CROSS UK
COLLABORATIVE REPORTING FOR SAFER STRUCTURES

The Institution of Structural Engineers

ice

The Institution of Fire Engineers

CROSS Newsletter

CROSS-UK Newsletter 71 | **December 2023**

Share knowledge to help create a safer built environment

Editorial

Since the last issue of the Newsletter, you will have no doubt seen the extensive coverage in the media on Reinforced Autoclaved Aerated Concrete (RAAC). CROSS played a significant role in raising the alert on RAAC and helping the industry to prepare.

The first warning from CROSS (or SCOSS as it was back then) dates back to 1999 when the Standing Committee on Structural Safety recommended that owners of buildings with RAAC roof planks have them inspected.

Since then, CROSS has received multiple reports connected to RAAC. The **first of these>** was published in 2007. In it, a reporter describes their experience during the construction of a building in the 1970s where a RAAC plank failed and fell to the ground. When the reporter investigated the failure, they found that the reinforcement in the plank did not extend to the bearing ends; and that it had failed in shear. After further investigation, they condemned 30% of all the roof planks due to poor manufacturing quality.

This is interesting, as poor manufacture is a significant contributing factor to the current concern regarding RAAC, with reinforcement not necessarily being located over the critical bearing supports.

Fast forward to 2018 and the collapse of a RAAC plank at Singlewell Primary School in Kent. It was this event, together with previous CROSS Reports, that triggered the release of our Safety Alert on RAAC planks in 2019.

The Safety Alert> was targeted at owners of buildings dating from the 1960's to the 1980's and specifically mentioned government departments and local authorities with responsibility for schools or similar buildings. It called for RAAC planks to be identified, inspected and, ultimately, for consideration to be given to their replacement.

This really brought the problem to the attention of the construction sector. As a direct consequence of the Alert, the Institution of Structural Engineers (IStructE), following CROSS advice, set up a RAAC study group which led to the publication of their **Investigation and Assessment guides>**, which are now being used widely to assess the condition of RAAC planks across the public and private estate.

In many ways, RAAC is a great example of how the sharing of information can work well. CROSS can raise the alert and the Professional Engineering Institutions can prepare to advise on technical matters. Since 2019, CROSS has worked with the Department for Education, the NHS and the Cabinet Office discussing proposals for how estates can be best investigated to assess if they have any RAAC. We've also worked with the National Federation of Roofing Contractors in developing an alert for their members. There have, to date, been few recorded incidents of RAAC plank collapses in comparison to the huge number that are out there, and luckily there is no record of anybody being injured. However, it is likely, that we do not have the full story and many planks will have previously been replaced or strengthened.

The situation continues to develop. There have been several incidents reported this year that led to the Department for Education's decision to close a number of school buildings. These closures were immensely worrying to many parents, teachers and headteachers and disrupted children's education.

CROSS has anecdotal evidence that people were concerned with the degradation of RAAC well before the 2018 collapse. Such concerns, however, did not translate into a significant number of reports submitted prior to 2018.

This shows the importance of people reporting safety concerns.

Contents

Visit:
www.cross-safety.org/uk

Email:
team.uk@cross-safety.org

If all the knowledge of RAAC planks out there had been shared earlier, then perhaps an alert could have been issued earlier?

Each year, CROSS receive more reports than the year before. There has been a growing awareness of us, and a growing trust. This issue of the newsletter contains a selection of our most recent fire and structural Safety Reports, a handful of the many reports CROSS has received, reviewed, and published since its creation. However, there is still a long way to go. We depend on industry professionals, people like you, to submit concerns to us.

So please, if you have seen or experienced a fire safety or structural safety issue, submit a report.

As the events connected to RAAC have shown, reporting to CROSS **can** help to raise awareness of an issue. Your report will make a positive difference.

Paul Livesey
Scheme Manager, CROSS

Help to improve safety by submitting a report

Reports are the oxygen of our work here at CROSS. Our secure safety reporting system promotes a no blame culture, and all reports are anonymised and de-identified to ensure confidentiality.

The reporting process is straightforward, and we encourage anyone with information to share to submit a report. By sharing knowledge, you will help to create a safer built environment.

Find out more >

More from CROSS

CROSS Expert Panel Meeting at IStructE HQ on 15th November

CROSS held an in person meeting of our UK Expert Panels in November, our first face-to-face meeting since our remit expanded to include fire safety reporting.

Our **Expert Panels>** are at the heart of what CROSS does. Comprised of leading experts, the volunteer members use their expertise to help readers of CROSS safety information understand what can be learned from the reports we receive. The panels aim to identify the underlying causes of safety issues and provide references for relevant publications that can be accessed and used.

CROSS win Collaboration of the Year award

The CROSS team were delighted to accept the award for Collaboration of the Year at FIRE Magazine's Excellence in Fire & Emergency Awards 2023. The ceremony was held at One Great George Street on 1st December. CROSS were finalists in two other categories - Resilience and Learning from Major Incidents, and International Best Practice.

NCE's The Engineer's Collective Podcast

October's episode of **The Engineers Collective podcast>** featured CROSS Scheme Manager Paul Livesey in conversation with NCE Assistant News Editor, Rob Hakimian. Listen to hear the two discuss the history of CROSS as a unique, confidential reporting scheme, our expansion into fire safety post-Grenfell and the input CROSS had on the RAAC crisis.

Fire performance of timber cladding

CROSS Safety Report Report ID: 1194

This reporter relays a concern that guidance to The Building Regulations 2010 regarding the use of timber cladding may be the result of a misinterpretation.

Key Learning Outcomes

For designers and building control inspectors:

- A footnote in a table that forms part of guidance to The Building Regulations 2010 could be based on a misinterpretation of tests done and referenced in earlier guidance
- Decisions to use timber cladding on external walls should be made considering all available information, not restricted to Approved Document B

R Full Report

Approved Document B> has previously and continues to permit the use of *"timber cladding at least 9 mm thick"* in the guidance related to the reaction to fire performance of external walls. The current format of this guidance from Approved Document B, Vol. 2, states in the footnote of Figure 12.1, *"timber cladding at least 9mm thick is also acceptable"*.

The guidance makes no specific mention of the type or configuration of timber cladding, or indeed what may or may not constitute 'timber'. This led the reporter to investigate the origins of the recommendation to garner greater insight into how the guidance should be applied in practice, and its potential bounds of applicability.

The reporter is concerned that, given the current and necessary drive to reduce the embodied carbon in our buildings, greater use of this piece of guidance will be encountered in the future. It is, therefore, necessary to understand the context in which it can apply.

It is the reporter's understanding, that this element of the guidance comes from the former prescriptive regulations and has been transferred from imperial to metric units, with the relevant extract from **The 1965 Building Regulation>**, E7 below:

(*b*) Any cladding on any external wall situated 3 feet or more from the relevant boundary shall, if the building is more than 50 feet in height, have a surface complying with the requirements specified for Class O in regulation E14, except that any part of such cladding below a height of 50 feet from the ground may consist of timber of not less than $\frac{3}{8}$ inch finished thickness.

Figure 1: *Extract from The 1965 Building Regulation, E7*

3/8 inch thickness converts to around 9.5mm. The reference to 3/8 inch can also be found in Fire Research Note 8 (FRN 8, see Reference [1] below for further details), which sets out the principles embodied in the regulations, with emphasis on the external wall. Reference is made to the experiments of Ashton and Malhotra in

Structural Safety – Theory & Practice by Allan Mann

Allan Mann's new book, Structural Safety - Theory & Practice is now available to buy as **a hard copy>** and as **an e-book>**. It looks at the various reasons behind building failures and the lessons that can be learned.

This volume represents a distillation of many years' extensive experience and as such will prove of immense relevance (and the ideal Christmas present) for practising civil and structural engineers and students of these subjects. Designers and other personnel in the construction industry will also find this book of value.

Second Edition of Structural robustness and disproportionate collapse in buildings published 10th November

In 2010, the first edition of this guidance provided a background to the fundamental attributes of robustness. This included an interpretation of, and practical guidance to, the regulations being followed in the UK at the time (primarily British Standards), with more detailed guidance on each of the main materials (insitu concrete, precast concrete, steel, timber and masonry).

This **second edition>** builds on the first, to be fully aligned with Eurocodes — with a particular focus on BS EN 1991-1-7 and the Building Safety Act. It contains new chapters on risk, alterations to existing buildings, classification of existing buildings, and considers lightweight steel frame as a material distinct from steel. There is an emphasis on modern methods of construction (MMC) and a selection of new worked examples within each of the material specific chapters.

Fire Research Note 436 (FRN 436, see Reference [2] below for further details). Specifically, in reference to these experiments, Fire Research Note 8 says that:

> hour for fire loads representing a one-hour fire severity without any significant reduction in fire safety to a building or its occupants and that no undue hazard would be introduced by using a combustible cladding of solid timber not less than ⅜ inch in thickness.

Figure 2: *An extract from Fire Research Note 8*

Based on eleven large scale experiments with different wall constructions, in FRN 436 Ashton and Malhotra conclude that:

"... no undue hazard is introduced by use of a combustible cladding of solid timber. The use of other combustible materials needs separate consideration since they introduce undesirable hazards."

The statement in FRN 436 is broadly like that in FRN 8, apart from the mention of a dimension of 3/8 inch. The reporter has subsequently reviewed the experiments by Ashton and Malhotra to see what timber was tested. The cladding was said to have comprised of 1 inch cedar boarding on top of timber studs, backed by 3/8 inch plasterboard.

A section is provided below, with the thickness figure differing from the text of the report, noting the cedarwood to be 7/8 inch in thickness and not 1 inch.

