand at Lincoln [14]	Insufficient attention paid to dynamic effects. Crowd was more lively than expected.
Ceiling panels in Boston's 'Big Dig' tunnel	Failure of the post-drilled anchors. Reported as due to incorrectly installed resin fixings.
Montreal highway bridge	Failure of 'half-joint' leading to collapse of span onto road below. This joint detail is known to be problematic and is now avoided in UK bridges. Lack of inspection and maintenance are thought to be key contributory factors to the failure. The profession needs to learn from the Canadian experience.
Tower cranes: London and Liverpool	There has been a number of crane collapses. HSE issued a prohibition notice (January 2007) on the crane hire company, which supplied both cranes in these two instances, pending independent inspections of the entire tower crane fleet.
Milton Keynes scaffolding	Collapse of traditional scaffold structure; the cause is currently under investigation. Information is likely to be released as part of the inquest, due to be heard in November 2007.
Temporary stage structure at Colwyn Bay (for Children in Need)	Wind induced collapse of temporary stage structure. No official explanation has yet been released (April 2007).

German ice-rink roof	Failure of laminated timber roof beams, thought to be due to weakening of the glue due to dampness. An example of the combined effect of deterioration (in the adhesive joint) and relatively high load (repeated snowfall) leading to collapse: time-dependent reliability and the importance of whole-life considerations.
Polish sports-hall roof	Failure of steel truss roof. Cause thought to relate to use of standard design in inappropriate location.
Bournemouth car park	This has not collapsed but the structure had to be closed until propping had been installed. It is to be demolished. There is no definitive information as to the cause but is thought to relate to movement of the units relative to the in-situ frame, causing spalling. An interface problem.
Leeds 'CASPAR' flats	Evacuated due to concern over stability of roof under wind loads.
Moscow market	Unauthorised additions caused overloading to perimeter columns.
Holyrood Parliament Building roof	Poor workmanship leading to local joint failure.
Almunecar falsework, Spain	Collapse of significant bespoke falsework to bridge construction.
Cables in Forth and Severn road bridges	Significant corrosion of the cable wires.
Menorca airport roof	Collapse during construction: cause not yet known.
Salford footbridge	Wires of cable stayed footbridge affected by vandalism; an example of a malicious act. This category of action is not included within design codes of practice but relies on identification from an assessment of risk undertaken at the design stage. This example highlights how, on some structures, a major consequence (i.e. total or partial collapse) could arise from a simple act.
San Paulo tunnel collapse	NATM construction; this follows a long history of failure with this type of construction (see the failure data sheet on the Heathrow tunnel collapse, paragraph 2.8).
Sparrowpit dam, Derbyshire	Breach in dam causing flooding in adjacent village. Dam does not fall within ambit of Reservoirs Act (see Section 4.6 of 15th Biennial Report for discussion on issues associated with small raised reservoirs and dams).
Walls	There have been reports of a number of free standing walls being blown over - some causing fatalities. Boundary walls do not yet come under the Building Regulations.

Various	As noted in the CROSS Newsletters ( <a href="http://www.scoss.org.uk/cross">www.scoss.org.uk/cross</a> ) and in Chapter 3.
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- 2.6 There have also been ‘failures’ of a non-structural nature but which hold lessons for the structural engineering fraternity. These include:

Buncefield [15]	The fire that occurred in December 2005 following the initiating explosion was the biggest industrial fire since World War II. The HSE reports provide valuable lessons in respect of operation and maintenance issues, specifically: - failsafe mechanisms - maintenance of facility infrastructure - holistic appreciation of hazard/risk, e.g. adjacent housing/offices
BP Texas Refinery	A critical report [16] outlined shortfalls in management at all levels, poor maintenance and a lack of an appropriate safety culture within this, and other plants.
East Sussex Fireworks factory	No formal information available, but this was a significant fire (with subsequent explosions) arising from premises holding hazardous materials, in close proximity to other buildings.
‘Dreamscape’ inflatable, Chester Le Street Co Durham,	This was conceived as ‘artwork’ but in fact was a large, lightweight air-supported structure susceptible to wind uplift. The inflatable lifted-off under wind action. This incident emphasises the need to recognise the potential for adverse structural action in unusual situations, but where the action (wind, in this case) is not exceptional.

- 2.7 The Competent Authority (HSE and the Environment Agency) is to be congratulated for the exemplary manner in which the investigation into the Buncefield fire has been conducted in respect of progressive information release. Similarly, the report on the BP Texas plant explosion has been released within 9 months (with an interim report after only 6 months). These examples demonstrate that it is possible to release data without prejudicing future legal actions. It is hoped that they will form templates for future investigations which have a wider interest.
- 2.8 The Committee has also prepared a synopsis sheet, summarising the background, the incident and the lessons to be learned, for three collapses: Heathrow Tunnel (1994), Nicoll Highway (2005) and an access platform collapse in the USA (2002). These are available on the SCOSS website. Although they are very different structures, existing in very different circumstances, there are some common lessons.

## Learning the lessons

- 2.9 It is apparent that generic lessons may be learnt from all of the examples quoted in this Chapter, viz:

### *People*

It is not just a sensible business approach, but a legal obligation, to use competent persons for 'work activities', unless they are under training and appropriately supervised. This requirement comes under severe pressure in commercial situations, when there is a skill shortage, and during period of peak activity (such as is occurring at present), but is essential in the maintenance of a safe regime. 'Competency' has to be maintained and upgraded throughout the career-span.

The current worldwide movement and use of labour means that additional risks can arise as a result of differing cultures and languages. These present new challenges in terms of management and safety related communication.

### *Process*

The examples illustrate that a methodical, and risk-assessed process, is an important element of ensuring safety. Procedures need to be practical and be reviewed periodically. They need to cover the interfaces between stages or parties in the project. Unplanned or late departures from agreed procedures are high risk. Complacency is an ever-present danger.

### *Product*

Products will often deteriorate if not used as intended or maintained adequately; they also depend upon correct installation in the first instance. The relevance to safety of specific items (e.g. fixings to ancillary components) may not always be known to those personnel who lack competence in structural engineering.

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### 3 CONFIDENTIAL REPORTING ON STRUCTURAL SAFETY (CROSS)

#### Background

- 3.1 The Confidential Reporting on Structural Safety (CROSS)<sup>1</sup> scheme has been widely welcomed within the construction industry: it has had strong support in particular from the Presidents of ICE and IStructE who have jointly written to the CEOs of the top 100 construction companies encouraging their support. The ICE President has also held a meeting with CEOs of leading contractors as a means of engaging the construction side of the industry. SCOSS is grateful to those who have contributed so far.

The Director of CROSS and the Secretary of SCOSS have written papers and articles, met with companies, and given talks, as a means of raising the profile and explaining the wide benefits of contributing to the scheme.

- 3.2 CROSS was launched by SCOSS in June 2005 [1] after a long gestation period. This scheme is unique to the construction industry, but not so generally, as other industries had seen the benefit of such reporting some time before. CROSS is designed around the principles adopted for the UK Confidential Human Factors Incident Reporting Programme (CHIRP) which operates for the aircraft industry, and which has been running for 20 years and now receives around 250 reports annually. In all such programmes complete confidentiality is maintained. Indeed the NASA supported Aviation Safety Reporting System (ASRS) has had over 700,000 reports in 30 years without confidentiality ever having been breached.
- 3.3 An important element of CROSS is the link with the Scottish Building Standards Agency (SBSA) which has asked the scheme to receive, record and analyse reports from all Scottish local authorities, relating to falls of material from buildings. This has been denoted 'SCOTCROSS'.
- 3.4 So far, some 850 reports have been received via SCOTCROSS and 80 by CROSS. The difference in numbers reflects the manner in which the scheme is operated in Scotland.
- 3.5 CROSS has been approached by the Indian Association of Structural Engineers and also from the Government of Singapore, both expressing interest in establishing similar schemes. It is considered very encouraging that others wish to mirror this scheme.

#### Reported matters of concern

- 3.6 The prime means currently adopted by CROSS to draw industry's attention to the matters raised is through newsletters, of which there have been five (as at April 2007). These are available on the CROSS website. This Chapter analyses the contents of these newsletters to identify the common lessons to be learnt.
- 3.7 An analysis of the 51 items included within the newsletters, and scheduled using the '3Ps' of **people**, **process** and **product** shows the following:

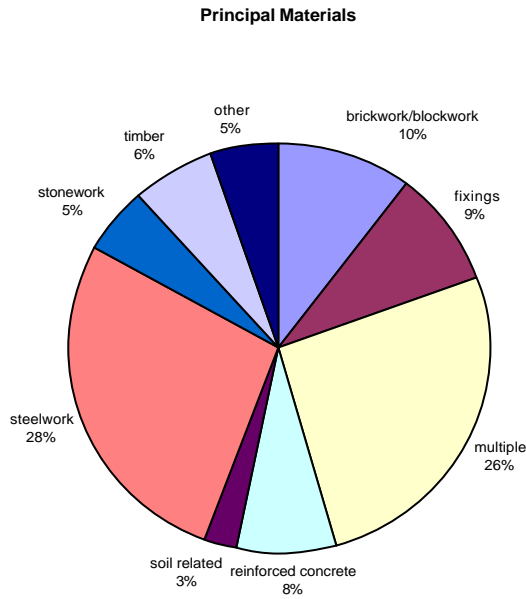
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<sup>1</sup> [www.scoss.org.uk/cross](http://www.scoss.org.uk/cross)

