CROSS AUS
COLLABORATIVE REPORTING FOR SAFER STRUCTURES

The Institution of Structural Engineers

CROSS Newsletter

CROSS-AUS Newsletter 5 | **May 2021**

Collaborative Reporting for Safer Structures - Australasia (CROSS-AUS)

Grouting of joints between load-bearing prefabricated concrete members

Failure of large aluminium composite panel

Share knowledge to help create a safer built environment

Editorial

This Newsletter heralds the launch of a new era for CROSS starting with a new name: **Collaborative Reporting for Safer Structures** to embrace our wider ambitions. Major changes include a re-designed website with much faster response times, an improved layout for reports, an easier method for reporting, and an improved database.

The new CROSS system has been developed over the past 18 months by a team in the UK led by Dr Paul Mc Nulty. We have all benefitted from their dedication to this demanding task that has got us to this point today. For more details of the "New CROSS" and the background to the changes we encourage you to read **CROSS - Collaborative Reporting for Safer Structures** in this Newsletter.

Since our last Newsletter, CROSS-AUS has continued to receive reports from concerned individuals about a range of issues. For this edition we have selected four, and although they are about different matters, they have some common themes. We use prefabricated components to achieve a better-quality product and to improve safety by reducing work on site. However, once assembled the finished product is only as good as its weakest link and that is very often the connection between elements. Reports 961, 962, and 993 deal with different aspects of how elements are connected together and the risks of failure if these are not designed and constructed correctly. Another theme is around who takes responsibility for "non-structural" elements. This is an unfortunate term as everything has structure and perhaps terms such as "primary structure" and "secondary structure" might be better. Reports 962 and 1000 deal with lightweight cladding panels and internal partitions, respectively. These elements are often considered to be "non-structural" and yet they can be subjected to significant forces resulting in failure.

CROSS-AUS continues to expand its team and we are delighted to welcome Karlie Collis as a Director of CROSS-AUS Ltd. Karlie is the immediate past chair of EA's Structural College Board, and she has been a long-term supporter of CROSS. Our Expert Panel has been strengthened by the addition of three New Zealand Engineers, Eamonn Doherty, Gordon Hughes, and Steve Kemp; and David Lilley (one of our existing Directors) has joined Mike Fordyce as one of the "Designated People" who can access submitted reports. We are also pleased to welcome the **Australasian Certification Authority for Reinforcing and Structural Steels>** (ACRS) who join with Engineers Australia (EA), Engineering New Zealand (ENZ) and the Structural Engineering Society New Zealand (SESOC) as CROSS-AUS Supporters.

More reports are always needed, on structural safety, and if you have a concern or experience go to the **CROSS-AUS website>** where guidance is given on how to make a confidential report.

Mike Fordyce
Director, CROSS-AUS Ltd

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Reporting to CROSS-AUS

Your report will make a difference. It will help us to create positive change and improve safety.

Find out more >

Visit:
www.cross-safety.org/aus

Email:
team.aus@cross-safety.org

Collaborative Reporting for Safer Structures - Australasia (CROSS-AUS)

News

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

Our secure and confidential safety reporting system allows professionals to share their experiences to help others.

The new CROSS

CROSS previously stood for Confidential Reporting on Structural Safety and as part of our re-launch we have a new description: Collaborative Reporting for Safer Structures (CROSS). The new name reflects the integrated way in which professionals collaborate for a common purpose.

As part of our mission to make structures safer, the remit of CROSS-UK has been broadened to include fire safety, although this does not apply to Australasia for the moment. This is a consequence of the Grenfell Tower fire in London in 2017 and has been driven by Dame Judith Hackitt's appointment by Government to carry out an **Independent Review of Building Regulations and Fire Safety>**.

Evidence was given by CROSS-UK based on reports received through our confidential safety reporting system that illustrated the depth and extent of safety issues within the building industry. This led to a recommendation in the final report which stated:

'…the current CROSS scheme should be extended and strengthened to cover all engineering safety concerns…'

Our background in structural safety

The Standing Committee on Structural Safety (SCOSS) was established by the Institution of Structural Engineers (IStructE) and the Institution of Civil Engineers (ICE) in 1976.