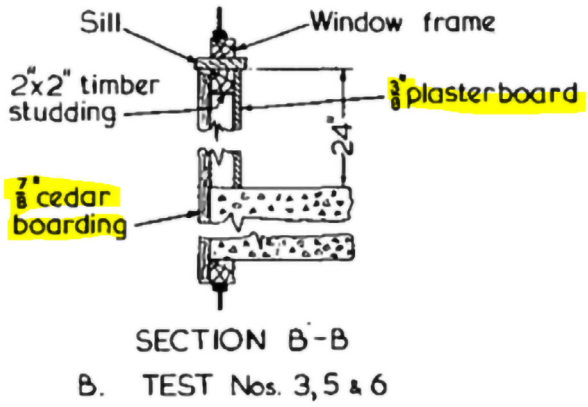

Figure 3: *A section of the report noting thickness of the cedarwood*

An elevation of the cladding is provided below to show the nature of the assembly that was tested:

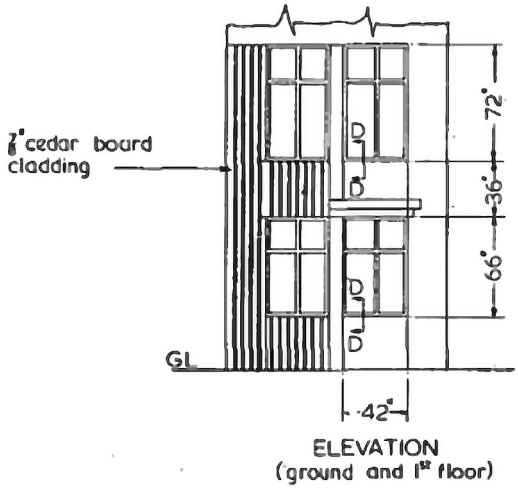

Figure 4: *The elevation of cladding*

News Roundup

In every interval between CROSS Newsletters, failures of some kind or incidents related to structural and fire safety are reported in the press. Here are some accompanied by a brief comment:

1. Luton Airport Car Park Fire >

The ability of fires to initiate and then spread was further illustrated by a very significant fire at the multistorey car park at Luton Airport. Approximately 1,400 vehicles were destroyed and the car park itself will have to be demolished. The fires appearance shows similarities with the fire that devastated the Liverpool Echo Arena car park in 2018.

CROSS issued a **press statement>** the day after the fire and Neil Gibbins, our Lead Fire Safety Consultant, and Alastair Soane, our Principle Consultant, were interviewed by The Times. The article is **available online behind a paywall>**.

2. Latest on RAAC and the safety of school buildings>

RAAC continues to be in the news as more buildings are found to contain the material and are deemed at risk. There are now around 240 schools which require remediation; several theatres have been closed and the roof over Cardiff's St Davids Hall is to be replaced.

On 19th November, the House of Commons Public Accounts Committee issued a report about RAAC with a news release title: *Unacceptable and alarming: Deteriorating school buildings prompt urgent warnings*. The **full report>** can be read on the House of Commons website.

The timber cladding was of a shiplap type construction, comprising 7/8 inch cedar boards, with planks spanning vertically, forming an essentially continuous and homogeneous flat surface.

Upon reviewing the work of Ashton & Malhotra, the reporter concluded that the interpretation (in FRN 8) of FRN 436 was likely incorrect, with the timber thickness (7/8 inch as per the above figure) mistaken for that of the plasterboard (3/8 inch).

This interpretation subsequently entered the regulations in 1965 and guidance, through Approved Document B, thereafter.

This is potentially problematic as any evidence relating to the adequacy of timber cladding at largescale was premised upon a thickness of circa 22 mm, not 9.5 mm. The figure has subsequently been rounded down to 9 mm, meaning a difference of around 2.3 times that of the timber cladding originally tested. Given that the ignition of timber will be influenced by its in-depth heating, it is foreseeable that this potential error could result in 9 mm timber cladding more readily supporting vertical fire spread than was originally observed or intended in the 1960s.

Further to this, the definition of 'timber cladding' relevant in this context is one of softwood (cedar) planks abutted in a manner to form an essentially flat and homogeneous timber surface. Any conclusions reached by Ashton and Malhotra would not be readily transferred to different configurations of timber cladding, for example, slatted systems with air gaps in between or behind planks, nor could it be readily extrapolated to timber based products such as plywood.

The underlying issue appears to be one of misinterpreting the research of Ashton and Malhotra when transitioning to National Building Regulations. Subsequently, there has not been a detailed review of the origins of the 9 mm value, with it reproduced through various iterations of the Regulations and, more recently, Approved Document B. The phrase 'timber cladding' has also been poorly defined, leaving it open to interpretation i.e., the types of materials and products that constitute timber cladding, and how they might be configured.

In the reporter's opinion, limited regard should be given to the 9 mm recommendation in Approved Document B or its reproduction in other codes and standards.

Whilst there might be no evidence of a potential hazard owing to the longstanding nature of the recommendation and its potential widespread application, the premise upon which the value was recommended appears to be incorrect.

It would be the reporter's recommendation, that greater emphasis is placed on the guidance relating to reaction to fire classifications of external surfaces, i.e., Euroclass standards. In such instances, the Euroclass achieved by 'timber' should not be generalised, noting that the reaction to fire performance in apparatus such as the SBI (Single Burning Item) rig is not a function of the material, but a function of a system, i.e., with dependencies on the material, the dimensions of components, the configuration of components, substrates, etc. This would help to address both the dimensional error identified and any ambiguity regarding what constitutes timber cladding.

References

[1] G. J. Langdon-Thomas and M. Law, 'Fire and the external wall', Joint Fire Research Organisation, Boreham Wood, England, Fire Research Note 8, 1966.

[2] L. A. Ashton and H. L. Malhotra, 'Fire Research Note 436. External Walls of Buildings - Part I. The Protection of Openings against Spread of Fire from Storey to Storey', Fire Research Station, Boreham Wood, 1960.

C Expert Panel Comments

The general feeling from the Expert Panel is agreement with the findings and opinions of the reporter.

The government needs to consider this further and reflect upon the apparent fragility of a guidance system that includes generic recommendations based on research that is more than 60 years old, with little evidence of subsequent re-examination and verification.

3. Barton House evacuation in Bristol>

A large Bristol apartment block was evacuated at short notice after 'structural faults' were discovered. The block is 65 years old and was home to around 400 people. It is understood that the building was constructed in the late 1950s and may be a Large Panel Structure (LPS).
The Building Safety Regulator (BSR) requires that all Higher Risk Buildings (HRBs) are the subject of Risk Assessments which consider potential dangers from extreme events such as explosions or fire.

There have been several CROSS reports submitted regarding the condition of older reinforced concrete buildings but little about HRBs despite the concerns that have been expressed about these in the public domain over many years.

Data must be collected on the state of HRBs and information shared for the public good. CROSS can collect and analyse such data so would encourage those with knowledge about LPS HRBs to submit reports.

4. Balcony failure in East London>

A balcony failure occurred in a four-year-old block of flats in East London. Photographs appear to show the collapse of the balcony perimeter brick slip cladding and the detachment of the balcony soffit. It has been reported that up to 80 balconies might require remedial work. CROSS has issued several reports on dangerous balconies including a **Safety Alert in 2022>**.

> **The government needs to consider this further and reflect upon the apparent fragility of a guidance system that includes generic recommendations based on research that is more than 60 years old, with little evidence of subsequent re-examination and verification**

The government should confirm whether the test mentioned by the reporter was used as a basis for the minimum 9mm timber cladding panel thickness. Also, it is essential to understand the factors considered for this decision. For example, based on current guidance, timber cladding can be used for buildings other than relevant and residential buildings up to 18 metres. That means there might have been some consideration regarding the tolerable risk level. However, if the consideration was only based on the chance of the spread of the flame, the argument would be different.

Ashton and Malhotra conducted a series of eleven tests, some of which used timber cladding.

In the ones where timber cladding was used, there was no gap between the timber claddings. The observations of the specimen after the test did not show any indication of flame penetration into the cavity. This could be because the design considered the impact of spandrel panels and separation on the spread of the flame. This point is important because the panels burned from a single direction in such conditions.

A standard timber cladding design, however, is likely to have a gap of 10mm between the panels, i.e., they are not designed to act as a fire resisting spandrel system. In such conditions, the fire may spread into the cavity, and the panels may be exposed in two directions. This could considerably increase the fire's intensity within the cavity and could cause more rapid and extensive external fire spread.

This is an interesting issue, with extensive historical research behind it. It is a very good point that a small amount of testing, conducted several decades ago, has translated into guidance which doesn't bear much resemblance to the original test findings.

However, it should be noted that this is not a new material, it is used regularly on buildings, and this guidance has been in place for several decades. There are many other factors that would affect the risk. These include the extent of the timber cladding (presumably if it is only used in isolated areas, it would be less of a concern than if it were over the entire facade) and the evacuation strategy for the building. Any building over 18m height with a 'defend in place' approach could not use timber cladding.

CROSS supports the call for further research.

Submit Report

Submit Feedback

5. Cambridge e-bike fire tragedy, fire service calls for law changes>

The Cambridgeshire Fire Service calls for law change on e-bikes and scooters, highlighting the fire dangers following the death of a mother and her two young children.

6. Failed concrete pour>

Five workers were hurt during a concrete floor pour when the temporary support failed. As ever, proper design of temporary works is critically important.

7. Crane collapse in Leeds>

Parts of Leeds city centre were evacuated after emergency services had to deal with an 'unstable' tower crane being used for high rise construction. The crane was later made safe.

8. Road tunnel collapse in India>

A road tunnel collapsed in India trapping 40 workers behind debris. Fortunately, they were successfully brought out after rescue work lasting more than two weeks. This is a reminder of the generic hazards associated with tunnelling and the need always to have a rescue plan.

9. Oxfordshire explosion: Crews work through night at recycling plant>

There was a dramatic gas explosion in an Oxfordshire recycling plant. Safety issues include the initiation cause (lightning), and the capability of fires to spread. Three out of five plant cylinders were destroyed.