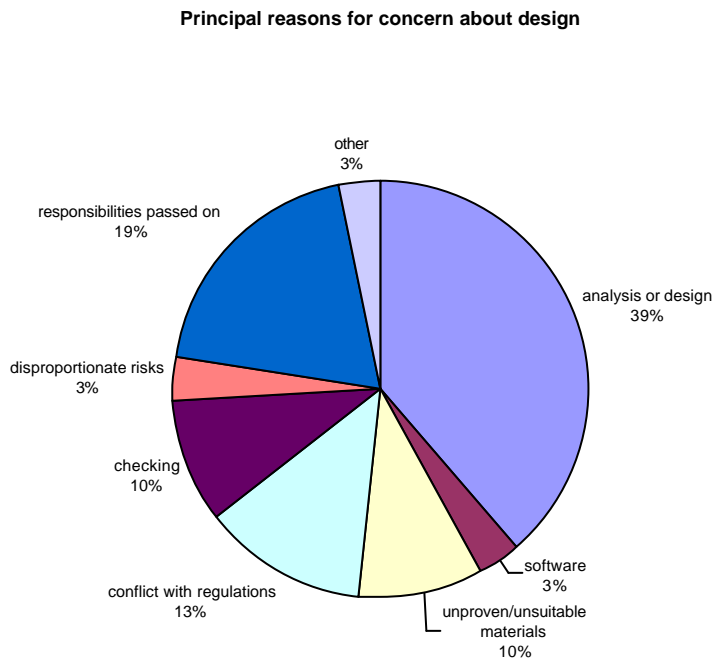
	<b>Category &amp; subject</b>	<b>Concern &amp; comment</b>
1	<b>People</b>	
	Competency	Evidence of poor quality submissions made in respect of Building Regulations submissions.
		Lack of appreciation of risks associated with software, and the appropriate controls required.
	Certification	Dangers associated with self-certification schemes (one report only).
	Failure to act	Failing to act on those items not specifically demanded by an authoritative source (e.g. a BS), but on which a risk assessment would indicate an action was required.
2	<b>Process</b>	
	Clarity of responsibility	Specifically in respect of overall stability and at contractual or physical interfaces.
	Control of change	The dangers associated with late change in the pre-construction design phase, or changes occurring during the construction phase itself.
	Acting outside contractual remit	Contactors making changes, either without designer's knowledge or with insufficient enquiry from the designer.
	Pre-construction information	Need for adequate information on ground conditions, existing structures and environs before commencing design and site work. (This probably applies more to modifications and refurbishments than new works)
	Interim stability	Need for designers to determine a safe way of executing the works and relay this to the contractor.
	Design of secondary items	Many of these can be of significant structural significance but sometimes escape scrutiny or fall within the contractual responsibility of those without structural competence. There have been instances of inappropriate fixing specification or use, and reports of wind damage to secondary building cladding.
	Building Regulations	Lack of adequate checking (either in extent or by competent persons) and difficulties due to competition and financial pressures within Local Authorities.
	Co-ordination	Failure of designers to give adequate consideration at interfaces.
	Control of completed structures	Either in terms of access and use, or in condition.
3	<b>Product</b>	
	Understanding material behaviour	E.g. aluminium, galvanised steel. Recognising the range of material characteristics that are relevant and the impact of design details, fabrication, treatment and use.
	Deterioration of materials	Some materials, e.g. adhesives are susceptible to deterioration in certain circumstances.
	Need to specify fully	E.g. full steel description in accordance with the BS. Strength characteristics alone are insufficient.
	Proprietary products	Incorrectly specified initially (or insufficient specification), changed inappropriately or not used in accordance with the manufacturer's instructions.

**Analysis of reports to CROSS**

3.8 An analysis by materials and reasons for concern, are illustrated in Figures 1-4 below:

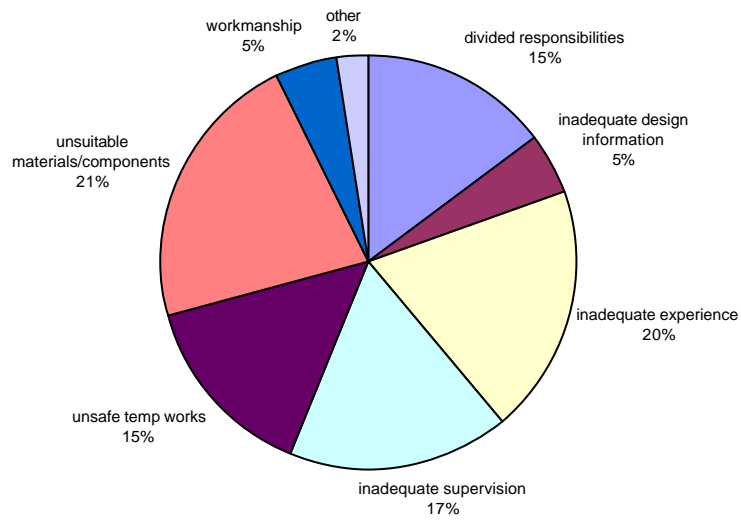


*Figure 1*



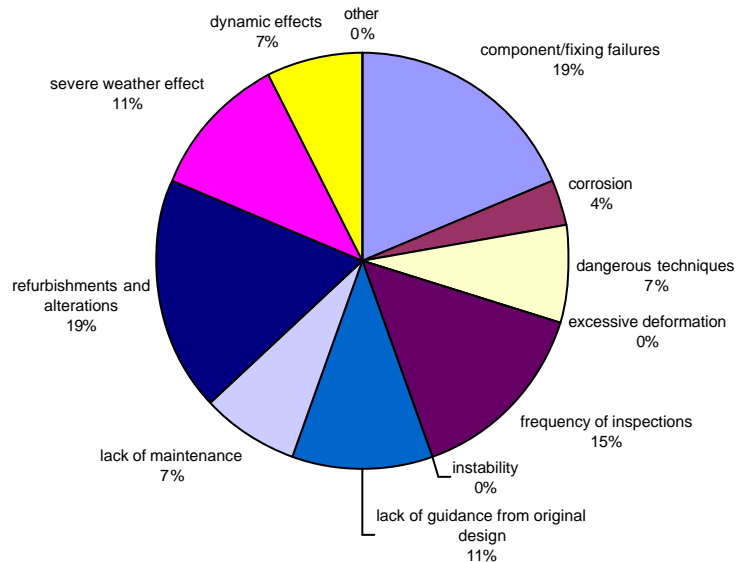
*Figure 2*

**Principal concerns about construction**



*Figure 3*

**Principal concerns about operations**



*Figure 4*

3.9 These are real data; all have the potential to impinge upon structural safety. Some reinforce concerns expressed elsewhere in the report, e.g. aspects relating to Building Regulations (Chapter 4, Section 4.16).

### **Specific successes**

3.10 The Committee is pleased to note:

- i) That as a result of the report on the need to protect scaffolding from vehicular impact (CROSS Newsletter No 4, Report No 053) the matter is being considered by HSE.
- ii) That the concerns expressed in respect of Building Regulation submissions are consistent with the issues raised in the SCOSS discussion paper on Building Regulations standards (Section 4.3) giving added weight to the argument for improvement.
- iii) Some Scottish Local Authorities are intending to use the SCOTCROSS data when planning for future maintenance regimes.
- iv) Major organisations such as British Waterways and BRE are using CROSS to openly report concerns.

### **The future**

3.11 Confidential reporting schemes operating in other industries are generally considered to be very useful in safeguarding life, and in furtherance of the essential need to learn from mistakes. The construction industry is no different and the selection of collapses shown in Chapter 2, and the material received by CROSS to date, bears this out. A successful scheme also has the potential to bring considerable financial benefit to the construction industry.

3.12 Ways must be found to disseminate the findings more comprehensively so that lessons are indeed learned from the experiences that are sent to CROSS.

3.13 Despite the good quality of reports received, the relatively small number of contributions made directly to CROSS is a concern in developing the scheme. The Committee is confident that there is a need for a scheme like this and that there is a wealth of experience that is not being effectively passed on which this scheme can help to transfer. The impediments to developing the scheme are:

- a) communication - CROSS is discussing with its sponsors the various channels for communication, as some relatively simple improvements in communication could yield great benefits, and
- b) the culture which in the construction industry is fragmented and defensive in the light of anything that could be interpreted as pointing a finger at others. CROSS could easily fail as being 'yet another' initiative, but the need to generate a culture where passing on lessons learned becomes an imperative rather than a secondary or tertiary activity is what drives the Committee to seek a successful establishment of this scheme. This path has been trodden in other industries; it has been equally hard and has delivered the benefits that we seek. We hope others share this vision and will take action to support the scheme by submitting reports.

3.14 Readers of this report are urged to consider how they might contribute to CROSS and encourage others to contribute.

## References

1. Standing Committee on Structural Safety. *15th Biennial Report*, Chapter 2 at [www.scoss.org.uk/publications.asp](http://www.scoss.org.uk/publications.asp)

## 4 TOPICS DISCUSSED DURING THE PERIOD 2005-2007

This Chapter summarises the issues discussed by the Committee in the period since the last report. Fuller descriptions of some of the issues (in the form of Topic papers or guidance notes) are given in Appendices A-E and on the website. A full schedule of items discussed is contained in Appendix G.

### **Independent review of structures** (see Appendix A)

- 4.1 SCOSS has been considering how best to promote the public safety requirements inherent in large or complex projects where a typical numerical check against design code may not be sufficient and where a different approach can bring broader benefit to the project. One way in which this can be achieved is by introducing the concept of an independent review.
- 4.2 The independent review is not a further layer of bureaucracy; it is designed to be useful to all parties and to assist in reducing risks and adding value to the project at affordable cost to the client. It is already accepted in specific sectors as a client-sponsored safeguard which recognises that the wider benefits greatly outweigh the additional cost.
- 4.3 The key characteristics of the process are that:
- The reviewer is seen as the project's (but specifically the designer's) 'critical friend', whilst retaining independence
  - The design team retain ownership of the design but are challenged to justify and consider design decisions and their impacts.
  - The reviewer is able to act objectively, without attracting liability.
- 4.4 The usual objectives are to review:
- i) Design philosophy (including the design safety objectives).
  - ii) Major hazards and consider whether they have been identified and dealt with<sup>1</sup>.
  - iii) The robustness of the structure and whether it has been adequately considered.
  - iv) Models of analysis and that they have been adequately validated by the designers. Also, to consider whether the results have been reviewed in terms of magnitude and pattern.
  - v) Design assumptions including the relationship to construction, use and maintenance, materials and specification.
  - vi) Design interfaces.
  - vii) Procurement and contractual arrangements including their compatibility with structural robustness.
- 4.5 The Committee has developed a guidance note on this topic and is seeking views of the profession through an on-line survey. It is the intent to place the final note on the website and encourage its use within the industry.

