Lessons from Confidential Reporting on Structural Safety

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Abstract

The UK CROSS system collects information on the concerns of civil and structural engineers which have led to near misses, or failures including collapses. Reports to CROSS are stripped of identifying features and reviewed by a panel of experts who give comments and advice as to how similar situations may be avoided in the future. Reports and comments are published quarterly in on-line Newsletters and are added to a web site data base. This free resource is used by practitioners, educators, regulators and others. Trends have included problems with; structural fixings, tension systems, anomalous documentation and imported products, building control, equipment failure, competency, items falling from buildings, contractors changing designs on site, and more. The aims are to encourage change in the way that engineers approach issues that are safety critical.

Keywords: CROSS; SCOSS; Structural-Safety; confidential; reporting; learning; alerts; newsletters;

1 Introduction

A very effective mechanism for preventing failure is to learn from previous experiences. For over 30 years the Standing Committee on Structural Safety (SCOSS) has been active in providing guidance on structural safety in the UK. It was formed by the two leading professional bodies for construction; the Institution of Structural Engineers (IStructE) and the Institution of Civil Engineers (ICE) following a number of high profile collapses such as Ronan Point (UK) and the Cleddau (Wales) and West Gate (Australia) box girder bridges. The UK government department, the Health and Safety Executive (HSE), later joined the Institutions as a sponsor for the programme. The objective is to examine incidences of failure or collapse, wherever they occurred, and consider whether there are lessons that can be learned and passed on to industry. The Committee is composed of senior members of the Institutions from consulting firms, contractors, academia and government and they gather information from published reports and publically available resources.

The Committee recognised that there were many events which were not of a scale to attract public or official attention but which, if information about them could be captured, would provide a rich source of data on structural safety. Using the American Aviation System Reporting System (ASRS) as a model the Confidential Reporting on Structural Safety (CROSS) scheme was launched in 2005. Some results from the programme have been given previously. In ten years of operation considerable experience has been gained on the collecting and analysis of concerns from structural and civil engineers. Many of the occurrences reported are referred to as near misses, defined as unplanned events that did not result in injury, or damage – but had the potential to do so. A better term for safety reporting is “near hit” which emphasises the importance of the event. In slightly different circumstances a near hit could have had more severe consequences including deaths and serious injuries. These are referred to as pre-cursors.

For several years CROSS and SCOSS operated separately in administrative terms but were merged in 2013 to form the Structural-Safety...
Group[3]. A major part of the work of the Group is to publish information of general benefit to the construction industry and these include quarterly CROSS Newsletters as well as Alerts and Topic Papers. The Alerts and Topic Papers are written in response to observed trends in the industry which give rise to concerns, and to structural failures. Alerts are to publicise the consequences of events that are in the public arena or that have come through confidential reports. Topic papers deal with events that have relevance but less urgency.

2 Method of operation

The most important, and challenging, task is to secure reports from engineers who are traditionally reluctant to reveal details of what might seem to be mistakes or weaknesses. This has been tackled by building a reputation for independence and integrity but more has to be done to make the scheme better known.

The system is internet based and the general operational cycle is shown in Figure 1 which starts when reports are submitted through a form on the web site. A name and contact details must be given and anonymous reports are not accepted. Neither are those where urgent action is required. In the latter case advice is given on whom to contact - usually the relevant regulator. A report is composed of a description, associated material such as photographs and pdfs, and an optional initial categorisation. Most reports come from senior personnel within firms and with agreement from the firms – this is not whistle-blowing.

The base reports are seen only by the director of the CROSS scheme who may contact the reporter for further information or to discuss the situation. Reports are then edited to remove details of the reporter and features that could identify a firm, a site, a product, or anything else that might be recognised. Backing up the system is a panel of volunteer experts chosen by the sponsors for their experience and ability as well as their independence. They are respected figures from all sides of the construction industry who review the de-identified reports and give comments on how such concerns might be dealt with. Blame is never apportioned and the aim is to enable lessons to be learned. Edited reports and comments are returned to the reporters for approval and finally to the group legal advisor for clearance to publish.

During the process the reports are stored as different versions including base; which is the raw data, de-personalised; from which the reporter’s details have been removed, de-identified; from which any recognisable features have been removed, and live; which is ready to publish. At an appropriate time after publication the base reports are purged from the system.