Collapse of folded plate timber roof at a school

CROSS Safety Report Report ID: 1160

This report is about a critical safety issue concerning folded timber roofs, in various settings, including over school halls.

Key Learning Outcomes

For owners and persons responsible for the safety of buildings including schools:

- Inspect and assess existing buildings, particularly those that are of a significant age, to see if they contain unusual forms of construction, including roofs similar to the reported failure
- If so, or if there is doubt, arrange for structural inspections and risk assessments to be undertaken by engineers who are suitably qualified and experienced persons (SQEP) – normally Chartered Structural or Chartered Civil Engineers

For inspecting engineers:

- Undertake a risk assessment of old and unusual structures where there is a life safety risk should they fail
- Consider what combination of causes could lead to a structural failure
- Understand where structural elements may be beyond their reasonable service life
- Look out for signs of distress, including those in hidden components or locations
- Be aware of the risks associated with moisture build-up, particularly where timber is a structurally significant component

R Full Report

This report is about a critical safety issue concerning folded timber roofs, in various settings, including over school halls.

In 2011, the reporter told CROSS (known at that point in time as SCOSS) of a sudden failure of a proprietary timber roof system over a school hall that had been constructed in 1959. In response to the failure, SCOSS issued **Report 273 - Collapse of proprietary timber roof>**. The reporter believes that local authorities shared that information to help identify similar roofs. However, the reporter, who is a Chartered Structural Engineer, has had another enquiry concerning a roof suspected to be of the same type of construction. In researching this enquiry, the reporter has come across a news report of a collapse of another school roof in England in 2019 which appears to be of the same type of construction as that which collapsed in 2011. The construction of the roof appears to be similar to that shown in Figures 1 and 2 below. The age of the roof is not known to the reporter.

10. Storm Babet in October> and Storm Ciaran in November>

Storm Babet caused much damage - severe flooding, riverbank erosion and landslides. In one National Trust historical house, the roof runoff rate overwhelmed the guttering. This is a known weak spot of large warehouse type roofs.
Storm Ciaran followed a month later. Ciaran was particularly strong and caused a large amount of structural damage in the Channel Isles. The pattern of house roof damage conforms with what might be expected from wind suction effects. There was also significant flooding.

11. Back of Cockermouth's Old Courthouse collapses into river>

The eroding effect of water was well illustrated by the collapse of the back wall of Cockermouth's Old Courthouse. Images show that three storeys plus the roof collapsed.

12. Stonehaven crash: Network Rail to face fatal derailment charges>

Network Rail pleaded guilty in a trial about the Stonehaven train derailment of 2020. The train hit a landslide, but this was initiated by a faulty drainage system which had not been maintained. Rail Accident Investigation Branch (RAIB) recommendations included 'better management of civil engineering projects and improved response to extreme rainfall'.

13. Aftermath of the Hawaiian wildfire disaster>

Fire spread is amply illustrated by the Hawaiian disasters of August. The town of Lahaina was effectively destroyed with 2,200 building lost. Damage costs have been put at $6 billion.

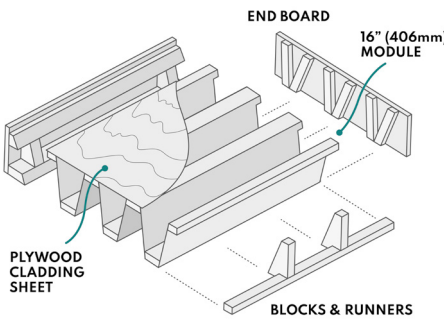

Figure 1: *sketch of roof system*

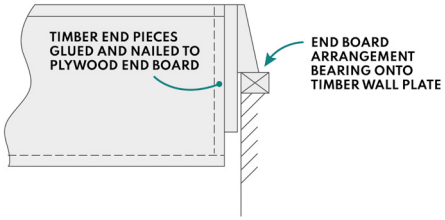

Figure 2: *side view at bearing*

The reporter considers that if the cases are similar, the end blocks of the roof, which were likely just held with glue and panel pins, may have become detached, as they did in the previous case, resulting in a sudden shear failure and the collapse of the roof.

If this second case does indeed concern the same proprietary system, continues the reporter, then it has been involved in two sudden collapses, either of which would have had catastrophic consequences if the buildings had been occupied at the time. The reporter considers that a significant number of these roofs, which may not have had failsafe remedial work undertaken, could exist, and users of such buildings may be at significant risk. The reporter is of the opinion that the failure of these roofs is almost inevitable as they age, and that a reminder concerning these structures would be very timely.

> **two sudden collapses, either of which would have had catastrophic consequences, had the buildings been occupied at the time of collapse**

The reporter also makes the point that a robust system for local authority surveyors to share safety information concerning their buildings is essential, given that such system builds were widely adopted and may, by now, be showing their age. However, given the erosion of in-house local authority services, the reporter is not sure if any such reporting mechanisms that existed may have atrophied.

C Expert Panel Comments

This roof collapse was reported as a sudden failure. Such types of failures should be guarded against as they often come with no warning. Very fortunately, the failure happened during a school holiday otherwise the outcome, as the reporter says, could have been catastrophic. The reporter is right that this incident should have been shared widely. This would especially be the case if the roof is a proprietary system where generic weakness may exist.

The cause of the collapse was not clear, however any structure that relies upon glue and panel pins is unlikely to be robust if water damage occurs at critical connections. It may be that a lack of maintenance permitted water penetration which impacted critical connections and precipitated the collapse. Any roof with suspected water penetration or water shedding problems should be inspected and repaired as a priority, as water degradation can cause structural damage and failures. Water and moisture generally are contributing factors to much deterioration and failure of buildings. Good detailing, construction, and maintenance of weatherproofing systems are essential.

Deterioration can contribute to the collapse of structures. An ice rink roof collapsed onto skaters in Bad Reichenhall, Bavaria, Germany, in 2006, killing fifteen people. Investigations found no single cause for the collapse, but rather a series of contributing defects and damage. The design capacity of the failed elements was found to be inadequate. This already inadequate capacity was then further reduced over time due to deterioration in the timber box girders. The structure was about 34 years old at collapse.

14. Large section of nursery roof collapses in London>

A large roof section of a London nursery collapsed completely onto classrooms below. Once again, good luck prevented a more serious incidient. All the children had gone home, and so there were no casualties.

Any roof with suspected water penetration or water shedding problems should be inspected and repaired as a priority

CROSS published **Report 1227 - Collapse of unusual hybrid concrete and steel strand truss on school roof>** in May 2023. This new failure in North West England, and the failure of the unusual hybrid truss, have remarkable similarities in that both are unusual forms of roofing structure, both were used in school roofs, and both roofs were of significant age.

For brevity, the findings of the unusual hybrid truss report, as well as CROSS **Report 273 - Collapse of proprietary timber roof>** (concerning the collapse in 2011 mentioned by the reporter) are not repeated here. However, readers are advised to read both as the issues and concerns are wholly related to this latest report.

This report markedly reinforces the importance of robust and timely inspection and maintenance strategies as outlined in both earlier reports.

This report markedly reinforces the importance of robust and timely inspection and maintenance strategies

The reporter is concerned that previous efforts to identify similar plywood folded box timber roofs may not have been completely successful. This failure in North West England appears to support that concern, and responsible bodies of buildings potentially containing such roof structures, are urged to take notice of this latest failure.

Responsible bodies of buildings potentially containing such roof structures, are urged to take notice of this latest failure.

The reporter also makes the point that a robust system for local authority staff to share safety information concerning buildings is essential, but the reporter is not sure if any such reporting mechanisms that existed may have atrophied.

This concern emphasises the importance of the voluntary reporting system provided through **CROSS>** and if any readers have experience of such roof systems then will they please submit a CROSS report.

In addition, CROSS understands that the Department for Education, seeks to make bodies responsible for education facilities in England aware of building issues of concern. Similar arrangements could be in place across other devolved administrations.

Submit Report

Submit Feedback

Serious inconsistencies when installing passive fire protection

CROSS Safety Report Report ID: 1199

An onsite fire engineer, engaged on behalf of the end client during the construction of a new residential development, reports a significant amount of inadequately installed passive fire protection elements.

Key Learning Outcomes

For principal contractors and clients:

- Ensure that fire protection work is carried out in accordance with the designed fire strategy
- The engagement of specialist fire protection contractors is likely to be necessary for work recognised to be specifically related to fire protection
- Other work, such as the fitting of door sets, may also be critical in terms of fire safety

R Full Report

This report relates to a project involving the construction of a new residential development comprising numerous blocks of flats.

The reporter's role was to act as the onsite fire engineer engaged throughout the construction period for approximately two years. Their role was to ensure that the works carried out were consistent with the requirements agreed in the fire strategy and relevant standards, and that the quality of work satisfied the functional requirements of the Building Regulations.

The reporter suggests that the project faced numerous challenges where, in their view, unqualified contractors carried out the installation of life safety elements, resulting in potential risks to the future building occupiers as well as creating significant delays.

> **the contractors carrying out the works were not aware of the intended function of these details or systems and lacked the necessary, demonstrable competence**

Whilst undertaking site visits at different phases of the construction, the reporter identified a significant amount of inadequately installed elements of passive fire protection.

Specialist fire stopping installers had been appointed to the project; however, in the opinion of the reporter, it soon became clear that the installation of certain details was carried out by various parties who did not have any specific qualifications nor could correctly record and document the executed works. This meant they failed to follow the principles of the golden thread, which the client intended to adopt. Furthermore, the contractors carrying out the works were not aware of the intended function of these details or systems and lacked the necessary, demonstrable competence.

Most fire stopping details, such as pattresses and proprietary seals, were installed by third party accredited, fire stopping installers; these details were generally of an acceptable standard.