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<sup>1</sup> see for instance the reference to 'abnormal hazards reasonably foreseeable' in Approved Document A para 5.1e. Examples of such hazards are also given in a topic paper on the publications page of the SCOSS website (Topic paper - A risk managed framework for ensuring robustness).



### **Centre of construction industry safety excellence (see Appendix B)**

4.6 Although the construction industry has made significant strides in recent years, in terms of improving its safety record, there is some way to go before it can claim success. It is considered that a major influence in achieving these future improvements will be the role of academia in:

- delivering the core risk management education to its students such that they graduate, with the appropriate knowledge base,
- providing specialist learning opportunities, e.g. MSc courses,
- providing co-ordinated industry-linked research to allow and encourage knowledge transfer.

At present there is no co-ordinated network between industry, the regulator (HSE) and academia. This is considered to be a significant shortcoming and a barrier to progress.

4.7 This strategy considers the issues associated with the establishment of a Centre of 'construction safety' excellence, including a professorial Chair of Construction Industry Safety, at a UK University.

4.8 The scope is suggested as:

- to further the collation and dissemination of information on construction industry safety issues
- to develop links with other university centres with an interest in safety issues such that overall benefit may be obtained
- to develop teaching aids and syllabi (for use throughout academia)<sup>2</sup>
- to develop post-graduate learning opportunities
- to further industry-related research
- to develop partnerships with industry and government agencies
- to review 'risk' terminology and approaches so as to bring clarity and consistency
- to act as a foil to the Regulators bringing balance to arguments submitted respectively by enforcers and practitioners recognising that in partnership the industry needs to set standards as to what constitutes the norm in acceptable safety standards
- to act as a public figure head in the media on construction safety issues.

4.9 The Committee has received strong support from the Institutions and the HSE for this proposal and continues to explore how it might be implemented.

### **Robustness: disproportionate collapse**

4.10 The Committee has reviewed this topic on a number of occasions over the period since the last Report. It is a wide and complex subject, but one that is fundamental to the establishment of safe structures.

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<sup>2</sup> This would be a major departure from the norm, whereby the incumbent, although based at one university, would be aiming to benefit academia at large.

4.11 In recognition of this situation, SCOSS sponsored a workshop in October 2006, to allow discussion amongst interested parties. These included the material sectors, Building Control, checking engineers, Department of Communities and Local Government (DCLG - responsible for the building regulations), and specific interested individuals.

4.12 From this, four threads of concern have been identified as outlined below (*concerns 1-4*):

*Concern 1 - Basic understanding and interpretation of design codes*

4.13 It is apparent from feedback received from industry (individuals, Verulam<sup>3</sup>, and organisations such as SCI and TRADA), that not all structural engineers are as familiar with the concepts of robustness as they might be. This is not assisted by the fact that there are difficulties in achieving adequate robustness by application of the ‘deemed to satisfy’ routes afforded by the design codes of practice (currently ‘BS’ based, but soon to be joined and ultimately replaced by ‘BS EN’ codes), e.g.

- i) Approved Document A is difficult to apply to existing structures when being altered; similarly it is sometimes difficult to apply to buildings of mixed materials, e.g. concrete frame with masonry walls.
- ii) Incompatibility between design codes of practice (steel, concrete, masonry) and where relevant clauses do not always correspond and guidance differs.

4.14 Achieving ‘robustness’ may require more than strict application of codes. Not all designers appear to appreciate this point.

*Concern 2 - Class 2A/2B buildings*

4.15 Approved Document A of the Building Regulations (England and Wales) creates a number of classifications for the purposes of deriving standardised provisions against progressive collapse. A common occurrence is for buildings to change from building class ‘2A’ to ‘2B’ (Table 11 of Approved Document A) as a consequence of a development/refurbishment project. Such situations introduce some uncertainties and inconsistencies in relation to situations found in practice. Points of note include:

- ii) The need to recognise the intense commercial pressure to develop in all ways possible.
- ii) That Building Control is there to assist development, (subject of course to Building Regulation compliance).
- iii) That advice given and solutions accepted by Building Control varies between authorities, creating uncertainty.
- iv) The significant increase in basement developments.
- v) The wish for simple (almost prescriptive) advice in respect of solutions and interpretations.
- vi) The belief that the Approved Document does not really adequately cover for existing buildings i.e. ‘material alterations’, or hybrid buildings.
- vii) For existing class 2B buildings the difficulties of inserting vertical ties when the building is under multiple occupancy or ownership.

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<sup>3</sup> As published in *The Structural Engineer*

*Concern 3 - Class 3 buildings*

- 4.16 The Approved Document does not suggest any ‘deemed to satisfy’ proposals for those structures classified as ‘Class 3’. Instead, designers must carry out a risk assessment.

There is some concern that, two years after this category was established, no formal guidance has been produced. Although informal advice has been published [1] and work is underway at BRE and in the USA, the situation remains unsatisfactory.

*Concern 4 - Standard of Building Regulation submissions*

- 4.17 It is apparent that in many cases the standard of submission made to Building Control departments for Building Regulations purposes is unsatisfactory. Evidence for this comes from Verulam, CROSS (see Chapter 3) and communications with those involved as originators, checkers or from Building Control personnel themselves, e.g.

- no indication of what building class the structure is assumed to be in
- no attempt to deal with progressive collapse despite the design ‘being in accordance with BS8110/BS5950’ etc.
- a lack of any identifiable competent person with overall responsibility for structural robustness.

- 4.18 The Committee has produced a guidance note on minimum standards and provision of information relating to submissions to building control, which is enclosed in Appendix C.

*Summary*

- 4.19 As a consequence of the situation outlined in Concerns 1-3 above, IStructE has accepted a proposal to produce a guidance document on structural robustness in order to explain the background, and the application of design codes, for all the common building materials (see Appendix D).
- 4.20 A discussion note has been produced in order to take forward the issues raised in Concern 4 above. This is enclosed in Appendix C.

**Temporary structures (entertainment events industry)**

- 4.21 The ‘events’ industry has seen a significant increase in the size and sophistication of its temporary structures over recent years. Large and complex stages and overhead lighting gantries are commonplace. To these must now be added TV/video screens- the increasing size reflecting the rapid advancements in visual data technology. It is not untypical for such screens to be of the order of 9m x 6m and some 11m high overall.
- 4.22 The screens tend to be supported off separate lattice portal frame constructions, or be lorry mounted.
- 4.23 There have been three known failures of ‘event’ structures since the last report:

Grandstand at Lincoln	Insufficient attention paid to dynamic effects. Crowd was more lively than expected.
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‘World Cup’ TV screen in Birmingham	Wind induced collapse of a temporary, but very substantial, TV screen structure. Under investigation at the time of writing this report (April 2007). Very fortunate that no injuries or fatalities occurred in view of the number of persons involved.
‘Children in Need’ stage structure in Colwyn Bay, North Wales.	Wind induced collapse of temporary stage structure. No formal details yet available.

- 4.24 The design of these structures should follow the guidelines outlined in the IStructE report *Temporary Demountable Structures; Guidance on Procurement, Design and Use* [2] which has recently been updated. Notwithstanding, the Committee has spent some time reviewing the procurement, control and structural adequacy of TV/video screen structures in particular, at the request of the IStructE drafting committee. The Committee hopes to be able to report on this topic in the summer of 2007.

### Other Items

- 4.25 A number of miscellaneous items have also been discussed.

#### 1 - Limestone aggregate:

Research has indicated [3] that for reinforced concrete members, utilising limestone aggregate, and when un-reinforced in shear, the resistance may be below the characteristic strength anticipated by the codes, specifically with higher strength concretes. This was raised with the relevant BSI Committee (B525/2) which stated [4] that it was satisfied with the provisions of the National Annex (NA) to BS EN 1992-1-1 in this regard. The NA (in respect of clause 3.1.2 (2)P ‘Strength’) proposes to adopt the recommended value of  $C_{max}$ . However above C50/60 the NA recommends that the shear strength should be determined from tests unless there is evidence of satisfactory performance of the particular mix including the type of aggregates used. This is likely to have the practical effect of limiting the shear strength of higher strength mixes.

#### 2 - Punching Shear in flat slabs:

The collapse of Pipers Row car park in 1997 provided a dramatic illustration of brittle failure [5]. It is recognised that designers should always endeavour to avoid such failure modes. However, there has been concern at the lack of insistence in design codes for (bottom) reinforcement to pass through the predicted punching shear failure zone, and thus provide some additional safeguard. The revision to BS8110 in December 2005 introduced a qualitative requirement, mirroring BS EN 1992-1-1. The Committee is pleased to note that the revised Concrete Society publication ‘Design of Flat Slabs’ [6] includes quantification of this reinforcement in terms of a force to be resisted. It is important to note however that this is not a ‘tie force’ requirement, assessed as a means of providing some catenary action. It is derived from dowel action analogy as promulgated by CIRIA Report 89 [7].

#### 3 - Liquid Metal Assisted Cracking:

This subject was discussed in Section 5.1 of the 15th Biennial Report and has been the subject of a Topic Paper (April 2006). The Committee welcomed the publication of advice for new structures setting out principles of good design, fabrication, galvanising

and inspection [8]. The Committee has been keen to see similar advice relating to existing structures.