Reports are encouraged which draw attention to:
- concerns about design processes which could contribute to failure,
- descriptions of incidents or near hits on site or in service,
- lessons learned, or identified, which will help others to contribute to a safer industry,
- concerns which may require industry or regulatory action.

The most significant reports, together with comments, are published in on-line Newsletters and are added to the web site data base. Other reports are added only to the data base including some from established media publications in the public domain. This free resource is used by practitioners, educators, regulators and others.
Registration for publications, which are free, is through the web site and whilst most respondents are from the UK there are others from around the world. In the year March 2014 – March 2015; 62% of web site visits were from the UK, 10% from Australia, and 6% from the USA, with the remainder from a range of other countries. Subscribers are sent emails when a Newsletter, Alert or other publication is issued.

Once Newsletters are circulated by email they may be distributed further by representative and trade bodies and internally by some organisations, so the numbers who have access to them is greater than the 7,500 registered subscribers.

More than 300 reports have been published in nine years and there are almost 500 on the data base. There is the highest potential for reducing risk of structural failure through the Newsletter because of the number and range of issues that have been highlighted.

3 Reports received

The subject matter for reports covers structures of many types; generally buildings and bridges. The range shows both the breadth of activities undertaken by structural and civil engineers and the extent to which they recognise concerns of actual or potential values.

Individual reports can be significant but usually it is more important if there are a series of reports along similar lines. If these indicate a trend then there may be a case for a general alert. Most importantly the findings, including trends, are used to influence change which will improve structural safety across the industry. This is the last and most important segment of the operational cycle, examples of which are described later in the paper.

The growth in number of reports received is shown in Figure 2.

The following three examples; one about design issues, a second about a near collapse on site, and the third about fixings, are abbreviated versions of reports that have been published in Newsletters.

3.1 Design of tall asymmetric structures

One reporter touched on the topic of analysis and design of structural systems for tall buildings which are asymmetric and may be irregular in plan. These might have a concrete core and an external steel frame with floors spanning between core and frame. Tall buildings which are complex in plan raise interesting issues concerning the methods of analysis that should be used, and there is conjecture that a first order linear analysis may not represent the structure adequately. It has been argued that non-linear geometry effects should be included so as to provide a better representation of the behaviour of the structures.

Comments from CROSS

The problem is that of the validation of analysis models. Deciding whether the model is capable of properly representing the real structure, requires a logical and disciplined approach to computer assisted engineering. The questions to be expressed and answered are:

- Is the model satisfactory in its representation of structural behaviour?
- Is the software and the way it is used appropriate and suitable?
- Are the results correct?
Analysis software must be used within the limitations of its applicability. It is all too easy to believe that because a structure has been computer modelled the output is therefore accurate. Asymmetry in a tall structure may exacerbate non-linear effects under both vertical and horizontal loading. In designing a non-standard structure, the process should start by ensuring that all possible aspects of behaviour can be represented by the model until there is confidence that they can be ignored. The validation of software, and its proper use, is a matter that needs to be addressed both in practice and in education.

3.2 Near collapse of bridge falsework

There was a near collapse of a birdcage scaffold falsework structure during an 800 m³ (1,050 yd³) concrete pour on a highway bridge. Adjustable diagonal braces were designed to be used throughout. The structural concrete checklist was signed off by members of the construction team and the design team. Shortly after the pour there was evidence of buckled vertical members in the falsework. Collapse was prevented by bowing distortion of the verticals providing some moment capacity at each joint between the standards and the ledgers, and by an adjacent retaining wall. During investigations it was found that a copy of a specialist’s drawing had been marked up in an uncontrolled manner to show bracing every fourth bay rather than on every bay. Recommendations made by the reporter’s organisation included: more vetting of sub-contractors, adequacy of management procedures, training on management procedures, recognition of the temporary works co-ordinator role.

Comments from CROSS

Lack of appreciation of basic stability is a vital issue and the competency of the individuals making the decisions on site is part of the problem. It can and does lead to fatalities. Routing the inspection back to the designer of the temporary works is important as it emphasises that these are designed systems; the cost of an inspection is trivial. The general management issues recommended above could be extended to training of the people installing the equipment – tool box talks on the consequences of omitting parts of the design. The person signing the installation checks should be carrying out regular checks whilst an important structure like this is installed. It is very difficult to check on completion and much more time consuming and expensive to correct. Record photos and video clips can be used to help check the installation against the drawings. Whilst experienced old hands on site may know as much or more than the designer this cannot be relied upon.