However, other fire stopping details, for example within plasterboard partitions, were installed by dry lining operatives with no appropriate accreditation or expertise in fire stopping. Some of the reporter's key findings are summarised below:

- Inadequate products were used which would not perform correctly in the installed arrangement
- Products from different manufacturers were inappropriately mixed with each other, thus not meeting any standard (tested and certified) installation detail
- Products that may have been appropriate were installed incorrectly, essentially creating a breach in the fire resisting element
- Fire protection elements such as intumescent putty pads behind electrical sockets, smoke seals of fire doors along the escape routes, and linear joint seals, were found to be missing altogether

- Fire resisting door sets were inadequately installed, either by not adopting a specific detail or because installation was based on architectural drawings which were subject to significant alterations from the tested detail without any supporting information
- Fire dampers were not appropriately installed and gaps were observed around the items
- Plasterboard partitions did not include an adequate head detail to accommodate any slab deflections during a fire
- Other non standard details were used without documented evidence of their suitability

The construction included numerous service penetrations, or openings through fire resisting partitions, which were inadequately sealed, thus creating breaches through various fire resisting elements. These included compartment walls between flats, protected corridors, and protected entrance halls.

> **eventually, the reporter advised the client not to proceed with the handover of the building until all issues had been resolved**

The reporter goes on to explain that at various stages of the process, different stakeholders and technical specialists were involved in discussions to try and justify the inappropriate works that had already been completed. However, the reporter asserts that the arguments were purely qualitative and product manufacturers were unwilling to provide any sort of guarantee for non-standard details retrospectively to reflect the works onsite. This resulted in difficult conversations and eventually, the reporter advised the client not to proceed with the handover of the building until all issues had been resolved.

In principle, it would be expected that any fire stopping or passive fire protection works are carried out by competent professionals. This is similar to the expectation that masonry partitions would be constructed by bricklayers, building services would be installed by mechanical or electrical engineers. Whilst it is not a legal requirement for third party accredited installers to carry out these works, there is an obligation that the systems function as intended and are suitable from a workmanship perspective, as indicated in **Regulation 7 of the Building Regulations>**.

Regulation

Materials and workmanship

7. (1) Building work shall be carried out—

(a) with adequate and proper materials which—

(i) are appropriate for the circumstances in which they are used,

(ii) are adequately mixed or prepared, and

(iii) are applied, used or fixed so as adequately to perform the functions for which they are designed; and

(b) in a workmanlike manner.

The relevant extract from Regulation 7 of the Building Regulations

Following the Grenfell Tower tragedy, the construction industry is undergoing a significant culture change, where more emphasis is placed on life safety and ensuring that buildings are safe to be occupied. In the reporter's opinion, there is still a long way to go. There is a need for everyone involved in the construction industry to raise the bar and not accept compromises on safety aspects that can have a significant impact in the long term.

It is important that people are accountable for their work and a concise record is maintained of all life safety elements, not only to assure the end client of the safe condition of the building, but also to ensure the building can be appropriately maintained throughout its lifetime.

Ensuring continuity in the design process by following the principles of the golden thread of information is crucial. It is also key that fire engineers are involved throughout all design and construction stages up to handover to mitigate risks and ensure that the fire safety principles are correctly adopted. The importance of third party accreditation, quality assurance and accurately recording evidence should also be emphasised. These provide assurance of the competence and quality of workmanship of contractors carrying out the works.

C Expert Panel Comments

The issues discussed in this report are, sadly, still typical of the industry, and certainly what we continue to experience.

While it is encouraging that qualified (competent) subcontractors were used in some areas in the project described, it clearly was not enough. There is a movement towards ensuring the competency of installers, using correct products, with third-party assurance, but this is still a work in progress.

It is felt that the necessary culture change is not happening quickly enough at the installer level.

It is still the responsibility of those carrying out building work to ensure that the construction meets the requirements of the Building Regulations. Thus, they need to appoint competent people and utilise appropriate products to achieve that aim. Moreover, as stated in this report, when third party accredited installers are used, the quality of the installation is as expected. This point reaffirms the recommendation stated in **Approved Document B>**

"Third party schemes of certification and accreditation of installers can provide confidence that the required level of performance for a system, product, component or structure can be achieved. Building control bodies may accept certification under such schemes as evidence of compliance with a relevant standard. However, a building control body should establish before the start of the building work that a scheme is adequate for the purposes of the Building Regulations. For further information about third party certification schemes and competent person schemes, see Chapter 5 in Volume 1 and Chapter C in Volume 2 of the Manual to the Building Regulations."

The fire safety sector has an enormous challenge in improving the level of understanding throughout construction companies and by individual operatives

CROSS has received a significant number of reports about issues with passive fire protection. When these come to light, there is often a significant impact on occupiers and other stakeholders, including financial misery and stress.

The fire safety sector has an enormous challenge in improving the level of understanding throughout construction companies and by individual operatives, of the seemingly trivial details, which if installed incorrectly, potentially undermine the entire fire performance of the structure. We cannot expect individuals or construction companies to close this gap themselves; such an approach is expecting individuals to know what they don't know. The fire industry needs to develop a structured process for educating the construction industry as effectively as it discusses its failings amongst itself.

Another aspect worthy of note is the apparently significant number of fire engineering judgments used to justify otherwise unsubstantiated installations. It is felt that often such submissions are little more than opinions, made with neither the necessary competency nor an established basis upon which to justify an acceptable technical assessment. The Passive Fire Protection Forum's **Guide to Undertaking Technical Assessments of Fire Performance of Construction Products Based on Fire Test Evidence, 2021>** is a useful reference.

Submit Report

Submit Feedback

Understanding finite element analysis for pile caps

CROSS Safety Report Report ID: 1152

A reporter has encountered situations where two-dimensional finite element (2D FE) shells are used to model structural elements such as pile caps, combined bases and large ground bearing or pile foundation structures for stability cores. However, the depth or thickness of the structural element is such that the reporter questions the validity of the structural model.

Key Learning Outcomes

For civil and structural design engineers:

- The design of basic pile caps can be carried out using strut and tie methods
- Be mindful of The Concrete Centre advice that 'Design using FE analysis requires engineering judgement and a feel for the behaviour of concrete'
- If a finite element method (FEM) is used, designers should know and understand the theory while being aware the selection of element type and size will affect the results

R Full Report

A reporter has encountered situations where two-dimensional finite element (2D FE) shells are used to model structural elements where the depth or thickness of the structural element is such that the validity of a 2D FE surface, and in particular, the application of the underlying theory used in the formulation of the elements, is questionable. The models encountered were being used to design elements such as pile caps, combined bases, and large ground bearing or pile foundation structures for stability cores. In each case, the depth of the structural element could not be considered small.

The reporter says earlier versions of FE modelling would have been based on Kirchhoff-Love theory, often referred to as 'thin plate theory', which is the 2D extension of Euler-Bernoulli beam theory. The underlying assumption of the Kirchhoff-Love theory is that the thickness of the plate is significantly smaller than the in-plane dimensions. For this version of the theory to be relevant, the span-to-depth ratio needs to be greater than 10.

To overcome this limitation, general 2D FE structural analysis software tends to employ Mindlin-Reissner plate theory, which is the 2D equivalent of Timoshenko beam theory - often termed 'thick plate theory'. According to the reporter, various resources give slightly different limits but the span-to-depth ratio should be no lower than in the range 3-5.

modelling of structural thicknesses greater than the upper limit may give inaccurate results

In both cases, in the reporter's view, modelling of structural thicknesses greater than the upper limit may give inaccurate results. The structure may be over-constrained, and the effects of shear may be underestimated. A design based on FE elements used outside of their range of applicability may therefore give forces that are lower than they might be in the real structure.

The reporter contends that too often FE analysis is used without sufficient thought and understanding. Before using any FE analysis software, they believe the designer should know the underlying theory used for the elements being employed and understand the potential impact this may have. In general purpose structural software there is often no choice (or a very limited choice) of elements to be made, but in more specialist FE software a range of elements are used, and choosing the correct element for the problem in hand is of vital importance. In the reporter's experience, proficiency in using FE within structural engineering is often measured as the ability to use a software package rather than the ability to understand the underlying basis of the software.

> **The element size should be less than span/over 10 and its width larger than the slab depth**

The reporter believes the situation is not helped by the available guidance, which is either too general in nature or too specialised. In response, the reporter has resorted to researching texts and references on plate bending theory itself. The reporter found only one publication they felt dealt satisfactorily with the issue, The Concrete Centre's publication **How to design reinforced flat slabs using Finite Element Analysis>**. This says the element size should be less than span/over 10 and its width larger than the slab depth. Therefore, the span would need to be more than 10 times the depth to comply.

The reporter goes on to say that while it is the responsibility of the user of the software to make sure they understand the analysis and limitations, the software producers could perhaps also do more. Though it is difficult to implement dimensional checks due to the relative geometric freedom that FE gives, they could perhaps give more explicit details of the FE formulation used and any limitations.

Both British Standard BS 8110 (now withdrawn) and Eurocode BS EN 1992-1-1, place limits on the ratio of beam depth to span length over which a beam is considered a deep beam. The Eurocode also provides an explicit limit on the thickness of a slab. In both codes, the standard design rules are limited to those structures not considered deep beams or slabs. In the case of the British Standard, the designer is referred to specialist literature. In the case of the Eurocode, while no direct mention is made of the design of deep beams, it does contain a reference to 'strut and tie' design methods. The reporter contends it appears that these code requirements, which are not specific to FE but do reflect the underlying limits of Euler-Bernoulli beam theory, are not well known by designers or perhaps reflect a mistaken belief that FE is somehow unlimited in its use.

In conclusion, the reporter says that FE analysis is perhaps used in some cases without a proper understanding of the underlying theory. They believe the focus may be on producing a photorealistic representation of the structure rather than producing a valid and appropriate model. The reporter considers that guidance is needed specific to structural engineering and aimed at the practicing engineer.