#### 4 - Eurocodes:

There is a concern that BS EN 1990 (Basis of Structural Design) may not be studied with the same attention as the ‘technical’ sections of the Eurocodes. It does however contain important information on the underlying assumptions. As noted in Section 1.10, the Committee has produced a paper on the six key assumptions, with a practical commentary relating to their implementation (Appendix E).

## References

1. Alexander, S. J. *New approach to disproportionate collapse*. The Structural Engineer, Vol. 82, No. 23, 7 December 2004, pp14-16
2. Institution of Structural Engineers. *Temporary Demountable Structures; Guidance on Procurement, Design and Use*. 3<sup>rd</sup> Edition, 2007
3. Regan, P.E, Kennedy-Reid, I.L, Pullen, A.D and Smith, D. A. *The influence of aggregate type on the shear resistance of reinforced concrete*. The Structural Engineer, Vol. 83, No. 23/24, 6 December 2005, pp32
4. Private communication with RS Narayanan (December 2006)
5. Wood J.G.M. *Pipers Row car park, Wolverhampton: quantitative study of the causes of the partial collapse on 20th March 1997*. HSE Report at [www.hse.gov.uk/research/misc/pipersrow.htm](http://www.hse.gov.uk/research/misc/pipersrow.htm)
6. The Concrete Society. *Guide to the design and construction of reinforced concrete flat slabs*. Technical Report 64, 101pp. Camberley, April 2007
7. CIRIA. *Behaviour of reinforced concrete flat slabs*. CIRIA Report R89. 1981
8. British Constructional Steelwork Association and Galvanising Association. *Galvanizing structural steelwork: an approach to the management of liquid metal assisted cracking*. Publication No 40/05. BCSA, 2005

## 5 LOOKING FORWARD

- 5.1 The need for vigilance, and the careful management of risk, continues to be essential if safety is to be assured. This is an oft-repeated message from SCOSS and the need for this is demonstrated in part by the continuing examples of structural failure (and often accompanying loss of life) as illustrated in Chapter 2 and in the items submitted to CROSS (Chapter 3).
- 5.2 For the near future at least the working environment is predictable: a commercial marketplace with constraints on time and resource, operating alongside ever increasing sophistication of the means of analysis and design; and, for many engineers, the advent of the structural Eurocodes, bringing change on a scale which has not previously been seen.
- 5.3 To this has to be added the globalisation of business operations, the language and cultural differences that arise from this, and the significant recent growth in the worldwide migration of labour.
- 5.4 All these issues present a significant challenge in a buoyant economy where structural engineering skills are heavily in demand. To meet it requires some key checks and balances to be in place. Most of these need to be concerned with the **people**, **process** and **product** of structural engineering. However, they also need to relate to the definition and perception of structural engineering and the future role of the profession [1].

Our work has identified some significant concerns.

### People

- 5.5 The lack of effective control over who undertakes structural engineering, coupled with a competitive market place, has allowed a minority to partake in this professional arena without the necessary competence or adherence to acceptable minimum standards.
- 5.6 HSE has classified structural engineering as ‘safety-critical’ and yet there are no stated prerequisites to practise in this field.
- 5.7 This classification infers in particular that building regulations submissions under Part A should be made by competent persons but it also extends to general levels of supervision, and making allowance for any language and cultural difficulties.
- 5.8 The concerns outlined in this report reinforce the need for Institutions, which are the guardians of professional standards, to ensure their members reach and maintain the requisite levels of competence.

### Process

- 5.9 The key to ensuring the adequacy of the ‘process’ - design, procurement, construction - is to eliminate the unnecessary hazards and reduce the remaining risks. SCOSS would like to see a greater emphasis, on all projects, for explicit risk management<sup>1</sup>.

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<sup>1</sup> a move promoted also by PI insurance brokers.

- 5.10 This approach is supported (if not driven) by statutory requirements. The added value comes from using these requirements in a positive manner to bring broad business benefit to the project.
- 5.11 The introduction of the Eurocodes gets ever closer. As has been noted previously, the key to successful implementation is adequate planning, tailored to suit individual organisations. SCOSS is concerned that industry should not underestimate the impact of such a significant change. The transition period, prior to the withdrawal of existing national standards is limited and less than might have been expected: all conflicting standards will be withdrawn during or before 2010<sup>2</sup>.

### **Product**

- 5.12 The increasing specification and use of ‘CE’ marked products will, initially, introduce unfamiliar terminology, requirements and safeguards. In addition, SCOSS has drawn attention to existing shortcomings associated with the specification and use of certain products.
- 5.13 Hence the adequacy of products will depend upon the inter-linked issues of competency, control and supervision.

### **Conclusions**

- 5.14 The experience of the Committee, gained over the 30 years it has been in existence, would suggest the following:
- The fundamental causes of structural failure and distress are often rooted in human and organisational failings.
  - We can learn much from the mistakes and problems of the past.
  - Implementation of an integrated approach to managing risk, and an appreciation of the importance of teamwork, is vital.
  - The role of safety as a driver for innovation is not widely appreciated.
  - We do not yet do enough to ensure that the learning process is enshrined in our work; the scheme for Confidential Reporting on Structural Safety (CROSS) is designed to assist this process.
  - Effective communication and clarity of responsibility are central to the provision and maintenance of safe structures.
  - Structures should be designed from a whole-life perspective, with adequate regard to construction, operational use and maintenance (including facility for appropriate inspection), and eventual de-commissioning.
  - Computers must remain the tool of the engineer and not become the intellectual master. This is a major challenge.
  - The influence of human factors (manifested through the individual and the organisation) on structural safety should be recognised and better understood.

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<sup>2</sup> the meaning and consequences of ‘withdrawal’ have caused some confusion: it is worth noting that compliance with Building Regulations Part A does not depend upon the use of a listed ‘deemed to satisfy’ code; neither does withdrawal necessarily mean that a code cannot be used, although with time lack of maintenance will become an issue. This is a subject which will no doubt receive attention in the months to come.

## References

- 1 May, I. Talbot, R. and Owens, G. *The Changing roles of structural engineers in society: report of a strategic survey [Summary]*. The Structural Engineer, Vol. 82, No. 19, 5 October 2004, pp27-30



## **APPENDIX A**

### **INDEPENDENT REVIEW OF BUILDING STRUCTURES: GUIDANCE NOTE**

#### **Purpose of Note**

This guidance note has been written to highlight the rationale for, and explain the implementation of independent reviews of large, complex, innovative or unusual structures. It also applies to more common structures but where there may be abnormal risk e.g. complex ground conditions, adjacency of existing structures.

The purpose of the independent review is to add value to a project by questioning the design team on their hazard elimination and risk reduction measures relating to the design, construction, use, maintenance and decommissioning of the structure. The concept of an independent assessment is not new; it is a well established process. The Highways Agency has adopted a system of independent checks on most highway structures for many years; the nuclear, and other specialist sectors also adopt rigorous review procedures. Some enlightened private sector clients have also seen the benefits. Although the detail and approach of these client-instigated reviews may vary they all have the common aim of reducing risk and adding value to the project.

However, although the process set out in this note operates through an independent reviewer in common with the examples quoted above, it differs in its approach from most existing examples. The key characteristics of this process are that:

- It is a high level ‘review’, not a ‘check’ as conventionally performed (that is for others).
- The reviewer is seen as the designers ‘critical friend’, whilst retaining independence
- The design team retain ownership of the design but are challenged to justify and consider design decisions and their impacts.
- The reviewer is able to act objectively without attracting liability.
- It should be an iterative process i.e. the reviewer becomes involved at an early stage and contributes throughout the design development.

#### **Independent Review of Building Structures**

1 For some time SCOSS has been considering how best to promote the public safety requirements inherent in large or complex projects, where currently there is no accepted adoption of independent review. The concept of independent reviews is considered useful since these already exist across our industry albeit in an inconsistent way. Most highway structures undergo some form of independent check<sup>1</sup>; in potentially hazardous industries there is a process of independent design verification (e.g. in the nuclear industry and in the entertainment rides industry, both of which involve public safety governed by the integration of several engineering disciplines such as civil, structural, mechanical and control). Although building structures are submitted to Building Regulation control that process is often too mechanistic to tease out safety issues inherent in major structural or infrastructure projects, which often fall outside the scope of routine regulation and, on occasions, outside the scope of standard Codes of Practice (and sometimes the experience of

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<sup>1</sup> This includes a code compliance check; some view the check as risk averse, which is different from the approach suggested in this note.

building control reviewers). Building Regulations only deal with the finished state and not with the construction stage (when the risk of failure is often higher) or with structural maintenance considerations.

- 2 The independent review is not a further layer of bureaucracy; it is designed to be useful to all parties and to assist in reducing risks and adding value to the project. As noted above, it is already accepted in specific sectors as a client-sponsored safeguard which recognises that the wider benefits outweigh the additional cost.

### Objective of independent review

- 3 The usual objectives are to review:

- i) Design philosophy (including the design safety objectives)
- ii) Major hazards and ascertain if they have been identified and dealt with<sup>2</sup>.
- iii) The robustness of the structure and whether it has been adequately considered.
- iv) Models of analysis and that they have been adequately validated by the designers. Also, to ascertain that the results have been reviewed in terms of magnitude and pattern.
- v) Design assumptions including the relationship to construction, use and maintenance, materials and specification.
- vi) Design interfaces.
- vii) Procurement and contractual arrangements including their compatibility with structural robustness.

- 4 However it is worth noting that there is often benefit to the project if the scope of such a review is widened to include other project issues: for example client brief, expected deliverables and finance; sustainability issues could also be included. This is the holistic approach.

### Selection of structures

- 5 The selection of structures (including temporary works structures) for independent review should ideally be based on risk. Given the practical difficulties of doing this however, and the likely need for guidance, it is proposed that the structures are generally chosen according to the categories of structure used in Table 11 of the Building Regulations, Approved Document A. These were derived from a risk related analysis.

- 6 Hence, it is recommended that any structure which falls into one of more of the following categories should be subjected to an independent review:

Category	Example
Potential hazard to large numbers of people	Theatres, stadia, large offices, underground stations, tunnels, bridges, long or deep retaining walls,

<sup>2</sup> see for instance the reference to 'abnormal hazards reasonably foreseeable' in Approved Document A para 5.1e. Examples of such hazards are also given in a topic paper on the publications page of the SCOSS website (Topic paper - A risk managed framework for ensuring robustness).

Are of critical design, materials or form	Use of specialist software in safety critical situations, Minimal redundancy, Tall structures, Use of new proprietary products where these perform key structural functions, Buildings designed using tests or first principles, rather than code formulae, Buildings with elements outside primary code limits Structures with complex and critical soil/structure interaction. Structures requiring special construction techniques
Have to resist significant and unusual hazards	Industrial processes, significant impact forces, terrorist actions, significant climatic effects.
Where procurement and contractual arrangements are critical	Use of design/build in complex situations; use of self-certification;
Have a crucial design/construction interaction	Structures with critical temporary stability or temporary works requirements.

This approach aims to select projects which are large, complex, innovative or unusual (a suggestion already promoted by others) and those with high risk.

- 7 This categorisation derives from a structural safety perspective. However, there may be compelling grounds for an independent review on economic, insurance, business criticality or similar grounds. (The chosen categories tie in with, and expand on, the suggestions made in the SCOSS 14th Biennial Report).

### **Implementation of review**

- 8 The review may be carried out by someone (or a team) from the same organisation as that originating the design, or by an external reviewer. However they must be independent of the originating team.

- 9 Suggested 'rules' for conducting the review are proposed as follows:

- i) To be of value, the review must be conducted at high level\*. It will be to consider whether the design principles are sound, that the construction proposals are properly considered and adequate proposals are in place for execution. To complete such work satisfactorily, the reviewer(s) must be thoroughly experienced and technically aware across the full range of disciplines, design and construction phases, inherent in the project. The reviewer(s) must be technically skilled to a level whereby design submissions can be properly appraised.

*\*The parallel activity of design calculation and code compliance checking should continue to take place.*

- ii) To be of value, all parties in the project must regard the reviewer as a ‘critical friend to the team’. In turn, that implies willingness by the reviewer to help resolve problems in an open manner without losing independence. The reviewer must therefore be someone of integrity, not to be swayed by contractual positions but equally ethically bound not to use confidences to the contractual detriment of any party. The reviewer’s duty is to act independently of the team, but to the benefit of all.
- iii) If the reviewer is to provide maximum assistance, in order to help resolve the inevitable difficulties that arise, (s)he must not be constrained in offering best judgement for fear of financial penalty (civil action), notwithstanding the obligation to use reasonable skill, care and diligence.
- iv) The reviewer must be independent of the team. However, the interaction with the team should be flexible and open with the emphasis on reducing risk and adding value. The review should commence at an early stage so that key project decisions may be considered in a contemporaneous manner. A key focus should be placed on safety and risk reduction through highlighting and addressing concerns. This can very effectively be achieved through presentations by the team to the reviewer along with the generation and maintenance of risk registers. The reviewer should point out errors or concerns and allow the designers to explain their rationale; solutions must be fully owned by the team.
- v) The team should be encouraged to provide the written draft reports and outputs, stemming from presentations, workshops and discussions with the reviewer. The drafts are then assessed and commented on as appropriate by the reviewer. This process thus serves as a useful check on communication and also enables the input and value from the reviewer to be maximised. It also places the onus on the team to address the issues and develop solutions thus maintaining the necessary ownership. However, whilst the onus is on the team, it does not preclude the reviewer from pro-actively making constructive contributions.
- vi) The cost of the review must be proportionate to the risk i.e. it must add value; it is a matter of negotiation between the parties. However the budget must be reflect the required input if the process is to bring any real benefit to those more directly involved.

### **Liability of the Reviewer**

- 10 In order for the independent review concept to work efficiently and to bring added value to the project it is essential that those undertaking the role, whilst using due skill care and diligence, are not constrained by fear of formal action (para 9 iii).
- 11 If the reviewer comes from the same organisation that is employed to design the facility, then the question of liability (in the corporate sense) does not arise. It is then a question of ensuring that internal procedures and culture allow and encourage the reviewer (as an individual or group) to act according to their professional judgement.

- 12 If the reviewer is from a separate organisation from that of the designers then, appointment documents should be constructed to avoid subsequent action. This might appear to be radical; however, if the process is conducted as suggested, with the reviewer being the 'team's friend' and of established reputation, and ownership of change rests with the designers, it becomes a logical approach.

## **APPENDIX B**

### **CENTRE OF CONSTRUCTION INDUSTRY SAFETY EXCELLENCE: CHAIR OF CONSTRUCTION SAFETY<sup>1</sup>**

#### **Background**

Although the construction industry has made significant strides in recent years, in terms of improving its safety record, there is some way to go before it can claim success. It is considered that a major influence in achieving these future improvements will be the role of academia in:

- Delivering the core risk management education to its students such that they graduate, with the appropriate knowledge base
- Providing specialist learning opportunities, e.g. MSc courses, and also
- Providing co-ordinated industry-linked research to allow and encourage knowledge transfer.

At present there is no co-ordinated network between industry, the regulator (HSE) and academia. This is considered to be a significant shortcoming and a barrier to progress.

Whilst ‘risk management’ with specific applications is well understood by academia<sup>2</sup>, ‘health and safety risk management’ is a subject area that much of academia (in the Higher Education Sector) finds difficult to deal with [1].

#### **Introduction**

This paper sets out a proposal for enhancing education in occupational health and safety (within a structural engineering framework), for strengthening the knowledge network between industry and academia in this area, and for identifying, co-ordinating and implementing practical problem-solving research.

The paper considers the issues associated with the establishment of a Centre of ‘construction safety’ excellence, including a professorial Chair of Construction Safety, at a UK University. In this context ‘construction’ is intended to be a holistic term (usefully illustrated through the ‘3Ps’ approach of *people*, *process* and *product* as set out in the 15th Biennial report) applied to the whole process of adding to, maintaining and decommissioning the built environment.

SCOSS is concerned primarily with structural safety and hence the Centre would be expected to have a structural engineering bias in its approach. However this is inextricably linked with ‘occupational safety’ (reflecting also the interests and remit of one of our sponsors, i.e. HSE).

It is considered that what is often referred to as ‘health and safety’ is in fact part of the project risk management process and should be treated as such, hence the more appropriate term ‘health and safety risk management’. This is the approach taken by the Joint Board of Moderators [2] amongst others.

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<sup>1</sup> The title is important: this needs to convey the message that the Chair is interested in safety at all stages of the project process (see text also).

<sup>2</sup> Such as on technical issues or relating to project risk management.

## The rationale

Points that are supportive of such a centre of excellence include:

- The need as a profession to send out a message that our role as providers of infrastructure is underpinned by a need to make sure safety in design, construction and operation is integrated and just as important as any of the other technical issues with which we deal.
- The Royal Academy of Engineering and others have made valuable contributions to the debate over safety but that message needs to be expanded and consolidated into the education curriculum.
- The intellectual demands are formidable: How do we improve safety and how do we measure what we have and decide when enough is enough? How do we tackle the safety issues of an ageing infrastructure? Are we doing enough to reconcile construction safety risk with risk in other areas (e.g. rail)?
- Safety issues are disparate: they apply to fires, crowd control, construction, on-going maintenance, interaction between design and construction, contractual arrangements, terrorism, and so on. These interact with structural safety issues such as safety factors and building design and inspection. So there is a need to collate general principles and provide an education service for the future.
- We do have a strong foundation to build on. Lessons have been learned from other industries e.g. the off-shore industry, the rail industry, from accidents such as that involving the Herald of Free Enterprise, from structural failures, and from large construction projects like the Channel Tunnel, T5 and so on. The chemical industry and nuclear industries have evolved techniques for assessing the safety of plant using Safety Assessment Principles and deterministic and probabilistic techniques. There are administrative procedures such as HAZOPs, which explore failure paths, and skills such as the drafting of Safety Cases that could be more widespread. Yet as a community of engineers we have no recognised centre for the collation, recording, evolving or promotion of all this information. That is inconsistent if we really attach as much importance to public safety as we claim.

These raise a wide range of issues; in taking this proposal forward some rationalisation may be required in order to keep the brief within practical limits.

## Existing University ‘safety’ centres

There are a number of centres of ‘safety’ excellence in existence, in addition to Universities offering ‘safety’ related courses; for example:

University	Centre	Comment
UCL/IC	Centre for Transport Studies	Lloyds Register sponsored Chair (Professor Andrew Evans) in Transport Risk Management.
Aberdeen	School of Engineering & Physical Sciences	Chair of Safety Engineering (Prof Michael Baker). Centre has developed an MSc in ‘Safety Engineering, Reliability

University	Centre	Comment
		and Risk Management' geared towards the oil and off-shore industry. (*Note 1)
Aston	Engineering Systems & Management	Richard Booth, Professor of Occupational Health & Safety. Undergraduate courses but no MSc or substantive research.
Cranfield	Institute for safety, risk and reliability (www.cranfield.ac.uk/safety)	The Institute focuses on trans-disciplinary and multi-sector approaches to safety research, consultancy and teaching.
Liverpool		Is incorporating a generalised risk syllabus developed by HSE/HSL.
Sheffield		MSc in Process safety and loss prevention.
Loughborough	Civil Engineering	Prof Alistair Gibb has led on a number of occupational 'safety' projects. The European Construction Institute (ECI) is also based at Loughborough.