The main function of SCOSS was to identify in advance trends and developments which might contribute to an increased risk to structural safety. General findings were published periodically, along with publications on specific matters of interest. More than one hundred topics have been closely studied over the last 45 years. Many of these by their nature are fundamental and ongoing issues.

Voluntary safety reporting for the built environment

In 2005, SCOSS implemented a system for the collation of data on matters of concern relating to structural safety. The system was named Confidential Reporting on Structural Safety (CROSS). It was based on the success of confidential reporting in the aviation industry.

CROSS allowed professionals to share in confidence their experiences to help others. It aimed to improve safety by publishing information which would not otherwise be available in the public domain.

To date, CROSS has received over 1,000 safety reports on topics ranging from issues with domestic buildings to major structural collapses. Each report contains information from which the industry can learn to make structures safer.

The expansion of CROSS-UK into fire safety

Conversations with the fire safety community as a natural partner to the structural safety community started a decade ago in the UK and relationships have been evolving ever since. Prior to its expansion into fire safety, CROSS-UK received a number of reports related to fire safety. These were generally in the space where fire safety and structural safety come together.

> **Each report contains information from which the industry can learn to make structures safer**

Reporting to CROSS

Our secure and confidential safety reporting system allows professionals to share their experiences to help others.

CROSS-AUS welcomes reports about structural safety issues related to buildings and other structures in the built environment. Reports should aim to include information that will help others to learn from the safety issue identified.

Reports typically relate to concerns, near misses or incidents.

Our confidential reporting system can be used by professionals who work with buildings and other structures. This includes anyone with an interest in, or responsibility for structural safety.

If you would like to know more about **reporting to CROSS-AUS>**, we have further guidance on our website.

Benefits of safety reporting

The aim of reporting to CROSS is to make structures safer and ultimately to save lives and reduce injuries. Safety reporting helps to achieve this by:

- **Promoting a culture change:** to encourage professionals to identify and report safety issues that occur during the design, construction and occupation or operation stages.
- **Sharing lessons learned:** to identify key lessons to be learned from safety reports to help professionals to make structures safer.
- **Identifying pre-cursors:** to identify and provide an opportunity to address pre-cursors which might result in a risk to life safety in similar circumstances if not addressed.
- **Identifying shortfalls:** to identify and provide an opportunity to address shortfalls in the design, construction and occupation or operation stages.
- **Improving competency:** using published safety reports as training and learning will form a key part of increasing the competency levels of all professionals.
- **Supporting regulatory activities:** information from analyses of the reports can be used for enforcement and wider regulatory activities such as planning future activity, publishing guidance and providing training and advice.
- **Supporting industry activities:** safety reports can be used by industry bodies as a learning resource for their members. Trends identified from reports can be used by industry to publish guidance and provide training.
- **Assisting with horizon scanning:** culture change and improved competency will help professionals and others to look ahead and predict future potential safety risks not yet identified. These include low probability but high consequence safety incidents.

The CROSS-AUS Expert Panel

The Expert Panel is at the heart of what we do. The Members are all volunteers.

Expert Panel members comment on reports we receive. They use their experience to help you understand what can be learned from the reports. Where possible, they aim to identify the underlying causes and make reference to other publications that those reading the report can access and use. Blame is never apportioned. The aim is to enable lessons to be learned so that similar situations can be avoided.

The Expert Panel members have a number of other roles, including maintaining a continuing review of matters affecting safety in the built environment and helping to write additional safety information for CROSS.

You can find out more about the **CROSS-AUS Expert Panel>** on our website.

> **Expert Panels comment on reports we receive. They use their experience to help you understand what can be learned from the reports.**

How to become part of the CROSS community

We want all professionals in the built environment to be part of our community. Here are some practical ways that you can be involved:

- **Share safety information for others to learn from:** you can do this by using our secure and confidential reporting system. Professionals who work with buildings and other structures can use our reporting system. You can find out more on our website.
- **Use the information on our website to make structures safer:** here are some practical ways that you can use the information:
  - As part of your continuous learning and development
  - Improve your knowledge of safety for your area of work
  - Keep up to date with emerging safety issues
  - Find out more about best practice
  - Share it with your team and others.
- **Get in touch with us if you would like to collaborate:** we are always interested in exploring opportunities to work with others to make structures safer.

Grouting of joints between load-bearing prefabricated concrete members

CROSS Safety Report   Report ID: 961

This report highlights the risk of failure if grouted joints between load-bearing prefabricated concrete members are not designed and installed correctly.

It demonstrates that design of grouted joints can be complex and that there are many factors to be considered.

It discusses the roles and responsibilities of the parties involved and the importance of adopting correct grouting procedures.

Key Learning Outcomes

For civil and structural design engineers:

- Understand the roles and responsibilities of the In-Service Designer as defined in *AS3850: Prefabricated concrete elements.*
- There is good practical advice available such as the NPCAA **Understanding Grouted Precast Joints: A guide for engineers and building contractors>**.
- Carefully consider the many factors that may affect the design and provide full details with accompanying procedure to the builder/contractor.

For construction professionals:

- Talk to the In-Service Designer to ensure that you have full details and understand the correct grouting procedure.
- Consider conducting trials to prove the adequacy of the grouting procedures.

R Full Report

A reporter has been concerned for some time about the design of grouted joints between loadbearing prefabricated concrete units. There appears to be much less effort applied to the design and installation of grouted joints when compared with connections between steel elements.

They note that there have been several failures, particularly in high-rise buildings in Australia over recent years, and that the cost of remediation generally far outweighs any extra cost and time in grouting the joints correctly in the first place. While all parties involved in the design, documentation, and inspection of grouted joints have a role to play in avoiding failures, the In-Service Designer (as defined in AS3850) has particular responsibilities as outlined below. Accordingly, it is important that contract documents, for example project technical specifications, align with AS3850 so that there is no confusion regarding which party is responsible for a potential failure.

What can be reported to CROSS-AUS?

CROSS-AUS welcomes reports about **structural safety** issues related to buildings and other structures in the built environment.

Reports should aim to include information that will help others to learn from the safety issue identified.

Reports typically relate to concerns, near misses or incidents.

If you would like to know more, we have further guidance on the **reporting to CROSS-AUS>** page on our website.

While all parties involved in the design, documentation, and inspection of grouted joints have a role to play in avoiding failures, the In-Service Designer (as defined in AS3850) has particular responsibilities

Responsibility for design of joints

The National Precast Concrete Association of Australia (NPCAA) has produced a guidance document: **Understanding Grouted Precast Joints: A guide for engineers and building contractors>**. While strongly recommending that all those involved with the design and erection of prefabricated (precast) concrete elements should adopt this guide, the reporter stresses that it is the In-Service Designer who must check the capacity of the joint and the adjoining concrete to be satisfied that all actions can be appropriately transferred through the joint to reduce the risk of failure.

It is the reporter's experience that many grouted joints are not designed but are assumed to be satisfactory if they are the same size and strength as the prefabricated concrete they are joining. While this may be adequate for low-stressed joints, it is not adequate for high-stressed joints. Grout may have similar properties to concrete, but unlike concrete, grout is typically placed into spaces that cannot be inspected and it is often batched on-site by relatively unskilled labour with little verification of mixing proportions or consistency.

Detail design of joints

In the opinion of the reporter, it is not good enough simply to state on the drawings or in the specification words such as "Grout all connections" and leave it up to the prefabricated concrete manufacturer, erector, or the contractor to sort out what is required. That is not their responsibility, and nor should they accept it. In such circumstances, a prefabricated concrete manufacturer, erector or contractor should ensure that non-acceptance occurs in written correspondence.

It is the In-Service Designer's responsibility to design, specify and document correctly the performance requirements for the grouted joints. They should select grout materials from a proprietary supplier, review the technical information and be satisfied that it is appropriate for the intended use.

It is the In-Service Designer's responsibility to design, specify and document correctly the performance requirements for the grouted joints

The reporter notes the following items to be considered by the In-Service Designer:

- The load to be transmitted through the joint;
- The type of joint, e.g., if it is stepped externally then the lower step should not be grouted;
- The joint may be reduced in width for sealants and have other constraints such as chamfering, adjoining slabs or offsets;
- The brittle nature and low tensile strength of grout;
- Allowance for all construction tolerances;
- Joints need to be designed to facilitate air displacement to maximise bearing contact with the grout to be placed. Grouting of flat, horizontal surfaces without appropriate air venting must be avoided; and

CROSS-AUS Supporters

The following organisations have a common interest in promoting structural safety and better standards in the building and construction industry. They have agreed to be recognised as a Supporter of CROSS-AUS.

These organisations will assist in raising awareness of CROSS-AUS and will promote the benefits of sharing experiences and lessons learned to their membership and through their networks.

- **Australasian Certification Authority for Reinforcing and Structural Steels (ACRS)>**
- **Engineers Australia (EA)>**
- **Engineering New Zealand (ENZ)>**
- **Structural Engineering Society New Zealand (SESOC)>**

- Whether the joint has dowel bars passing through it with dowel ducts in the adjoining prefabricated concrete elements.

For load bearing joints the reporter has noted that the following key items are not always fully considered:

- The sequence of construction and the stage when joints are to be grouted related to the application of load e.g., from floors above;
- The implications of the use of high-strength concrete that may exhibit increased brittle behaviour; and
- For highly-loaded joints there is likely to be an ineffective zone at the edges reducing the effective width of the joint.

Grouting procedure

Good grouting procedures are important, and the experience of the grouting company should be reviewed by the In-Service Designer. Some of the issues that concern the reporter are:

- Insufficient use of testing of grouting procedures and lack of on-site inspections.
- The use of levelling shims and ensuring these are removed at the correct time.

C Expert Panel Comments

Precast/prefabricated concrete construction can be used by engineers, architects, builders and contractors very effectively to achieve speed of construction with quality and aesthetically pleasing finishes. With medium and high-rise apartment construction, load-bearing prefabricated elements (walls and columns) are commonly used as the primary structure and the reporter raises valid concerns if correct grouting procedures are not followed.

With precast construction the crucial part of the system is the ‘Grouted Joint’ where all the design actions are transferred through a very small area, and the importance of this part appears not to be fully understood by many engineers. If it is not designed, detailed, and built correctly there is a high likelihood of failure similar to that which has been witnessed in recent years.

With precast construction the crucial part of the system is the ‘Grouted Joint’ where all the design actions are transferred through a very small area

The In-service Designer

The National Precast Association of Australia (NPCAA) document referenced in the report gives good guidance with respect to grouting of precast elements. As the reporter states it is the structural engineer who is responsible for the correct design and details of the grouted structural joints and this is now recognised in the recent edition of AS3850 with “In-service Engineer’s” responsibilities.

It is the In-Service Designer’s responsibility to identify the load-bearing and non-load-bearing prefabricated elements and to convey the correct details to the builder/contractor including dimensions of the grout seating (minimum structural requirements), the required grout strength at loading (compressive strength test on grout), and the grouting procedure.

Installation procedure

It is important that the builder/contractor correctly follows the design and details by having a documented QA procedure and the experience of the grout supplier can be called upon to provide input and to train construction workers on correct grouting procedures.

For highly-loaded joints, it is important to consider the shrinkage and creep properties of the grout and the potential for differential behaviour relative to the precast elements. Where there is doubt, the

CROSS-AUS Presentations:

Mike Fordyce presented a paper **“Development of Confidential Reporting on Structural Safety in Australasia”** in the Forensic Engineering session at the **IABSE Christchurch Virtual Congress>** on 3 February 2021 and contributed a “rapid-fire” presentation **“Improving Structural Safety by sharing lessons learned”** to the **Safety 2022 Virtual Pre-Conference Global Injury Prevention Showcase>** on 24 March 2021.

Panel member John Woodside will present a paper “Development of CROSS in Australasia” at EA’s Second Engineered Safety symposium in Adelaide on 4th May 2021.

A recent article by **NSW Building Commissioner>**, David Chandler, **“OC Audits are now evidencing construction’s fault lines”>** notes that Occupation Certificate (OC) Audits are about raising industry awareness of the standards with which building works need to comply and that the three building elements that evidence the most consistent fault lines are waterproofing, structure and fire system installations (both passive and active).

Visit the **Australian Building Codes Board (ABCB) Consultation Hub>** to participate in the discussion papers produced in response to the Building Confidence report.

The **ABCB** is presenting the **National Construction Code (NCC) Seminar>** series in May in all capital cities that will cover the application of the Building Code of Australia, and an overview of some provisions proposed for NCC 2022.

It is important that the builder/ contractor correctly follows the design and details by having a documented QA procedure

procedure could call for testing and monitoring of completed high-risk joints.

As the reporter notes, the sequence of construction and the application of loads from above are important, and this may affect the effectiveness of grouted joints. For example, the grout may be damaged even with the slightest movement of the precast elements, e.g., from adjacent construction activities. To mitigate this risk an additional temporary stabilising system could be used to prevent movement until the grout reaches sufficient strength.

Overseas experience

Although this report is directed at prefabricated concrete elements, correct grouting procedures are equally important for steel structures, as noted in **Recommendations for Structural Grouting>** by Mullins and Parker published in Structure magazine Sept 2019 that reports on some failures in the USA.

Submit Report

Submit Feedback

The **Australasian Certification Authority for Reinforcing and Structural Steels (ACRS)** has partnered with the leading international construction steel certification authority, CARES, to introduce its market leading **Sustainable Constructional Steels Certification Scheme>** into the Australasian markets.

CROSS-AUS Panel member Gordon Hughes has presented the first two in a series of **Engineering New Zealand (ENZ) Lessons to be Learnt>** webinars on "Engineering Failures" and the "Cave Creek platform collapse".

There is also an Auckland Structural Group presentation by Gordon **"Learning from Structural Mistakes">** that is available on YouTube.

Engineers Australia's EA On Demand series includes **Risk Management of Temporary Works>** that looks at key differences between temporary works and permanent works and highlights some of the shortcomings on recent temporary works failures in Australia.

The **NSW Design and Building Practitioners Act 2020** commences on 1 July 2021 and among the changes are two new registration schemes for practitioners working on class 2 buildings – one for **Professional Engineers>** and one for **Design and Building Practitioners>**. For further details go to **Class 2 building industry reforms>** on the NSW Government Fair Trading website.

Failure of large aluminium composite panel

CROSS Safety Report   Report ID: 962

This report highlights the importance of correctly designed fixings and anchoring systems for cladding panels to buildings to minimize the risk of failure.

It discusses how the failure in this case might have been avoided if there had been an adequate facade inspection regime in place.

Key Learning Outcomes

For civil and structural design engineers:

- Remember that fixings and anchoring systems are generally the critical parts of all cladding design and require appropriate investigation of the possible modes of failure.
- All fasteners into concrete should comply with AS5216 - Design of post-installed and cast-in fastenings in concrete.
- Being exposed to the weather, cladding requires consideration of durability of materials and the corrosion potential with dissimilar metals.
- When designing cladding and other elements for wind pay attention to the possible dynamic effects under low wind speeds.

For building owners and managers:

- Be aware that all elements of cladding present a significant risk to the public and require correct design and installation by qualified experienced practitioners.
- Consider having a regular inspection and maintenance program performed and documented by a competent engineer who has experience with the form of construction.

R Full Report

An aluminium composite panel (approximately 3m tall by 1m wide) fell from the façade of a multi-storey building into a high traffic pedestrian area. