

# Development of CROSS - Confidential Reporting on Structural Safety

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## Introduction

The Standing Committee on Structural Safety (SCOSS) has operated since 1976 by gathering information from general sources about structural failures and incidents, considering the reasons underlying these, and publishing sixteen biennial reports containing the findings. Specific alerts and papers have been issued from time to time. However it was decided that a more formal system was required to obtain additional data on trends in failures and potential failures, so the Confidential Reporting on Structural Safety (CROSS), was launched in 2005. It is a programme for collecting, analysing, and publishing concerns about the safety of structures. The purpose is to learn from the experiences of engineers and others, and disseminate information from these experiences for the benefit of the public and those throughout the construction industry. Similar programmes are used in aviation and several other areas where the control of risks is important, but this is the first for an engineering discipline. Although suitable mechanisms for collecting data were available, a system had to be developed that applied to structures.

There are other reasons for changing the mode of operation for SCOSS to keep pace with developments in construction. Overall there is a perception that skill levels are dropping and the need for education and training at all levels is increasing. Contractual relationships have altered and there are weaker links between some of the participants in a project than there used to be so that risks may not be recognised. The technology of information exchange has altered dramatically bringing both advantages and disadvantages to safety regimes. Applications to local authorities and third party checkers range widely from those containing low quality material with no engineering input, to electronic submissions with large volumes of computer output and many hundreds of drawings. Both create difficulties, and these and other changes have to be accommodated to keep SCOSS up to date and relevant.

In short SCOSS wants to:

- acquire more evidence about concerns
- get to a wider audience
- break new ground in terms of usefulness
- disseminate findings more quickly
- become more influential in its quest for improvements.

## Procedures

There are barriers to reporting and one is that the identity of the author, their employer, the client, the site, or a product may be revealed with negative consequences. The model for CROSS was Confidential Human Impact Reporting Programme (CHIRP), the UK aviation system which in turn has links to the Aviation Safety Reporting System (ASRS) - the incident reporting service for pilots in the USA. The assistance of both organisations in helping to establish Confidential Reporting on Structural Safety is gratefully acknowledged. The process for handling reports has been adopted and adapted from their procedures. At the most confidential level a reporter downloads a form in pdf format from the CROSS web site, fills in the details, and sends it to a Post Office Box. The envelopes are opened only by one senior person, the technical details are reproduced, but not the name or details of the reporter, and the original report is returned to the reporter with a reference number. No record about the reporter is kept and there is no electronic trail. CROSS therefore has no means of contacting the reporter, but the reporter can get in touch with CROSS by using the reference number.

It has been found that many reporters do not want or need this level of confidentiality so an email form is also available which is simpler and quicker. Some reporters want only to send informal correspondence, perhaps as a follow up to a published report, which is also done by email. All methods are acceptable provided the report can be verified as genuine, usually by talking to the author. Reports are de-identified and stored in a secure manner.

This is the first stage of a procedural loop and the second is to categorise and analyse the report. There does not appear to be a recognised taxonomy in general use for engineering events so an initial process for sorting the data has been used. The designations are:

<b>Category</b>	<b>Information requested</b>
Reporter	membership of an institution, job description
Reporter's Organisation	type and size
Project	age of project, individual project or series, stage
Construction	structure type, principle materials used
Scale of concern	actual or potential collapse, importance
Identification of concern	design, construction, operation, demolition, other

The intention is to expand these categories in future so as to collate information on the reasons for the concern and hence produce more statistical evidence. It will also be valuable to extend the classifications into the fields of human interaction with the circumstances of events, and systems to do this may be developed later. However such is the complexity of most failures, or near failures, that simple classification may not be the best way to describe events. Thought is being given to other ways of identifying potential weaknesses and issues of concern.

To consider the de-identified reports there is a panel of experts comprised of SCOSS members and other voluntary appointees. There are representatives from consulting engineers, Health & Safety Executive, contractors, and local government and central government. They review the reports and give recommendations on the practices that might be followed to avoid repetition in the future.

The third stage of the loop is to disseminate the information. De-identified reports with expert comments are published quarterly in Newsletters on the internet ([www.scoss.org.uk/cross](http://www.scoss.org.uk/cross)) and email notifications are sent to those who have registered an interest. Generally these are civil and structural engineers and building surveyors but anyone can register. Announcements about the Newsletters are made in the electronic newsletters of the Institution of Civil Engineers (ICE) and the Institution of Structural Engineers (IStructE) and other media outlets.