\* Note 1: The Aberdeen programme is closely aligned with one of the ten priority themes identified by EPSRC in its call for outline proposals in January 1999, namely "Risk, Safety and Reliability". Students are drawn from a wide range of first degrees and industries. It was decided not to introduce distance learning.

The need for engineers to have a better understanding of safety and reliability issues stems from the increasing need to try to obtain a suitable balance between excessive safety and consequent waste of resources, on the one hand, and under-design with the possibility of high failure costs and undesired failure consequences on the other (Professor Michael Baker).

There are some elements of this course which will be of direct interest to the construction industry.

There are a number of individuals (e.g. Graham Dalzell) in the process/off-shore sectors that have direct experience of undergraduate inputs.

It is noticeable that there is no existing construction-related centre of safety excellence and hence this proposal would appear to complement rather than detract from existing provision.

### Proposal

The proposal therefore is for the establishment of a centre of excellence for construction safety studies with the inclusion of a chair of construction safety. The scope is suggested as:

- To further the collation and dissemination of information on construction industry safety issues



- To develop links with other university centres with an interest in safety issues such that overall benefit may be obtained
- To develop teaching aids and syllabi (for use throughout academia)<sup>3</sup>
- To develop post-graduate learning opportunities
- To further industry-related research
- To develop partnerships with industry and government agencies
- To review 'risk' terminology and approaches so as to bring clarity and consistency
- To act as a foil to the Regulators bringing balance to arguments submitted respectively by enforcers and practitioners recognising that in partnership the industry needs to set standards as to what constitutes the norm in acceptable safety standards.
- To act as a public figure head in the media on construction safety issues.

It is suggested that the Centre of Construction Safety be supported by a Steering Group (industrial panel) drawn from across industry (e.g. HSE, CIRIA, CIC, CC, CCG) as means of providing guidance and reinforcement of the academia/industry sectors.

These proposals reinforce and develop the arguments put forward by Allan Mann in his joint ICE/IStructE lecture<sup>4</sup>.

### Model of Operation

There are a number of ways in which such a proposal could be delivered.

	Model	Comment
1a	Provision of funding to an existing university department in order to allow progression of a specific project, e.g. development of an MSc course or teaching material.	A schedule of projects should be identified (from a scoping study) from which the work would be drawn. A minimum solution
1b	Part funding to allow existing/new staff member to be appointed as 'Chair' for say 5 years in order to fulfil some specific objectives, e.g.: <ul style="list-style-type: none"> <li>- teaching material for undergraduates</li> <li>- flexible syllabus<sup>5</sup></li> <li>- MSc course in construction safety</li> <li>- to contribute to the debate arising from the bullet points scheduled above</li> <li>- liaison with other existing 'safety' centres in order to co-ordinate research knowledge and joined-up thinking.</li> </ul>	Although appointed to one university the work and modus operandi would be for the benefit of all HE.
2	New Centre, including Chair of Construction Safety.	Would consist of Chair, researcher, research assistants. A major investment. Funding for say 5 years.

<sup>3</sup> This would be a major departure from the norm, whereby the incumbent, although based at one University, would be aiming to benefit academia at large.

<sup>4</sup> *Construction Safety: An agenda for the profession*, 28 April 2005 at ICE.

<sup>5</sup> taking account of syllabus development work at Liverpool John Moore's University (via HSE), Inter-Institutional Group H&S Panel and JBM requirements.

### Cost Estimates

Some preliminary costings have been computed for the options identified above.

**Option 1a:** this will be project related and hence might vary between £50,000 (for a medium sized project) to around £100,000 (staff costs and the like for the establishment of an MSc and teaching material). See also 'offset costs'.

**Option 1b:** this is suggested as a 5 year appointment of an individual. The cost is estimated to be in the order of £375,000 which includes for the salary and associated employers costs, and assumed disbursements (travel etc), but assumes that office accommodation costs and nominal secretarial assistance is provided by the University, at no charge. The Chair would be on a fixed term engagement. See also 'offset costs'.

These costs assume a full time post, fully funded. An industry based salary has been assumed.

**Option 2:** this is a major venture. However it may be possible for the researchers to be funded through existing educational funding routes, and for the accommodation to be provided by the University at no charge. If so, the cost would be as Option 1b, plus the cost of an assistant. This is estimated as £525,000 in all. (Note that Atkins recently announced a 5 year Chair at Greenwich for a reported cost of £750,000. This may include other items. The costs are very dependent upon the assumed 'free of charge' items however). See also 'offset costs'.

### Off-set costs

In all cases illustrated above, the costs could be off-set by:

- any research project income
- the use of existing academic posts, which only require 'top-up' costs to be met in order to achieve 'Chair' status
- contribution or match funding by the University or others as has been the case in other similar examples
- sponsorship (this is examined below)
- industry levy.

### Sponsorship Funding

Funding sources need to be identified and followed through. These would include:

- Public sector e.g. HSE
- Private sector e.g. Construction industry organisations and companies
- Education/Engineering funding bodies: e.g. EPSRC, RAE.

### Deliverables

It is suggested that specific deliverables include:

- Development of a teaching syllabus and associated material on construction safety for undergraduate courses in Civil/Structural Engineering
- Development of specialised MSc courses
- CPD courses for academics involved in teaching of civil and structural engineering

- EPSRC Network co-ordinator<sup>6</sup>
- Establishing industry geared ‘risk terminology’ for improved communication and better understanding within industry and with the public.
- Identification of industry related research needs
- Implementation of specific research.

The scope and the deliverables will be constrained by the level of funding obtained.

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<sup>6</sup> Drawing together disparate groups with a common interest in order to make a credible application for research funding and to raise the profile of this area with EPSRC.

## **APPENDIX C**

### **STRUCTURAL SUBMISSIONS UNDER THE BUILDING REGULATIONS, PART A: MINIMUM COMPETENCE STANDARDS AND PROVISION OF INFORMATION**

**This note relates to England and Wales**

#### **1 Introduction**

- 1.1 Demonstration of compliance with Part A of the Building Regulations is an important safeguard against an inadequate margin of safety. This is a legal requirement that is usually discharged through compliance with the ‘deemed to satisfy’ codes of practice scheduled in Approved Document A.
- 1.2 Good practice would suggest that the submission made to Building Control is to a professional standard (regardless of whom actually makes the submission) reflecting the safety-critical nature of the submission, the technical complexity, and the legal obligation. This infers that the submission should:
  - i) clearly set out the key assumptions so that those assessing it may understand the approach taken.
  - ii) be co-ordinated
  - iii) be checked

Unfortunately, these basic requirements are frequently not achieved and there is no formal guidance on the matter.

This discussion note sets out what are considered to be:

- the essential standards and
- points of information that should be given at the beginning of the submission/calculations.

#### **2 Background**

- 2.1 Despite the fact that structural engineering is safety-critical (and formally recognised by HSE as such), there are no pre-requisites placed on those who choose to make submissions. The introduction to BS5950 (steelwork design code) states:

*It has been assumed in the drafting of this British Standard that the execution of its provisions is entrusted to appropriately qualified and experienced people and that construction and supervision should be carried out by capable and experienced organisations.*

Similar expectations apply to other material design codes of practice.

- 2.2 The use of standard details from Part A may signal to some that no specific expertise is required.

- 2.3 Those ‘designers’ who are submitting designs in furtherance of a business activity, have legal responsibilities under the Health and Safety at Work Act and in particular, the CDM Regulations, no matter what the size of project. They also have a duty of care under civil law. Unfortunately, those ‘designers’ who are not part of a business, typically general householders, have no responsibilities under HSWA.

Notwithstanding, existing legislation is a blunt tool in terms of ensuring standards are attained.

- 2.4 The process of determining compliance with the Building Regulations by local authorities has been significantly affected by a combination of:
- i) the obligation to recover their costs in discharging these duties, often leading to severe constraints on input,
  - ii) a lack of suitably competent staff,
  - iii) the influence of Approved Inspectors.
- 2.5 This situation needs to be viewed against the effect of commercial pressures on industry, skill shortages and the introduction of new codes of practice in respect of the maintenance of standards.
- 2.6 There is strong anecdotal and direct evidence to suggest that the current situation is undermining the importance of structural engineering to the health, safety and welfare of those in and around buildings, and is creating a situation where there is an ‘accident waiting to happen’.

### **3 Essential competence standards**

#### **Individuals**

- 3.1 Part A is concerned with structural safety. The analysis, design and checking of structures to ensure structural safety requires competent input. There are examples where even the simplest of ‘designs’-even using standard details- can lead to problems if the wider implications are not understood.
- 3.2 Ideally those undertaking this role should be members of an appropriate professional institution e.g. IStructE or ICE. Alternatively, they should be able to demonstrate appropriate competence in respect of education, training and experience.
- 3.3 In most cases it is not appropriate for someone without this background to be involved, regardless of the scale of the work.

#### **Submissions**

- 3.4 Submissions should be presented in an acceptable format i.e. one that allows ready assessment of the technical detail, methods used, software adopted.
- 3.5 Those originating submissions should not rely on the building control approval process as a primary check on their work. Anyone undertaking structural design has an obligation to satisfy themselves that it meets accepted standards and that they have exercised due skill and care.

## 3.6 All submissions should:

- Justify structures as structurally stable and complete (even if further elements of the project are yet to be submitted). A check cannot be undertaken on an incomplete structure.
- Include sufficient quantities of co-ordinated drawings and details to allow a proper understanding of the submission,
- Explicitly identify the party responsible for each element of design, and for overall stability.