3.3 Post-fixed RC anchors - erroneous assumptions leading to unsafe design

A consultant on a project reported that a number of steel to reinforced concrete moment resisting connections were required. The steel fabricator proposed forming these using post-fixed anchors and the design was undertaken by their engineer. During construction the reporter became concerned about one of the fabricator’s designs and undertook a check. It was found that several of the proposed fixings did not have the minimum concrete edge distance required, and when these fixings were disregarded the manufacturer’s software calculated that the design had only a small fraction of the required capacity. Extensive strengthening works were required and had these issues not been identified there was very real danger that part of the structure would have collapsed. The reporter is concerned that engineers may be using post-fixed anchors without complying with the manufacturer’s guidance or ensuring that their design assumptions are applicable.

Comments from CROSS

Fixing problems make up 10% of all reports to CROSS and many of these have related to post-drilled fixings. The Structural-Safety Alert “Tension systems and post-drilled fixings” published in March 2014 gives details of several cases of failure, together with advice on inspecting existing installations and installing new fixings. The importance of following manufacturer’s instructions is stressed. Many failure studies highlight that they result from errors in apparently
small items or that what one party thought was being built was not actually so. A feature in some of the ceiling collapses previously reported to CROSS\(^{[5]}\) was failure of the anchorages. A lesson might be that where these are key components, part of the QA procedure should be site testing to ensure their strength capacity. The selection and installation of top fixings for suspended ceilings published by the UK Association of Interior Specialists\(^{[6]}\) gives advice on all aspects including testing for smaller fixings.

Each report to CROSS describes a unique set of circumstances but trends appear when several have similarities and it is from these that the most effective feedback can be generated. Trends have included problems with; structural fixings, tension systems, anomalous documentation and imported products, building control, equipment failure, competency, items falling from buildings, contractors changing designs on site, collapses during construction of new buildings, collapses during alterations to existing buildings, issues with temporary works, and others. Lack of competence is believed to be a major reason for most of the safety-critical matters where competence is described as the “combination of training, skills, experience and knowledge that a person has and their ability to apply them to perform a task safely.”\(^{[7]}\) Other factors, such as attitude and physical ability, can also affect someone’s competence. Almost a half of all reported events, 44%, are related to construction and temporary works, with design accounting for 13%, and in service operations 34%, with a few other minor categories.

### 4 Achievements

Every two years the work of the organisation is reviewed and summarised, and a recent survey of all reviews since 1977 identified issues where recommendations from SCOSS, and from CROSS since 2005, had made an impact. The collection of hard facts and evidence from confidential reports has helped when lobbying for change both in terms of guidance from professional institutions and from trade organisations. Examples of changes that were successfully made are given below.

#### 4.1 Building Regulations

SCOSS campaigned for some time that the UK Building Regulations should be updated particularly in relation to disproportionate collapse. Partly because of this influence updates have been made over the years to including requirements on robustness and disproportionate collapse. CROSS reports have also highlighted concerns to regulators about the quality of submitted calculations and the quality of work on some sites.

#### 4.2 Risk recognition

Risk appreciation is a subject that most engineers deal with on an intuitive basis and inadequate assessments are sometimes made. It is another subject that has been of interest and to improve the quality of assessments CROSS gives practical advice on common issues found in design and on site. Guidance on risk has also been published by the Institution of Structural Engineers\(^{[8]}\).

Ongoing concerns have been expressed by SCOSS and supplemented by CROSS reports about the implementation of the Bragg Report\(^{[9]}\) in 1976 on the design and construction of temporary works. The result has been the establishment of the Temporary Works Forum\(^{[10]}\) in the UK. Their primary objectives are:

- Give authoritative guidance and when required professional leadership to the industry.
- Consider aspects of permanent works and interfaces between permanent works and temporary works as are relevant.
- Consider both current practice and likely development.
- Be aware of trends and innovations in design, construction and use.

Currently there is a project to find how risks associated with temporary works can be better evaluated.

#### 4.3 Site safety

Site safety has been a recurrent theme with the recognition that construction is one of the most dangerous work place activities. Almost half of all
CROSS reports are about events on site, and statistics from the UK’s Health and Safety Executive show how many accidents and incidents take place. However the numbers of deaths and serious injuries has been greatly reduced due to action by industry and regulators encouraged by the work of Structural-Safety.

It is difficult to assess the contributions from any safety scheme but the influence of the scheme has helped to change the safety culture in the UK and encouraged others to act. Guidance resulting from these recommendations has been issued by Institutions and trade organisations, and there have been amendments to regulations and government advice. Apart from formal changes the information published is well received by the industry. It is a learning tool for younger engineers, and a reminder and a resource for more experienced practitioners.

5 International

All too frequently a building or engineered structure collapses somewhere in the world. Every year many people are killed and many more injured. Examples include major building collapses in India, Africa, parts of Asia and in many other places. The deadly collapse in 2013 of the Rana Plaza building in Bangladesh, when 1,100 people were killed, had probably the largest death toll of any structural event which was not precipitated by external action such as an earthquake or a terrorist act. These disasters emphasise the need for care at all stages of the structural cycle everywhere in the world.

The human toll is shocking to those of us in countries where we have few major failures. It is however most important to be able to know what has gone wrong and in due course it is hoped that forensic explanations of major tragedies will become routinely available so that lessons can be learned by clients and engineers everywhere. Checks and balances exist in any regime where there are responsible designers and constructors working in accordance with sound regulations which are properly enforced. But there are always cases where something goes wrong and the difference between a near miss and a catastrophe can be wafer thin. In a learning culture such events are recorded, acknowledged, analysed, and the findings disseminated to make a difference in future. Cognisance of pre-cursors in any environment is a proven way of helping to reduce the consequences of more extreme events.

Expressions of interest in the operations of CROSS have come from groups in several countries. To provide a common platform for sharing information the web site was therefore further developed to create a CROSS Hub with sectors for new groups. The intention is for each group to be autonomous in terms of its local organisation with their final reports on concerns available to all. Lessons to be learned will hence be shared. The Hub concept is at an early stage and it remains to be seen how effective it will be on the international scene.

The first group to join has been from Southern Africa where the initiative to form CROSS-SA has been taken by the Joint Structural Division (JSD); which is a division of the South African Institution of Civil Engineering (SAICE) that is joined with the Institution of Structural Engineers.

SCROSS maintains a watch on events globally but remains the only body of its type anywhere. Governments and relevant organisations in other countries are encouraged to adopt similar
processes so that greater structural safety in their countries can be developed.

6 Discussion

Learning from experience is a fundamental tenant of all forms of teaching but often the experiences are from a previous generation. Indeed there is a theory that engineering failures go in 30 year cycles [11]. When a major bridge or building fails there is immediate public interest but detailed forensic information is not usually forthcoming for years, and in some cases it is never revealed for legal reasons. The engineering rationale for hiding valuable information is not obvious as there may be other failures from the same cause which could have been avoided if the reasons had been made public.

Below the horizon of these major events are a host of near hits, unnecessary repairs, shortened life spans, and concerns. Information from some is used to improve procedures within the organisations where they occurred, whilst others are neglected, forgotten or deliberately withheld.

One of the most challenging obstacles is to get information released on the causes of collapses when this is constrained by legal situations or confidentiality arrangements imposed by insurers.

In the UK the Health and Safety Executive has the power to publish information of a critical nature about certain types of event in advance of legal proceedings. This however is restricted to instances or circumstances which have not been seen before such as certain types of chemical explosion. There is no doubt that without the confidentiality restrictions often placed by the courts on revealing information the causes of more collapses would become known.

When there is a fatal event on a construction project the effects on the victim’s family are shattering. The consequences for everyone else concerned are severe. The reputations of large firms are damaged and the existence of small firms can be put in doubt. The careers of individuals are blighted and there may be prosecutions which result in gaol sentences. Guilt and depression can affect lives forever and often because of an apparently trivial decision – but the wrong decision. There are three main contributors for failures: people, product, and process, and of these people is the most dominant. Human actions are usually behind problems caused by products and processes.

If more attention were paid to the pre-cursors of failures then some collapses, with their tragic and inevitable consequences, could be prevented.

7 Conclusions

- CROSS is a unique project for gathering information on structural safety.
- It has been successfully implemented alongside the pre-existing SCOSS programme.
- Publications stemming from Confidential Reports contribute to structural safety by raising awareness.
- Guidance in the UK has been influenced by the findings and recommendations.
- There is scope for international collaboration to develop the system.
- There are benefits for clients, engineers and the general public.

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