The fourth and final stage is to influence changes in behaviour so that there are checks or reminders that may help to prevent the same type of events happening again. In important situations SCOSS will issue an industry wide alert, such as was done in 2008 for fixings. Other methods are to bring issues to the attention of institution technical committees, to government departments, and to industry associations to pave the way for their introduction into guidance documents. In specific instances SCOSS may talk to a supplier or individual company to point out that a report, or a number of reports, may have implications for that organisation.

## Reported concerns

Reports have been about collapses, failures and potential failures, building control issues, and near misses amongst other topics. Design, construction, normal use, maintenance and demolition have all been subjects of interest and an initial report can lead to the submission of further similar examples and hence the detection of a trend. Issues identified include: quality of design, inadequate experience or skills shortage, divided responsibilities, temporary works failures, fixing and bolt failures, corrosion and deterioration, warnings, and demolition.

## Quality of design

The greatest number of reports has been about the poor quality of Building Regulations submissions including concerns about inadequate calculations, sometimes from non-engineers but also from larger firms and component suppliers. Particular attention has been drawn to poor submissions for minor works and alterations to existing buildings. There are also reports about specific categories of building where the quality of design is not satisfactory. Major categories are shown in Figure 1.

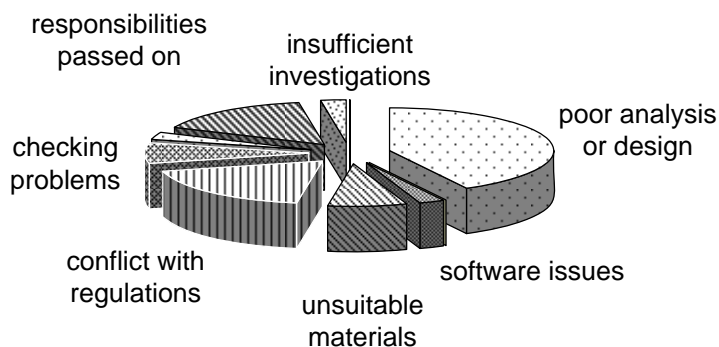


Figure 1 Design concerns

The experience of some reporters is that engineers routinely rely on local authority building control departments to check their work in lieu of proper in-house quality control. One reporter believes that some senior engineers or sole practitioners have either lost or have not attained the skills to reliably produce complex structural designs. This can result in poor quality submissions to building control. Of special concern to reporters is the use of software without any explanation of what is being done or indeed without any understanding of the process.

According to other reporters it has become apparent over the years that the standard of submissions being made has dropped significantly. These include submissions with no drawings or details, submissions with missing information, designs with no co-ordination between the elements, schemes with restricted engineering involvement and submissions from unqualified persons. Another problem is the increased use of manufacturers' details and proprietary systems. Many designers (and checkers) assume that these are correct but this is not always the case and there are also instances of incorrect interpolations of manufacturers' details. Worries have also been expressed about the increased complexity of design due to the implementation of Eurocodes.

At the root of these issues, say some reporters, are the low costs allocated to design by consultants because of fee competition and the need for local authority building control departments to be self financing. The net result is that in many instances inadequate checking is being undertaken. This may be unlikely to result in failures of buildings in the short term but could result in a disproportionate number of incidents once the design loads are achieved during periods of extreme weather or unforeseen loading conditions.

Brickwork garden walls have collapsed with serious consequences, including death and severe injuries, but it may be that these walls were not designed, but simply built on an ad hoc basis. There are of course publications giving recommendations for safe construction but it would be sensible to incorporate free standing walls in the Building Regulations. Other examples given of apparently minor works but with serious potential if they collapse are street light foundations and advertisement hoardings.

### **Inadequate experience and skills shortage**

A subject of continuing interest to SCOSS has been liquid metal assisted cracking when assemblies of structural steelwork have been hot-dip galvanised. Deformation, cracking, and indeed complete failures of members have occurred. In at least one reported case cracks were filled with galvanising material and a potential collapse only became apparent as construction loads were applied and the cracks opened.

Other examples of inadequate experience have included collapses during demolition due to combinations of circumstances that could have been avoided if more skilled operators or supervisors had been on site. Even the improper use of joist hangers in houses has been reported leading to failure because the joists have been loaded before there was sufficient dead load of masonry on the end of the hangers.

Missing elements in reinforced concrete construction have been the subject of several reports including rebars that have been omitted, mis-matched connectors, wrongly placed reinforcement, inadequate cover and bad detailing. Problems range from matters that were found to be deficient

before concreting to collapses of partially built structures. Steelwork deficiencies have also been reported such as wrong materials delivered to site, erection failures, and near misses. Figure 2 gives the main categories for concern about the construction process.

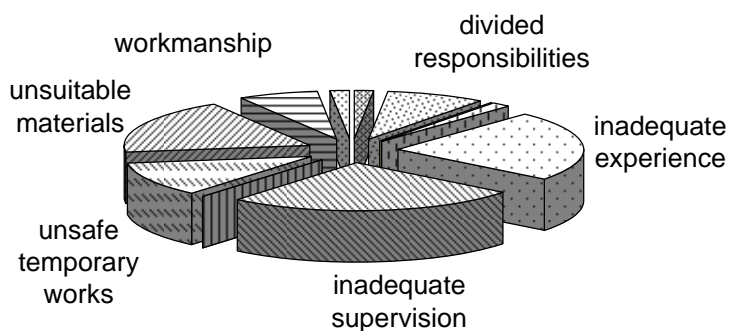


Figure 2 Construction concerns

### Temporary works and construction events

There are buildings, often small and often involving modifications, that will be perfectly adequate when complete but there are reported short comings in the execution. Unsuitable props adapted from standard components attracted the attention of some reporters as did inadequate scaffolds and inadequate protection of roadside scaffolds. There were instances of buildings where load bearing elements including complete floors had been removed with only minimal or indeed no propping. One report relates to a brickwork building with several storeys undergoing modifications. Part of a wall at ground floor level had been removed and insufficient propping had been provided resulting in floors above moving downwards and rendering the building unstable. This is typical of reports about a lack of proper engineering input. Wrongly sequenced under-pinning was also mentioned as a reason for concern.

There is no requirement for a method statement to be submitted with a Building Regulations application, and unless there is a visit by an engineer or building inspector to spot problems then failure can result if there is inadequate knowledge about temporary works. Indeed the fundamental issue may be that these deficient operations are carried out in an environment where there is no engineering input whatsoever – until that is when a problem becomes evident and engineers are called in.

Wind causes failures in various circumstances according to reports. Some internal masonry walls are built before the facades are complete and are blown down. Secondary elements on claddings have been blown off due to poor detailing, site hoardings have blown down because of a lack of appreciation of wind loads, and gables have been sucked off because they are not enough ties to the main structure.

Another example of inappropriate changes on site involved during the construction of two blocks of flats, with masonry walls and pre-cast concrete floors. The contractor requested that he be allowed to substitute an alternative make of steel lintols for those specified by the structural

engineer. This was agreed to in principle but the alternatives did not perform as required because the type selected was not as good as originally specified, with subsequent serious damage and costly repairs.

On a multi-storey building with concrete cores and a simple steel frame the consulting engineer provided shear loads for the beam to column connections. These were designed by another engineer for the fabricator to carry, as specified, vertical shear only. Unbeknown to this engineer there was then a change of plan and the contractor decided to build the concrete cores after the steel frame was complete. This was only noted when most of the frame was erected and concrete floors had been placed; so that there was no capacity in the structure to absorb any lateral load from wind or eccentricity. To make matters worse the frame was draped in tarpaulins thus increasing the wind profile. Fortunately the fabricator's engineer, who had not been involved since the earliest stages, realised the implications when he saw the site and temporary bracing was rapidly installed. A potentially serious collapse was averted.

### **Fixing and bolt failures**

A significant number of failures of fixings have been reported. The lining panels of a tunnel came loose due to incorrect selection of fittings. There were four cases of heavy ceiling collapses all of which happened, fortunately, when there was nobody underneath. These were acoustic mass barrier ceilings of much greater weight than normal. A lack of appreciation of the loads that would be applied when the ceilings were installed led to the use of fixings that were inadequate. An example of how serious can be the failure of overhead fixings was the collapse, with fatal consequences, of pre-cast concrete linings in the Boston tunnel in 2006.

Toggle bolts, or blind bolts, were the subject of two reports when partial collapses had occurred as a consequence of their failure. It may be relevant that such bolts are not covered by a British Standard, and in one case the tensile qualities of the bolts were suspect and in the other there were shear failures. Discussions with suppliers have led to changes in the way in which the bolts are described and their properties are given.

A type of lifting eye bolt caused concern when a weld failed and it deformed under a load which it should have been perfectly capable of carrying, causing a concrete component to fall to the ground. The suppliers took on board the representations of the contractor who was involved and changed the design of the bolt.

In many of these failures the engineer for the project has been remote from the events described, at least in the critical time before collapse. Fixings are usually specified at a level quite far down the construction chain and when purchased may be a different type than was envisaged. There can also be variations at the installation stage with the wrong size or method used and these alterations to the original concept are not picked up by inspection.

### **Corrosion and deterioration**

Hidden fastenings can corrode without warning and there have been reports of substantial falls, again fortunately without serious consequences. The mechanism for a lifting bridge over a canal

had a 22 tonne concrete counterweight suspended over a roadway. Fixings, which could not be inspected, corroded over time and the counterweight fell. There could easily have been a car underneath. A church built as a composite masonry structure has granite cladding on the front façade and steel joists as lintols behind the door and window openings. The steel corroded over the years and the resulting expansion pushed off large pieces of granite which fell without warning. Figure 3 shows the major categories of concern about operational matters.

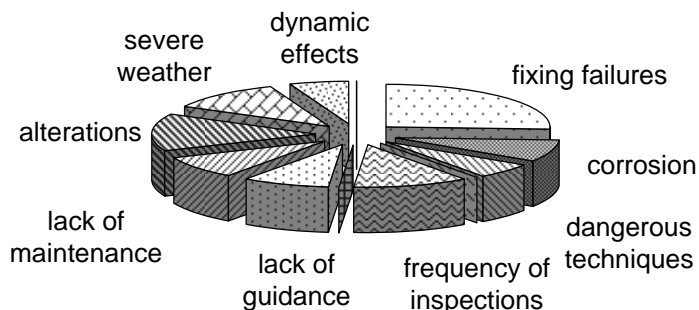


Figure 3 Operational concerns

A few years ago a young woman was killed by a masonry fall in Edinburgh. The subsequent enquiry posed the question as to how often such events occurred and an investigation was undertaken under the name SCOTCROSS on behalf of the Scottish Building Standards Agency. Over a two year period 1,300 reports were received from Local Authority Building Control Officers about materials or objects which had fallen, or were in danger of falling, from buildings. There were twelve instances of pedestrians having been struck by objects with several injuries being incurred. About half of all incidents involved roofs, with the other half being equally split between walls and miscellaneous objects such as TV aerials. The age of buildings most at risk, 100 years or more, was demonstrated and very adverse weather appeared to contribute to the number of falls. The final report with examples, analysis, and conclusions was published in May 2008 by the Scottish Government.

A CROSS reporter had a potentially far-reaching concern about unseen progressive deterioration in sandwich ceiling panels with mineral wool lamella cores. One example was of men working in the roof space above an industrial facility who fell through the ceiling when this collapsed under their weight and that of the load that they were carrying. One of the men was seriously injured. The ceiling was constructed of metal-faced sandwich panels with a core of mineral wool lamellas. The cause of the collapse was progressive degradation under repeated heel impacts as men walked on the ceiling.

The top flight of a staircase to a multi-storey concrete car park collapsed approximately 10 years after construction. The stair was constructed insitu and cast against the existing slab which had protruding continuity reinforcement to connect the elements. The failure occurred at the construction joint between the slab and the stair landing and was due to corrosion and then failure of the bars across the construction joint.

## Warnings

Two reporters had been involved in projects on sites where river walls forms part of the strategic flood defences for the area. These are of driven steel sheet piling held back by tensioned ground anchors up to 30m (or more) in length and date from the mid - 1970's or early 80's. Their concern is that although the anchors should be looked after by their owners. Even when ownership is clear, records are not readily available which indicate the types of anchor used, their positions, original pre-stress loads or procedures for maintenance, checks and inspections. They recommended a data base be set up of such installations for future maintenance.

Failure of dams in the UK is very rare, but incidents do occur and lessons learned will be published by the Environment Agency who is responsible for a voluntary system of post-incident reporting. The scheme has been linked to CROSS as a suitable vehicle for publicity.

There have been a small number of instances where sections of the soffit of precast concrete floor units have become detached and fallen within buildings. This appears to arise from corrosion of the embedded steel reinforcement, and CROSS was asked to publicise this and seek evidence of more examples.

Another warning came from a reporter who expressed concerns about aspects of the CE (Conformité Européenne) marking scheme for structural steelwork. The worry is about the way that the process will be monitored, enforced and policed in the UK, since the use of CE marking is only voluntary here, but compulsory in mainland Europe.

These examples are of matters that might lead to problems in the future and should be brought to the attention of the engineering community so that practitioners are aware of them and the need to take care.

## Demolition

Several reports described demolition problems due to a lack of information, or knowledge, about the way structures had been built. During demolition of a tower block, a column arrangement collapsed. All involved were aware of the form of construction and temporary stability requirements. However the joints between pre-cast columns had not been grouted. On removal of the load from above, the column became unstable. On another site a floor suffered a sudden structural collapse during the demolition of a reinforced concrete building. Three excavators fell through at least one floor and one of the site personnel was injured and three others were rescued.

The collapse of a seven story 'flat slab' building occurred whilst the top floor was being demolished onto the next floor down and the debris removed. This process was being undertaken by three tracked vehicles actually operating on the floor. The slabs slid down the supporting concrete columns and four operatives were killed. It was, said the reporter, extremely difficult to identify a single cause of the failure, but a number of serious individual defects and causes were identified. The spacing of reinforcement in critical regions over columns was not correct and the cover was inadequate. Temporary propping was inadequate and there was no cross bracing, and static and dynamic loads from the excavators on the slab had been underestimated.

## Findings

Many of the reports reflect what experienced engineers might expect to happen, but under CROSS they have been gathered together in an evidential way, and presented as a means of informing others without blame being attributed. There have been few major headline collapses in the UK in recent years but there are obviously a good number of near misses (or as one contractor describes them 'near hits') and collapses that would otherwise go un-reported. Concerns about events that could lead to collapses make up a good proportion of the reports.

There is the view, repeated in many reports, that there is an overall skills shortage from designers through to site operatives. In the worst cases poorly thought out designs are submitted for Building Regulation approval to be checked by over-stretched local authority staff. Software is used without the necessary background knowledge and many elements are left to specialist suppliers to design. There can be a lack of co-ordination between concept and completion with many parties becoming involved and no overall responsibility. On some sites temporary works are of unacceptably low standards and either due to lack of experience or lack of supervision good, or even moderately good, quality construction is not achieved.

Of particular concern have been reports of fixing failures and SCOSS have issued an industry wide alert on the need to be vigilant about specification, selection, purchase, installation, and supervision of fixings and associated components. Hidden fixings which cannot be inspected create additional difficulties.

Corrosion, decay, structural movement, and the effects of weather have led to numerous falls and collapses in older buildings. Warnings about the need for vigilance in connection with aging infrastructure have been given. As climate change occurs the severity of weather events will increase so more such problems can be expected.

Linking these categories of event is difficult because of the myriad of reasons that inter-connect to cause failure. Professor Hatamura in Japan has described the 'forest of failure' that may entrap the efforts of an enterprise and many of the elements on his 'trees' have been described to CROSS. They are:

- Ignorance
- Misjudgement
- Carelessness
- Poor analysis
- Ignoring procedures
- Changed circumstances
- Bad value
- Poor operation

To make best use of the information that has been received, and will be received in future, there has to be a wider dissemination of the reports and the recommendations from SCOSS. This will be a key issue in the development of the programme.

## Developments

The Institution of Civil Engineers, the Institution of Structural Engineers, Health & Safety Executive, the department of Communities and Local Government, representational bodies from industry, major firms, and many individuals are strong supporters. However much work has to be done in order to expand the scheme and a particular task is to encourage more reporters to come forward. In the medical field it is said that 75% of hospital doctors are familiar with close calls but few report their experiences and the proportions in engineering are probably similar. Publicising the results from CROSS and giving feedback will help to overcome the barriers and persuade more engineers and others to participate.

Not only in the UK but elsewhere the work is attracting attention. Sometimes reports are received from far afield and these are a valuable contribution. In several countries there are plans for local versions and one has already been started in New Zealand by IPENZ (Institution of Professional Engineers New Zealand). Interest has been expressed from several countries in Europe, the Confederation of European Building Control (CEBC), as well as India, Singapore, and Australia.

Experience shows that programmes like this have a slow initial response and can take many years to mature. SCOSS is therefore planning a move from a CROSS pilot scheme to a larger scale permanent process which will have an important role to play in the safety of structures. It will make far greater use of the web with the latest techniques to simplify all of the processes from receiving Newsletters to interrogating a data base of reports. The objective is to have the information from SCOSS and CROSS available as a useful, or even essential, tool for designers, checkers, constructors, and facilities managers.