#### 4 Essential information

4.1 In order that submissions may be adequately assessed, it is suggested that all submissions should schedule the answers to the following technical questions on a frontispiece to the calculations:

	Question	Comment
1	Is the submission made on a 'deemed to satisfy' basis ?	If only in part, describe the boundary.
2	If yes to Q1, list the structural design codes with which it complies:	This is particularly important as we will be entering an era when Eurocodes will be used alongside existing codes.
2a	If Yes to Q1, and the submission utilises standard details from Approved Document A, confirm that the structure satisfies any limitations on the use of these details.	
2b	If no to Q1, explain the basis of design	This requires sufficient detail to allow others to understand the structural principles used.
3	Into what class has the structure been placed for purposes of disproportionate collapse design (Table 11 of AD-A)	If the structure is in a number of classes describe the division.
3a	Describe: i) how the class has been arrived at, and	i) This is particularly important with existing structures which are subject to a material change.
	ii) the measures taken to guard against progressive collapse.	ii) The Approved Document allows a number of structural options.
4	Describe (illustrating as required to give sufficient clarity) the load-path to the foundations and how lateral stability is achieved.	This should deal with both the final and key interim construction stages.

5	Confirm that: i) the structure may be safely built and,	i) A requirement of the CDM Regulations
	ii) that suitable information in this regard will be made available to the contractor.	ii) In all but simple cases this should include a description/diagram of the assumed construction sequence of the key members, illustrating any issues relating to interim stability (see Q4).
6	Name the organisation, or individual, which has overall responsibility for the stability of the structure as required by BS 8110, 5950, 6828 as appropriate.	See Clause 1.02 (BS5950); Foreword (BS8110), Clause 1 (BS5628) and Clause 1.3 (EN 1990).
7	Schedule the software used, and for what purpose; confirm that its application and limitations are understood and that the results have been verified.	

### *Software*

- 4.2 The ubiquitous use of software has made the review process difficult. Many submissions are made with an abundance of output but without any explanation as to assumptions, limitations, defaults and the like. Software is often misused.

## **5 Conclusions and Recommendations**

- 5.1 The Building Regulations approval process should be as simple and open as possible, consistent with safeguarding the health, safety and welfare of those in and around buildings. However it also needs to recognise that:
- i) structural engineering is safety-critical
  - ii) submissions must be made by competent persons
  - iii) submissions need to make clear the fundamental assumptions on which they are formulated.

**APPENDIX D**

**PROPOSAL FOR A ‘WORKING ENGINEER’S’ GUIDE ON STRUCTURAL ROBUSTNESS AND DISPROPORTIONATE COLLAPSE**

**Background**

SCOSS has become aware from a number of sources of concerns relating to the topic of robustness generally and disproportionate collapse specifically. This concern was articulated most recently at the workshop initiated and sponsored by SCOSS and held at IStructE on 30 October 2006.

It is clear that there is wide support for a guidance document, aimed at practising engineers, giving basic advice and solutions to common situations.

The aim of the guide would be to:

- Clarify the definitions, mechanisms and relevance of robustness and progressive collapse
- Summarise the requirements (and limitations) of the Building Regulations and the ‘deemed to satisfy’ material design codes (including incompatibilities and inconsistencies between codes).
- Illustrate, material by material, the specific issues and suggested solutions (*if required*)
- Illustrate solutions to hybrid construction and inter-material problems,

i.e. a practical explanation and guide to all structural designers and building control authorities which will enable consistency in the implementation and enforcement of design for robustness.

It is intended to be a working guide, not a thesis on the subject.

This note sets out a proposal for such a guide, and a suggested route for its production.

**1 Scope**

1.1 The scope has been derived from consideration of the concerns expressed though the SCOSS Workshop, the Verulam column in *The Structural Engineer*, and other contacts with industry. It is suggested as follows:

<b>1</b>	<b>Introduction</b> - background - need for guide - aims - limitations
<b>2</b>	<b>Terms and definitions</b> - clarification of common terms
1	Robustness
2	Progressive collapse



<b>3</b>	<b>Building Regulations - Part A3</b>	
	1	Requirements - general - Class 1, 2A, 2B, 3
	2	Issues associated with existing buildings - classification - multiple ownership - hybrid construction
	3	Standards of submission - assumptions - use of software - single point of responsibility
<b>4</b>	<b>Design Codes and standards</b>	
	1	Current codes and comparisons - general (introductory assumptions) - technical issues - limitations
	2	Eurocodes (EN 1991-1-7) - assumptions
<b>5</b>	<b>Issues and solutions by material</b>	
	1	Steel (hot and cold formed), including composite construction
	2	Concrete (including precast work)
	3	Masonry
	4	Timber (including proprietary fabrications)
	5	Hybrid constructions
	6	Alterations and extensions
<b>6</b>	<b>Bibliography</b>	

**Note:** It is likely that the scope and content will evolve. The intent of chapters 1-4 is to describe (as needed) material specific issues. The problems associated with inter-material applications and hybrids would be covered in 5. Section 5.5 and 5.6 specifically will evolve with drafting and discussion.

- 1.2 The guide would take cognisance of other work in this area in order that it did not duplicate effort, including publications by NHBC, the material sectors, e.g. SCI and in *The Structural Engineer*. It is expected that guidance for class 3 structures will be limited to buildings which can be justified as needing no more than to comply with the criteria for class 2B.
- 1.3 The guide is not intended to be an academic treatise on this subject; it is intended for the practising engineer and building control authorities with the emphasis on safe design details, rather than the theoretical background.

**Endnote**

- 1 The initial idea for this guide came from SCI. SCOSS is grateful for their support in this respect.
- 2 Following discussions between SCOSS and IStructE, the latter has agreed in principle to the production of this guide. This is considered to be an important step forward.

## **APPENDIX E**

### **THE ASSUMPTIONS BEHIND THE EUROCODES**

#### **Introduction**

- 1 All design codes of practice are constructed around a number of assumptions and limitations; these relate to the competency of those using the code, the analysis and design process and the material itself. In current codes of practice these assumptions generally feature in the Foreword or Introduction e.g. BS 5950, Clause 1.02<sup>1</sup>. This note considers the implications of the equivalent assumptions relating to the structural Eurocodes which are given in BS EN1990.

#### **Eurocode requirements**

- 2 BS EN 1990 (Basis of design) states in Clause 1.3 that ‘*A design which employs the Principles and Application Rules is deemed to meet the requirements of EN 1990, provided the accompanying assumptions are satisfied*’. These six assumptions are fundamental to achieving compliance with the Eurocodes generally, and, specifically, the execution of safe structures. It is important these assumptions are not forgotten amongst the technical detail BS EN1991-9, and that designers have a strategy for ensuring they are met. They are examined in paragraph 7.
- 3 Clause 2.2 states that: ‘*the reliability required for structures within the scope of EN1990 shall be achieved by:*
- *Design in accordance with EN1990-1999*
  - *Appropriate execution*
  - *Quality management procedures*’.
- 4 Clause 2.5 (Quality Management) refers to ‘*organisational measures*’ and ‘*controls at the stages of design, execution, use and maintenance*’ being in place.
- 5 There is a note (following Clause 2.5) which indicates that EN ISO 9001: 2000 is an acceptable basis for quality control management, where relevant. Hence there is an assumption that a structured quality control system is required although not necessarily one which is formally registered.
- 6 Annex B to BS EN1990 (Management of structural reliability for construction works) provides greater explanation and is referenced in the commentary to assumption 3.

#### **The six assumptions behind Clause 1.3**

- 7 These assumptions are scheduled below, together with a commentary:

7.1 *1-The choice of the structural system and the design of a structure is made by appropriately qualified and experienced personnel.*

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<sup>1</sup> This requires one person to have overall responsibility for structural stability. It is noted that the Eurocodes do not have any similar explicit requirement.

- 7.1.1 The choice of an appropriate structural system and the adequacy of the associated design are clearly very important. SCOSS has advocated project risk reviews [1] which would allow this assumption to be tested in the early days of a project. In so far as these choices might affect safety, the Construction (Design and Management) Regulations 2007 (CDM) also require consideration to be given to the structural system and design process. The considerations might include:

Choice of system	Does this provide adequate robustness? Can it be safely and economically constructed and maintained? Will interfaces be appropriately engineered and controlled? Is it an established system, used in normal circumstances, or is it unusual in some way?
Structural model validation	Does the structural model sufficiently represent the actual structure? Are the sensitivities of the model known?
Output verification	Has the input been checked and the output reviewed to determine its accuracy within acceptable bounds?
Codes and their applicability	Does the proposed structural analysis extend beyond the code limitations; are there additional actions that need consideration?  Eurocodes do not necessarily include all elements of comprehensive design. Excluded items will generally be identified in the National Annex (NA), but on occasions critical issues may lie outside the scope of these also.
Non-codified items	A project specific assessment should be made to ascertain if there any items of note outwith the EN or associated NA.
Interim stability issues	It is essential that interim stability issues are identified by the designer. Have these been examined and identified in some way e.g. on the drawings?
Measures to prevent progressive collapse	Do the adopted measures provide the robustness required? Do they take account of interfaces between different materials and/or proprietary units?
Actions	Has the design taken account of all foreseeable actions?
Personnel	See 7.2 below.

- 7.1.2 A record of such a review should be retained in the project files.

7.1.3 SCOSS is currently developing a guidance note relating to the independent review of certain structures [2]; this would greatly assist in compliance with assumption 1 in these cases.

7.1.4 The use of appropriately qualified and experienced personnel is commented on in 7.2 below.

7.2 *2-Execution is carried out by personnel having the appropriate skill and experience.*

NOTE: in this clause it is assumed that ‘execution’ is meant in the dictionary sense of ‘performing a task’, and hence it encompasses ‘design’ as well as ‘construction’. Elsewhere in the Eurocodes it excludes design activity.

7.2.1 The need for personnel who have the appropriate skill and experience is a requirement which relates to both the design phase and the execution phase. Both phases are commented on in this section and fall within the ambit of the Construction (Design and Management) Regulations 2007 (CDM 2007).

7.2.2 These regulations require those involved in ‘construction work’ to be competent unless under supervision. The associated Approved Code of Practice (ACoP) [3] gives guidance in respect of the corporate competence of the organisations and of the individuals involved. It is important (and a specific requirement) that those who lack competence e.g. from a shortage of experience, are allocated appropriate supervision.

#### *Design*

7.2.3 In the early days of Eurocode application few design practitioners will have any experience in its use. Hence the supervision, checking and review processes will need to reflect this ‘immaturity’ to ensure that an appropriate level of confidence is attained. Although much of the Eurocodes is similar to existing codes of practice such as BS 8110 or BS 5950, there are some key differences which could lead to errors until fully assimilated into contemporary practice e.g.:

- in steel design the orientation of the x-x and y-y axes differ to current practice
- the Eurocodes adopt the continental style of ‘,’ for a decimal point. Thus, 2.34 is given as 2,34, and spaces are introduced, e.g. 1 000 in lieu of ‘,’
- new software that does not have the benefit of established use to have identified any bugs/misinterpretations.

7.2.4 Further examples of potential misunderstandings are given on the SCOSS website, on the Eurocode Expert website ([www.eurocodes.co.uk](http://www.eurocodes.co.uk)) and in occasional ‘Q&A’ articles in *The Structural Engineer*.

7.2.5 Part of the project risk assessment (illustrated in paragraph 7.1.1) should be devoted to an assessment of the proposed design staff.

*Contractors*

7.2.6 Designers may need to alert the client to any specific requirements, relating to those who may construct the structure. These might relate to the complexity of the structure or fabrication needs. These can then be ensured during the pre-qualification and tendering process. Particular attention should be paid to ensuring the requisite standard is applied to all subsequent sub-contract arrangements.

7.3 *3-Adequate supervision and quality control is provided during the execution of the work, i.e. in design offices, factories, plants, and on site.*

NOTE: in this clause 'execution' is meant in the dictionary sense of 'performing a task', and hence it encompasses 'design'.

7.3.1 The requirement for adequate supervision and quality control is applicable to all stages of the project. It is clear from paragraph 5 that such supervision and quality control should be of a recognised standard, broadly consistent with one complying with ISO BS 9001.

7.3.2 Most sections of the Eurocode have references to other BS ENs which spell out the requisite quality standards relating to the construction stage e.g. BS EN 3834 (welding); BS EN 13670 (execution of concrete structures) and, until such time as the National Annex is available, the National Structural Concrete Specification (NSCS).

7.3.3 There are no specific cross references to the supervisory levels or quality control of designers. This links back to paragraph 7.2.3.

7.3.4 EN1990 allows for some variation in supervision and quality control, within the scope of a recognised quality management system, depending upon the classification of the structure (Annex B Table B4 and B5). These tables are repeated below.

7.3.5 The 'RC' classification in the tables refers to a structure's reliability; it relates to the consequences of failure, as noted below (see also Table 8.4 of ref 10):

<b>Consequence Class</b>	<b>Reliability Class</b>	<b>Description and examples</b>
CC3	RC3	<b>High</b> consequence: grandstands, public buildings
CC2	RC2	<b>Medium</b> consequence: residential or office buildings
CC1	RC1	<b>Low</b> consequence: agricultural buildings

## 7.3.6 Designs to the Eurocodes will normally be based around CC2/RC2

Table B4

<b>Design Supervision Levels</b>	<b>Characteristics</b>	<b>Minimum recommended requirements for checking of calculations, drawings and specifications</b>
DSL3 (relating to RC3)	Extended supervision	Third party checking.
DSL2 (relating to RC2)	Normal supervision	Checking by different persons than those originally responsible and in accordance with the procedure of the organisation.
DSL1 (relating to RC1)	Normal supervision	Self checking: performed by the person who has prepared the design.

7.37 Checking ‘... *in accordance with the procedure of the organisation*’ is taken to mean in accordance with the design organisation’s quality control system noted in paragraph 5. Annex 5 B4 clause (2) states that *design supervision levels may be linked to these reliability classes or the importance of the structure, in accordance with National requirements or the design brief*, and implemented through the quality management measures mentioned in paragraph 5.

7.38 Without supplementary clarification, this is considered to be too vague; it is suggested therefore that it will need careful clarification on a project by project basis and should feature also as part of the project risk review.

Table B5

<b>(execution) Inspection levels</b>	<b>Characteristics</b>	<b>Requirements</b>
II3 (relating to RC3)	Extended inspection	Third party inspection.
II2 (relating to RC2)	Normal inspection	Inspection in accordance with the procedures of the organisation.
II1 (relating to RC1)	Normal inspection	Self inspection.

7.39 Inspection ‘in accordance with the procedures of the organisation’ is taken to mean in accordance with a quality control system noted in paragraph 5. However this relates to the procedures of the ‘executing’

organisation i.e. the contractor, which may not match the expectations or requirements of the designer. Hence, this may require contractual clarification.

7.4 *4-The construction materials and products are used as specified in EN 1990 and ENs 1991 to 1999 or in the relevant supporting material or product specifications.*

7.4.1 This must be achieved through adequate contract documentation, coupled with appropriate supervision as noted in 2 above. SCOSS is aware, for example, that:

- changes are sometimes made on site to specified items [4], without the necessary involvement of the designer.
- some products are incompletely specified e.g. steel [5].

Such occurrences will invalidate this assumption.

7.4.2 The use of CE marked products, in accordance with the Construction Products Directive, is becoming more common and will further accelerate in the near future. It is important that the scope and limitations of EU driven certifications measures are understood [6, 7, 8] and that construction contracts contain appropriate controls.

7.5 *5-The structure will be adequately maintained*

7.5.1 As is the case with current codes of practice, the partial safety factors for materials denoted in the Eurocodes do not allow for deterioration. Hence it is important that structures are maintained during their life to avoid diminution of the safety margin. This need requires designers to produce a *maintenance philosophy strategy* or similar statement: *CIRIA* describes how this might be done [9]. The essence of this advice is that maintenance should be discussed during the design phase and that the client should buy-in to the strategy proposed. The statement should set out the assumptions regarding the nature of maintenance, its frequency and the assumed means of access and egress; it should consider also, as appropriate [10]:

- Costs of design, construction and use
- Costs arising from hindrance of use
- Risks and consequences of failure of the works during its working life and costs of insurance covering these risks
- Planned partial renewal
- Costs of inspections, maintenance, care and repair
- Costs of operation and administration
- Disposal
- Environment.

7.5.2 BS EN1993-1-2 (Fire) Clause 1.3 adds the comment that ‘any passive fire protection systems taken account of in the design should be



adequately maintained'. Hence for this to be realised the required actions must be passed on to the client, or those responsible for maintenance. In the case of buildings, the Approved Document for Part B requires the designer to make appropriate information available to those in charge of the building in order that the Regulatory Reform (Fire Safety) Order 2005 may be complied with.

7.5.2 Such considerations are supported by the requirements of CDM 2007 in respect of the need to eliminate safety hazards and reduce risk, to pass on information, and to contribute to the Health and Safety File. It is anticipated that the client interaction suggested will encourage discussions on 'capital' versus 'whole-life' costs.

7.5.3 A key element of any maintenance regime is 'inspection', the detail of which will vary, structure to structure. Specific structures already have detailed guidance in respect of maintenance e.g. car parks [11] and bridges [12].

7.5.4 In all cases the client should clearly understand the safety implications of failing to implement maintenance in a competent manner.

7.6 *6-The structure will be used in accordance with the design assumptions.*

7.6.1 Structures may be designed to a client's specific requirements or to general standards. However, in neither case is the client likely to appreciate the engineering limitations on the structure.

7.6.2 This Eurocode assumption will require designers to schedule the key design assumptions regarding:

- i) Its 'Use' (as assumed in the design)
- ii) Design life
- iii) Design actions
- iv) Means of achieving resistance to progressive collapse
- v) Details of any special (project related) actions considered.

7.6.3 This data should feature as part of the Health and Safety File, if there is one, or communicated to the client in some other way in other cases (preferably via the drawings).

## Summary

8 If current designs are given as being 'in accordance with a specified BS' it infers that measures have been taken to ensure compliance with the assumptions given in the Foreword and Introduction of the named code. Evidence suggests that this is not always done.

The advent of the Eurocodes provides a useful opportunity to remind ourselves of these assumptions and to have particular regard to the six assumptions given in BS EN1990. This Appendix is intended to be an initial attempt to identify the key issues.

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12. Roads Liaison Group. *Management of highway structures: a code of practice*. London, TSO, September 2005

**APPENDIX F****MEMBERSHIP OF THE COMMITTEE***Chairman*

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## **APPENDIX G**

### **SCHEDULE OF TOPICS DISCUSSED AND OTHER COMMITTEE ACTIONS DURING THE PERIOD 2005-2007**

#### **Topics**

- Blind bolts
- Building regulations: standard of submissions
- Centre of construction safety excellence
- Education in the history of structures
- Embedded wind posts
- Eurocodes: assumptions
- Eurocodes: misunderstandings
- Flat slabs: punching shear
- Independent review of structures
- Limestone aggregate in reinforced concrete (shear capacity)
- Robustness: progressive collapse
- TV screens as used at outdoor entertainment events

#### **Alerts**

- Stainless steel in swimming pool environments
- Timber joist hangers

#### **Sponsorship of events**

- ICE 3rd international conference on forensic engineering: *Diagnosing failures and solving problems* (10-11 November 2005)
- ICE conference: *Structural safety across the lifespan of buildings* (4 October 2006)
- Robustness workshop: *Issues associated with class 2A/2B buildings - disproportionate collapse* (30 October 2006)
- ICE seminar on software: *Quality assuring the use of structural analysis and design software* (3 May 2007)

#### **Other**

- Confidential Reporting on Structural Safety (CROSS)