C Expert Panel Comments

It is important to emphasise that engineers should understand the nature and probable behaviour of a structure irrespective of any FE analysis. Pile caps in practice are thick stiff units, not thin slabs, and manual design with the traditional strut and tie method is generally a reliable way of proceeding.

In 2018, CROSS issued the Safety Alert **Effects of scale>** in which the design process suggested, FE analysis being relevant to thin slabs, is inappropriate for 'thick slabs' (although what is meant is not thickness directly but short 'beams' with very high depth/ span ratio).

There is even a case on safety grounds for concern about using normal beam design here. The problem is that the high depth/span ratio will result in relatively low rebar and the capacity of the concrete section based on reasonable concrete strength may exceed the section strength based on rebar. Under overload, the section could fail as concrete cracks and the rebar, giving lower strength, does not contribute. The performance of the section has been transformed from ductile to brittle - very undesirable. However, the rules for minimum reinforcement in the Eurocode are generally formulated to give reinforcement with at least the same strength as the cracking strength of the concrete section.

> **what the beam analysis will not pick up is that the force is fairly constant between the two piles and will not drop off as predicted by beam theory**

In most cases, the FE analysis will give a reasonable approximation of the maximum forces. For example, the maximum area of tension steel calculated for a two pile cap from an FEM may be similar to that found by using beam theory or strut and tie. However, what the beam analysis will not pick up is that the force is fairly constant between the two piles and will not drop off as predicted by beam theory.

A worrying aspect is that some software packages are starting to be used directly for detailing and, in this case, it would be very possible to get an unsafe design. To expand on this; 2D elements, whether formulated as thick or thin plate/shell, work on the assumption that the structure is essentially working in bending, but pile caps are usually of such thickness that they act as deep beams. In other words, shear behaviour is significant and they are better considered as behaving as a strut and tie.

If a pile cap is being modelled in 2D elements and the analyst is only interested in how the forces are distributed into the piles, then the mesh density makes little difference. However, if an understanding on what is happening within the pile cap is desired, then the 2D elements will give only a partial picture based on the assumption the cap is working entirely in bending and ignoring (or minimising) the effect of shear in transferring the load.

Moving on to FE modelling more generally, The Concrete Centre publication mentioned earlier lists a series of advantages and disadvantages of FE analysis on its front page. One of the disadvantages is 'Design using FE analysis requires engineering judgement and a feel for the behaviour of concrete'. CROSS is concerned about the number of reports being submitted about problems with the use and understanding of FEM.

One Expert Panel member is also a reviewer for the Institution of Structural Engineers (IStructE) chartered membership and, when presented with multicoloured FE analysis plots in a portfolio, they typically ask candidates to explain how the structure is working and whether they have produced

There is a lack of knowledge, and the evidence suggests software is being used without a proper understanding of how it works

'order of magnitude' checks to satisfy themselves that the FE analysis answer is reasonable (particularly when it produces reinforcement quantities).

The reviewers do not always get satisfactory answers, and these often get worse when candidates are asked about FE analysis deflection calculations and the material parameters used. There is a lack of knowledge, and the evidence suggests software is being used without a proper understanding of how it works and, significantly, without an independent check by someone more experienced in the use of these systems and their limitations.

The issue with use of FE analysis is far wider than just the appropriate selection of shell, plate or solid elements. There should be more rigorous verification and validation as well. Validation is the comparison with known results (numerical or experimental). Verification establishes that the model is not sensitive to discretisation or imperfections and the like. It is useful to reflect on the fact that the only exact formulation for a finite element is that for a beam, all other formulations are approximate.

Discussion on element types

Looking at the theory section, to quote the National Agency for Finite Element Methods and Standards (NAFEMS) publication, Finite Element Analysis for Engineers - A Primer (2013):

'In Kirchhoff theory, the out of plane normal remain straight and normal to the 2D surface. In Mindlin theory, also known as Reissner-Mindlin theory, the normal remain straight but can rotate relative to the 2D surface. Both theories allow simple bending behaviour with either the absence or presence of shear straining, respectively.'

It is worth noting that a plate carries only bending, a plane stress element carries only in-plane forces, and a shell is a mathematical combination of a plate and a plane stress. This means that shells using Kirchhoff/Kirchhoff-Love formulation (known as 'thin plates' or 'thin shells') are suitable only where there is minimal shear, such in a membrane structure like a cooling tower.

shells are great for general structural modelling but they begin to lose accuracy where shear dominates

It is not thought that many structural FE analysis packages use such formulations, apart from those where they might be available as an advanced option. Shells that use Mindlin formulation ('thick shells') do include shear stiffness but they still assume that the normal remains straight, meaning that while shear deflection is included in the behaviour, deformation of the section is not.

This means shells are great for general structural modelling but they begin to lose accuracy where shear dominates. It is not a particular problem in the region around a column in a flat slab, as this is a small part of the overall structure, and the recommendation is to consider shear in this zone in a separate, more detailed model. Where shear dominates throughout, they do not capture the full behaviour of these structures.

As mentioned, this is a different consideration to the element size itself. The NAFEMS guides do not give recommendations for minimum element sizes, but the converse. For example, their Finite Element Analysis for Engineers - A Primer publication states:

"Use enough elements to provide results of sufficient accuracy, with smaller elements in areas where the physical behaviour varies most rapidly, such as near stress concentrations, and larger elements away from such areas."

Similarly, The Concrete Centre publications, How to design reinforced concrete flat slabs using Finite Element Analysis, states:

"Definitive advice cannot be given as to the ideal size mesh size, but a good starting point is for elements to be not greater than span/10 or 1000 mm, whichever is the smallest."

And

"…a finer mesh giving more accurate results. The engineer has to assess how fine the mesh should be; a coarse mesh may not give an accurate representation of the forces, especially in locations where the stresses change quickly in a short space e.g. at supports, near openings or under point loads. This is because there are insufficient nodes and the results are based on interpolations between the nodes."

Note that these statements are in direct opposition to those given by the reporter in their submission to CROSS. In the IStructE's **Computational Engineering>**, there is the recommendation that:

"the element width should be at least twice its thickness"

However, this is for usefulness of result rather than accuracy. The engineering sin is not that the elements are too small, but rather are too large in areas where the stresses are changing rapidly.

The Panel agree with the reporter that all too often FE analysis is used without sufficient thought and understanding.

Submit Report

Submit Feedback

The stack effect and considerations for smoke control

CROSS Safety Report Report ID: 1250

Stack effect can significantly impact fire safety and smoke spread in the escape stairwells of tall buildings. The reporter states real world tests have demonstrated that existing smoke control systems, designed in accordance with standard industry design guidance and idealised conditions, may not suitably account for typical winter stack effect conditions.

Key Learning Outcomes

For designers and installers:

- When modelled, smoke control systems such as smoke extract shafts should account for realistic building and environmental conditions to demonstrate they can overcome the powerful and competing air flows driven by the stack effect
- Testing and commissioning of smoke control systems should not be done in isolation, it should be carried out in realistic and suitably representative building conditions to capture the impacts of the stack effect

R Full Report

The stack effect is a natural phenomenon that occurs predominantly in tall buildings, where difference in air temperature results in pressure between the inside and outside of a building and causes air to flow through vertical spaces. In the event of a fire, the stack effect can promote smoke and hot gases to rise and accumulate in the upper floors of a building, while drawing fresh air from the lower floors. This can create a hazardous situation where smoke and heat are drawn into the stairwells, which are critical as escape routes for occupants of the building as well as for fire rescue service intervention.

As illustrated in Figure 1, the stack effect can interfere with the operation of certain types of smoke control systems by encouraging a flow of air that is opposite to the desired direction of airflow.

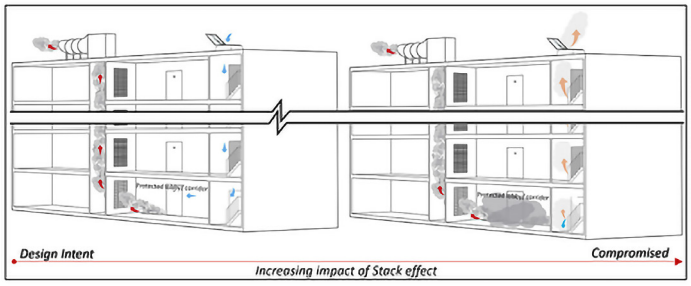

Figure 1: *Fire safety impact of stack effect*

Design and commissioning

The internal and external temperature distributions and gradients before a fire are not always accurately represented by practitioners in design approaches that utilise Computational Fluid Dynamics (CFD) based fire modelling, such as the widely used Fire Dynamics Simulator (FDS). Moreover, when these pre-fire temperature conditions are included in the model, the prevalent use of the default inert wall thermal boundary conditions in FDS may significantly influence the preservation of temperature gradients. This happens because these conditions model an infinite heat transfer to keep the wall temperature at a steady 20˚C.

Stack effect is often overlooked in smoke control design with some guidance, such as EN12101-6-2006 Annex B (informative), even suggesting to intentionally reduce or remove the impact stack effect during the commissioning of smoke control systems: "B.*2 Where stack effect is likely to be a significant factor, this may be minimized by operating the pressure differential system for a period of one hour before testing so that the external air and shaft temperatures can equalize."*

This report highlights alarming observations where the impact of stack effect in tall buildings undermined the active smoke control systems and illustrates how, if not suitably designed for, means of escape and fire rescue operations may be compromised.

Observations

Responding to reports of various fire system faults, recent investigations were carried out during winter and spring months at several tall buildings.

For **Observation Test 1** the building was a 40-storey residential building with a naturally ventilating Automatic Opening Vent (AOV) provided at the top of the escape stairwell intended to act as a make-up air source for a smoke extract shaft within the lobby. The interior temperature was 18˚C-26˚C, and the exterior was 8˚C -10˚C.

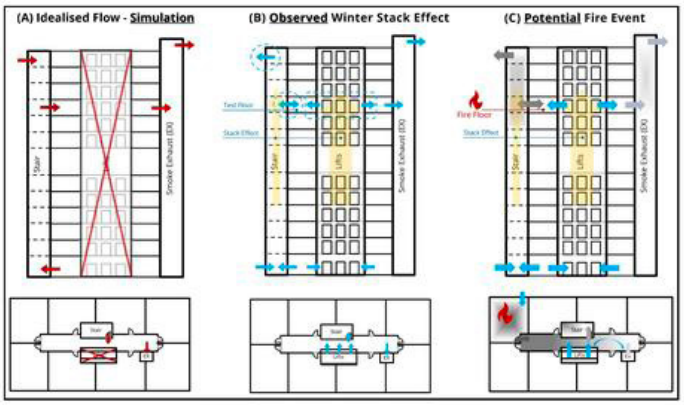

Figure 2: *Observation Test 1*

Figure 2(A) illustrates the typical idealised flow to remove air via a smoke shaft in the lift lobby (driven by a smoke extract fan) with airflow being drawn from the stairwell's open AOV. During a test of the smoke control systems, the main entrance and exterior stair doors at ground level were open.

Figure 2(B) shows what was observed during the test, namely how the smoke exhaust systems were unable to counter stack effect driven flow up the stair shaft. This required retroactive amendments to the system which may not have been undertaken in other buildings, particularly those commissioned on warmer days.

Finally, Figure 2(C) demonstrates that if a fire occurred while the building was experiencing a winter stack effect condition, smoke could be actively pulled into the stair as the exhaust shaft is unable to overcome the draw of air into the stair. Furthermore, it shows it is likely to be exacerbated by fire driven mechanisms such as a buoyancy driven upwards air flow, increasing pressure in the lobby corridor.

For **Observation Test 2** the building was a >30 storey office building with protected firefighting lobbies containing a dedicated firefighting lift and smoke extract shaft. The escape stair which opens into the firefighting lobbies at each level was provided with an AOV for natural make-up air. The interior temperature was 22˚C-26˚C, and the exterior was 5˚C -8˚C. Fire curtains were included in the smoke control system to provide compartmentation to reduce smoke movement through the lift shafts in lieu of fixed lobbies. These fire curtains were designed to activate on the ground (escape) level and the level where the fire is detected.

Figure 3(A) illustrates the idealised design flow, which was observed to not sufficiently account for flow through the firefighting lift. The exhaust function was intended to generate a pressure differential across the escape stair door to prevent airflow into the escape stairwell. During the test, the lift motor room vent was open as well as the main entrance and exterior stair doors at ground level.

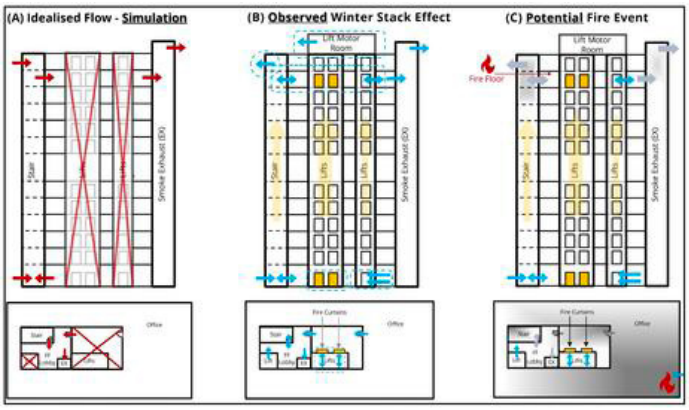

Figure 3: *Observation Test 2*

Similar to Observation Test 1, Figure 3(B) shows how, during the test, the air flows within the escape stair were reversed compared to the design flow. Additionally, the combined force of the smoke extract system and stack effect caused fire curtains in front of the lift doors to fail to fully close on the fire floor and the ground floor. However, it should be noted that in a similar case with a taller building, the ground level fire curtains were pulled out of the runners when the ground level doors from the lobby to the exterior were opened. In some instances, particularly when the firefighting lobby door to the main office floorspace was opened, the firefighting lobby exhaust was also unable to prevent airflow into the adjacent escape stairwell.

Figure 3(C) demonstrates that if a fire occurred while the building was experiencing a winter stack effect condition, vents at the top of the building will likely exhaust warm air (even on milder days), compromising the design intent of the smoke control system.

Observations have also shown that the winter stack effect can be further exaggerated when escape stairs are glazed. A glazed stair with high solar gain can allow sunlight to enter the building and heat up the surfaces and air inside, creating a larger temperature difference between the interior and exterior of the building. If the glazed stair is in an area of the building where the stack effect is already strong, such as a tall building, the high solar gain can enhance this effect significantly.

It was observed that the failure of the smoke control systems to prevent airflow into the escape stairwell was due to the lack of consideration for the stack effect in both the design and guidance assumptions. Specifically, standard testing methods allow for stack effect to be ignored and considers stairwells in isolation to all other vertical shafts.

This is not representative of modern building behaviour. Recent publications, amendments and additions to codes have begun to identify stack effect, and wind, as key design conditions. However, these are often limited to 60m+ tall buildings (EN12101-13). While being a predominant cause of issues in tall buildings stack effect, wind-driven flow will be present in all buildings and can affect air movement in even low-medium rise buildings.

If a fire occurred in a tall building that was experiencing a stack effect condition due to cold external temperatures, and the building was not suitably designed to accommodate the stack effect, then smoke could be drawn into the escape stair.

While this report focuses on active depressurising systems, similar stack effect air flows in fully naturally ventilated stairwells may result in similar issues in taller buildings.

Stack effect should be reflected in the modelling, design and testing of smoke control systems. Specific attention should be put on medium-high rise and taller buildings, and layouts which provide open connections at the top of interior vertical shafts and the exterior.

Within the industry, a greater emphasis needs to be placed on ensuring that testing and commissioning is carried out in realistic and suitably representative conditions, e.g. occupied levels heated. Testing which ignores the stack effect and considers stairwells in isolation should not be considered suitably representative.

C Expert Panel Comments

The Panel agree with the concerns raised by the reporter, which also highlight the issue of a lack of engineering rigour. No engineered solution should be considered valid without sufficient examination of the sensitivities and parameters that could lead to the failure of such a system. Once the parameters of failure have been identified, an analysis of the likelihood that such circumstances could be present would provide an indication of the level of confidence that can be applied to the solution being proposed. This should form part of the design process, and not be left to be uncovered during testing of an installation.

Submit Report

Submit Feedback

Painted faying surfaces leads to connections with insufficient load capacity

CROSS Safety Report Report ID: 896

Painted, rather than the required unpainted connection faying surfaces, were identified by the resident engineer of a reporter's firm during the erection of a primary frame for a large project.

The painted surfaces resulted in the connections not having sufficient load carrying capacity and necessitated remedial works.

Key Learning Outcomes

For civil and structural design engineers:

- If there are any unusual features of a design, these should be made known to all parties and emphasised both in the specification and with notes on drawings
- Good communication between designers, contractors, and site supervisors is essential and there should be a suitably qualified and experienced person responsible for coordinating this
- The importance of finishes on faying surfaces on joints should be more widely recognised

For steel fabricators and contractors:

Where there are large connections with faying surfaces ensure that the specification for finishes is agreed with the designer

Where special conditions are specified, ensure that all parties know what these are and can comply with them and that adequate quality control measures are in place

Pay particular attention to inspections of painted/unpainted areas and the requirements of the specification

Steel fabricators should not make unilateral changes to the engineer's specification or design without their approval

R Full Report

Faying surfaces are the surfaces or faces placed in tight contact to form a joint. During the erection of a primary frame for a large project, the resident engineer (RE) of a reporter's firm identified the presence of painted faying surfaces, rather than the required unpainted ones.

The issue was identified by the RE when the steel was delivered to site and prior to it being erected. The error was brought to the attention of the contractor, who took the decision to erect the steelwork despite it being non-compliant with the design or with the specification requirements.

The connections in question were significant and were present in the main long span roof trusses of a major structure with some connections carrying very high loads. The long span nature of the roof structure meant that slip in the connections, arising from movements made possible by bolts in clearance holes, would cause considerable deflection of the trusses. The designer's specification therefore called for no slip in the connections at ultimate limit state (ULS).

The reporter continues that the connection design submitted by the subcontractor complied with this requirement and assumed fully prepared unpainted faying surfaces at the connections for maximum friction, together with tension control bolts to ensure that the correct clamping forces were achieved.

> **should slip occur in the joints suddenly, at or close to serviceability limit state (SLS) loads, significant additional dynamic forces could be generated**

The reporter was also of the view that, should slip occur in the joints suddenly, at or close to serviceability limit state (SLS) loads, significant additional dynamic forces could be generated because of the very substantial weight of the roof dropping suddenly. Once it was found that the

faying surfaces had been painted, and so therefore the design assumptions had not been met, the reporter's firm undertook an independent review of the implications and laboratory testing. This review showed that the slip factor was dramatically reduced, and that the connection could slip at ULS.

> **In the reporter's view, this case calls into question the quality and checking regimes on some major sites where there are Consequence Class 3 buildings**

The reporter considers the issues to be significant due to the scale and mass of the roof structure involved and the risk of joints slipping under serviceability design loads. In the reporter's view, this case calls into question the quality and checking regimes on some major sites where there are Consequence Class 3 buildings (as referred to in **Approved Document A)>**. Furthermore, the reporter cites that in accordance with **BS EN 1990:2002+A1:2005 Table B5 - Inspection levels (IL)>**, such buildings should have been subject to extended inspection including third party inspection.

The reporter says remedial works, including welding and plating, were subsequently undertaken. These were however, in the opinion of the reporter, not completed without frustration.

The reporter has highlighted the issues above, to emphasise the risks of inadequate site supervision, the potentially dangerous impact of changes to design, and the safety risk that may arise from any lack of ownership and responsibility to rectify identified defects.

C Expert Panel Comments

This is an interesting report which raises several issues. Years ago, when high strength friction grip (HSFG) bolts were widely used, there were many technical articles about them. There was a good deal of discussion about how to guarantee the preload and what the surface friction values were, largely because their introduction was to replace rivets. It then became accepted that modern high strength bolts didn't need to be pre-loaded (at least for standard applications), however US practice at that time was always to torque the bolts up. Much of this knowledge of prestressing bolts was forgotten and it is unusual nowadays to look for no slip connections in building structures.

Bridge designers however, sometimes require no slippage at ULS so it may be that the designer used a bridge connection design approach. If so, bridge fabricators, with their associated higher design and workmanship standards might have been familiar with this condition.

It is certainly true that slip in truss joints will potentially add to truss deflection and requiring a nonslip joint is one strategy. However, it is questionable whether it can be achieved. This follows because at high loads, plates in tension will thin and that thinning will lead to loss of preload

> **Were the implications of painting of the steelwork highlighted on the drawings and in the project plan? If so, was there a communication issue between the designers and fabricators?**

and so earlier slip. The basic philosophy of such joints in Codes has always been nonslip at SLS, with slip at ULS, but with limits on plate thicknesses to assure that shear capacity and in bearing capacity is achieved. This means that strength capacity is there even if the joint slips.

Detailed information on the subject can be found in the **Guide to Design Criteria for Bolted and Riveted Joints, 2nd Edition>** from the American Institute of Steel Construction.

> **The basic philosophy of such joints in Codes has always been nonslip at SLS, with slip at ULS, but with limits on plate thicknesses to assure that shear capacity and in bearing capacity is achieved**

There are two significant issues in this report. The first and most obvious is that painting the faying surfaces was in contravention to the specification. The second issue is that while the design team may have departed from normal practice by requiring no slip at ULS, the contractor should not have proceeded with the works once the issue was raised. If something unusual is being proposed, then it becomes very important to ensure that everyone concerned, including the fabrication team, understands the implications.

In this case, were the implications of painting of the steelwork highlighted on the drawings and in the project plan? If so, was there a communication issue between the designers and fabricators?

The panel agrees with the reporter about the safety critical importance of communications between designers and fabricators, and the recognition of the importance of changes.

As has been said before, a robust specification supported by robust inspection and test plans, combined with adequate supervision are good precautions against points of difference between designers and fabricators.

Submit Report

Submit Feedback

Provision of water for firefighting

CROSS Safety Report Report ID: 1204

The reporter suggests that there is inadequate guidance on firefighting water provision for more complex and larger buildings.

Key Learning Outcomes

For designers and fire engineers:

- Consider all information available when developing fire strategies for complex or large buildings to include fire-fighting water supplies

R Full Report

Firefighting operations, and therefore firefighting water provision, are critical elements of intervention building fires. The reporter suggests that relevant legislation and appropriate guidance is inadequate and does not make the connection between firefighting operations and the provision of sufficient water.

The reporter asserts that there is no check of adequate provision of firefighting water at the design stage. Guidance such as BS 9999 and **Approved Document B>** (and national equivalents) do not seem to address this requirement, especially in respect to the volume/flow of water required for larger buildings.

Without adequate water supplies, firefighting could be ineffective resulting in extremely large fires with total building loss. It could also impact the principles of 'stay put' as this is reliant on the fire and rescue service dealing with the fire at the source and preventing it from spreading to other residential units. If there is no water, or a delay in accessing or locating hydrants, it could be critical to a successful outcome.

This issue is exacerbated by reduced water pressure in town mains, an active strategy by water authorities over the years to reduce leakage.

The reporter cites one useful document, the **National guidance document on the provision of water for firefighting (3rd edition; Jan 2007)>**, which gives guidance on the volumes required for various buildings. This is not referenced in the Approved Documents for England and Wales and, in the opinion of the reporter, the guidance in **Approved Document B Volume 2 (Sections 16.8 and 16.12)>** is not adequate. These sections require alternative supplies of water if *'pressure and flow in the water main are insufficient'*. However, it does not state what *'insufficient'* means. This leads to a judgement being made on the water supply that would be required for the building. Large buildings may need a larger water supply, and so if the town main isn't sufficient, it would mean that a separate water tank would be required.

C Expert Panel Comments

Firefighting equipment, tactics and resourcing have changed and the design guidance has not had a wholesale review in a long time; as such, it is in our view, not sufficient in some areas.

We understand this is being looked at as part of the technical review of guidance such as **Approved Document B>**.

When Approved Document B is used or cited, it should be directly linked to the 'common building situation' for which it may be appropriate, but more importantly those where it is not. Chapter 7, page 22 of **Manual to the Building Regulations from July 2020>** supports this. For example, in all practical terms, how can the provision of a single fire hydrant be sufficient for a very large warehouse? It needs to be acknowledged by all, that where there is an insufficient provision of firefighting water, this will directly affect firefighting operations and decision making, potentially leading to defensive tactics being deployed.

Under the HSE's Planning Gateway One process for planning applications for tall residential buildings, one piece of information required in the Fire Statement is to confirm whether the local firefighting water supplies have been tested to see if they are adequate. This will presumably help address this issue for any new buildings which go through that process.

Interestingly, in the case of the **Liverpool Car Park fire>** the mains supply was completely inadequate and three pumps had to be brought in to provide water from an adjacent dock.

Submit Report

Submit Feedback

Combination load cases in proprietary software cause concern

CROSS Safety Report Report ID: 1170

A reporter is concerned about a widely used software package that does not, in their opinion, generate load combinations in accordance with the Eurocodes being followed.

Key Learning Outcomes

For civil and structural design engineers:

- Software users should be sufficiently competent and experienced to recognise incorrect or unexpected situations and outputs
- It is good practice to carry out 'sense checks' and validate all analysis and design outputs
- If you are concerned with any outputs, raise this with the software companies technical support team and seek clarification
- When purchasing software, consider how outputs from the packages being considered will be validated

For software developers and suppliers:

- Evidence of validation against a wide range of published test cases is reassuring
- Ensure software updates and errors are notified to all users

R Full Report

This report concerns a widely used software package that the reporter does not believe generates load combinations in accordance with the Eurocodes being followed.

The reporter's experience of a proprietary package is that for roofs, the software combines imposed loads with snow loads and wind actions. This, the reporter says, contradicts the relevant Eurocode [clause 3.3.2(1) of EN 1991-1-1] which states that on roofs (particularly for category H roofs) imposed loads need not be applied with either snow loads and/or wind actions.

The reporter is concerned that this may lead to an overdesigned structure.

They are further concerned that for certain load combinations, the software utilises incorrect load factors for leading and accompanying actions.

The reporter believes that the algorithm for the automatic generation of load combinations is incorrect and furthermore, that the interface with the software does not readily allow for manual intervention. This makes it difficult for designers who rely on the software for the selection of load combinations and could lead to incorrect design outputs, such as unnecessarily conservative designs or unsafe designs.

The reporter has presented their concerns to the software supplier concerned.

C Expert Panel Comments

The reporter deserves credit for doing enough validation to establish that the software appears to be combining loads incorrectly, and is right to have highlighted their concerns to the software supplier.

Where there is any concern with software outputs, the issue should be raised with the software technical support team and clarification sought. Raising awareness is the first step in the process of bringing about improvements to industry practices.

Software deficiencies are relatively rare but they do happen. CROSS **Report 538 Failure to check designs produced by software>**, published in 2016, concerned an error in a design package that the software developer later confirmed had not been previously picked up. It is a pre-requisite for using software that the user must be able to recognise incorrect or unexpected situations and outputs. Simply put, software should only be relied upon by those who can anticipate the outputs, otherwise, they will not recognise errors in the software or more likely, errors in the use of the software. 'Sense checking' of all outputs, including load combinations, should be carried out as part of output validation.

> **Any concern with software outputs should be raised with the software technical support team and clarification sought**

The reporter raises an important concern about selecting appropriate load cases and factors. The selection of combinations and factors should not neglect any possible circumstances, for example, where wind loading may cause uplifts on roofs, care must be taken when considering the partial factors. Under the Eurocode system, where an imposed load is favourable, as is likely in a wind uplift case, a suitable partial factor (normally zero) should be applied.

Software developer responsibilities

Software developers should validate that their software complies with code requirements such that users can trust the software when using it within clearly defined constraints. Evidence of validation against a wide range of published test cases is reassuring.

When errors in commercially available software are found, suppliers should be challenged to demonstrate both the validation and the calibration of their software. Where an error in marketed software is confirmed, it would seem reasonable to expect a software house to issue revised software to all licence holders. In addition, all previous users of the software could be notified of the error so that the implications upon earlier work can be assessed.

The reporter also makes a valid point regarding the ease of checking software outputs. When selecting software, designers should think through how the outputs presented by different packages will be validated. An offering with numerous intermediate outputs, and more transparent processes, may well enable effective validation to be more easily applied.

The designer should never forget however, that the responsibility and liability for all outputs rests with the designer and not the software supplier.

CROSS **Report 1075 Potentially unsafe buckling resistance checks using software>**, published in 2022, considered anomalies in software outputs from a structural steelwork design package.

The designer should never forget however, that the responsibility and liability for all outputs rests with the designer and not the software supplier

Submit Report

Submit Feedback

Failure of Firefighters lift to operate

CROSS Safety Report Report ID: 1232

The reporter tells of an instance when a Firefighters lift switch, located on the Fire Service Access Level (FSAL) of a multi storey building failed to operate. After an investigation, the switch was found not to have been connected.

Key Learning Outcomes

For commissioning engineers:

- Check the operation of lifts conforms to the agreed cause and effect strategy. BS EN 81-72 on Firefighter lifts applies

For fire and rescue services, responsible persons and risk assessors:

- A lift for use by firefighters or for evacuation has a range of critical, pre programmed behaviours that only start upon activation of the firefighter's switch. The failure of these features would not be apparent in normal passenger use. They must be specifically checked in firefighting mode
- Responsible persons should ensure regular checks are carried out on Firefighter lifts

R Full Report

The reporter tells of an instance when a firefighting lift switch, located on the Fire Service Access Level (FSAL) of a multi storey building, failed to operate. When turned on, the switch did not recall the Firefighter lift to the FSAL.

The reporter then interrogated the operation and maintenance drawings and discovered that the switch was not connected to the relay to recall the lift. Therefore, the switch did nothing.

The electrical engineering drawing for the lifts showed only a communication line running to the FSAL. This was for the two way communication between the lift car and the Firefighter lift switch intercom.

Figure 1: *Example of Firefighters lift control*

It is felt by the reporter, that those persons with responsibility for buildings are not conducting regular checks on lifts provided for the fire and rescue service (FRS), or on evacuation lifts. They suggest that there are occasions where lift engineers do not have a thorough understanding of these types of lifts.

Furthermore, the reporter feels firefighters are not checking the operation of these lifts when they conduct their familiarisation visits, and that fire risk assessors are not checking test records, which is of particular importance for higher risk buildings as it is a requirement of **The Fire Safety (England) Regulations 2022 (Reg 7).>**

> **persons with responsibility for buildings are not conducting regular checks on lifts provided for the fire and rescue service**

The reporter suggests that this might be a widespread issue. They hope this report will raise awareness of the guidance issued by the Lift and Escalator Industry Association (LEIA) on the tests and inspections of lifts for use by firefighters, evacuation lifts, and lifts with recall.

C Expert Panel Comments

A widespread issue

This is, unfortunately, a common occurrence. It is often discovered Firefighter and evacuation lift controls are not operational, either because they were never connected and tested, or because they subsequently failed and have never been subjected to periodic testing during routine maintenance.

It is rare to see any comment in a fire risk assessment regarding the existence or nature of emergency lift controls. If such provision is noted, commentary regarding their maintenance is usually limited to identifying which part of the organisation retains the maintenance certificates.

Commissioning and routine checks

All functions should be confirmed as operational for the commissioning and sign off. There appears to have been an initial design error, which was then missed due to error in the commissioning. These errors were then in turn missed in the ongoing maintenance.

There is a need to review what functionality is checked by different parties, including the fire service. Any reliance on commissioning checks alone is likely a flawed approach. This issue also exemplifies the need for an independent third party approval system in the construction industry that would carry out such essential tests prior to a Building Regulations completion certificate being issued by the building control body.

Guidance highlighted by the Expert Panel

Checks should follow **BS 8899 Improvement of firefighting and evacuations provisions in existing lifts – Code of practice>** once revised, but in the meantime, advice on routine checks can be found in section 3.1 of **Checks and inspections of lifts for use by firefighters, evacuation lifts, and lifts with recall>** on the Lift and Escalator Industry Association website.

Fire Safety (England) Regulations 2022 add additional requirements for Responsible Persons and Accountable Persons of high risk residential buildings in England. They must:

Undertake monthly routine checks of lifts for the use of the FRS and evacuation lifts and make a record available to residents. All Responsible Persons should regard regular checks such as these as best practice

- Inform the fire and rescue service electronically, as soon as practicable, when an identified fault with a lift cannot be rectified within 24 hours
- Record information on all the lifts in the building on floor plans stored within a secure information box (SIB)

As a final note, readers of this report may find **CROSS Report 1182 Design criteria for firefighting lifts>** helpful as it explains the terminology for lifts provided for use by the FRS. Firefighters lift indicates a minimum level of protection compared to the standard. There are also firefighting, firemen's and evacuation lifts, and those with some specifically described (but limited) levels of protection.

Submit Report

Submit Feedback

Fire protection to structure by cavity barriers

CROSS Safety Report Report ID: 1231

A reporter is concerned about a potential misconception in the construction industry regarding the role of cavity barriers and the impact their design and installation can have on the structural performance of a building.

Key Learning Outcomes

Fire and structural engineers/designers:

- As cavity barriers have a role in protecting the structure as well as inhibiting the spread of fire and smoke, they should be specified carefully, in particular when they have a role in protecting the structure

R Full Report

A reporter contacted CROSS about a potential misconception in the industry regarding the role of cavity barriers and the impact their design and installation can have on the structural performance of a building.

In the reporter's view, cavity barriers are needed for construction technologies that incorporate cavities in their final assembly. Technical guidance for such instances is outlined in **Approved Document B>** and Regulation B3 - Internal fire spread (structure) of the Building Regulations 2010 must be satisfied:

"The building shall be designed and constructed so that the unseen spread of fire and smoke within concealed spaces in its structure and fabric is inhibited."

The guidance sets out two approaches to meet this regulation. The first approach is to sub divide cavities with cavity barriers (resisting fire spread within the cavity). The second is to close the edges of cavities (resisting fire spread into the cavity). The minimum recommended fire performance is E30 and I15.

> **the reporter would like to highlight a further intent set out in Approved Document B which is to inhibit the unseen spread of fire to reduce the likelihood of structural failure**

In the reporter's view, this functional requirement is specific to limiting unseen fire and smoke spread, with the aim to protect occupants, users, and first responders situated away from the compartment of origin. This may set a specific bias to practitioners that the role of cavity barriers is solely to inhibit the spread of fire and smoke. However, the reporter would like to highlight a further intent set out in Approved Document B which is to inhibit the unseen spread of fire to reduce the likelihood of structural failure. Functional requirement B3(1) on internal fire spread (structure) states:

"The building shall be designed and constructed so that, in the event of a fire, its stability will be maintained for a reasonable period."

Some forms of construction, such as some panel walls, some floor systems, and some light framing solutions rely on their enclosing sheathing/linings to protect the structural elements located within a cavity. Such systems rely on the integrity of these linings to achieve their rated fire resistance.

> **in most cases the cavity barrier achieves substantially lower fire resistance compared to that which is recommended for the structural frame**

In the case of external loadbearing walls, the possibility exists that the wall will be exposed on two sides at once; on the internal side by the compartment fire, and on the external side by venting flames or hot gases. This is not explicitly covered in the current technical guidance, which considers exposure on one face only. The reporter is of the mind that these walls may form part of the structural frame, and their performance should be investigated for simultaneous exposure on each side.

Fire can circumvent internal protection linings and heat structural elements by entering a cavity where there are penetrations in the wall, e.g., at a window. This route of fire spread is mitigated by installing a cavity barrier. However, the cause of concern is that in most cases the cavity barrier

achieves substantially lower fire resistance compared to that which is recommended for the structural frame.

It is understood by the reporter, through experience from reviewing fire incidents, that fire or hot gases can bypass the sheathing/lining and enter the cavity early to affect structural elements. This can also occur due to either a failure (or damaged state) of the sheathing protection, or occupant interventions like a fixing that was not installed appropriately. Another possibility is that this could occur due to an unprotected ventilation mesh grill on the outside of external walls (which may be exposed to external venting flames e.g., from windows, or from balcony fires).

Incorrectly specified barriers at the edge of such a construction, e.g., around a window opening, could compromise the protection to the structure. Typical E30 and I15-rated cavity barriers, recommended for purposes of resisting unseen fire spread, are unlikely to provide sufficient protection to the sheathing studs and columns.

Even where fire and smoke do not spread extensively within a cavity, there is a possibility that the loadbearing elements (columns, beams, or slabs) will be exposed to elevated temperatures at an early stage – thermal degradation, or decomposition if combustible construction is used, will then initiate. Apart from the inherent difficulties in suppressing such unseen fires, this may also lead to localised collapse of the structural elements, which in turn may render other cavity barriers ineffective and lead to subsequent fire and smoke spread beyond the compartment's cavity. This, of course, would be a matter of more significant concern in buildings where cavity barriers were incorrectly designed and installed.

In designs where the structure needs protection from fire, cavity barriers may be chosen to provide this protection; designers should consider the standard required for the structure rather than the, potentially lower, standard for the cavity barrier alone.

Designers should also seek to ensure that where sheathing linings are relied upon to protect the structure, these are adequately designed and installed for fire exposure on all relevant faces, which may include external faces, to maintain overall structural performance.

The reporter considers that more clarity in current guidance is welcome, and it could be helpful if the concern was considered in future updates for clarification and highlighting. Specifically, they are of the mind that any part of the structural frame, which might be exposed on any face, needs to be considered by designers for fire protection. This includes consideration of cavity barrier performance.

In the meantime, they believe it is helpful for the issue to be widely raised in the industry so that designers and building control bodies can give appropriate thought to the matter of structural protection when cavities exist, always in proportion to the size, height, and occupancy of the building.

C Expert Panel Comments

These comments merit a discussion between fire and structural engineers.

This report raises concern for cases where the structural elements are protected by a system (e.g. partition system) when there is a chance for them to have opening(s) (e.g. windows, doors, etc.).

As the reporter mentioned, we can see this in load bearing external systems.

In such a situation, since the structural element is protected by a system rather than a specific fire protection product, the primary objective of the cavity closer would be to act as a part of the protection system.

Thus, the overall performance of the cavity closer should be the maximum of the required performance as a part of the protection system and the minimum requirement given in **Approved Document B.>**

Submit Report

Submit Feedback

About CROSS-UK

We help professionals to make structures safer. We do this by publishing safety information based on the reports we receive and information in the public domain.

We are a trusted provider of free safety information for the built environment.

Visit the website>

Contact CROSS-UK>

How we are structured

The Institution of Structural Engineers

ice Institution of Civil Engineers

IFE The Institution of Fire Engineers

Sign up for our emails

If this Newsletter has been forwarded to you, please **sign up>** for email updates from CROSS-UK.

Email updates are the best way to receive the latest safety information and news from us, including our Newsletter.

CROSS on social media

CROSS UK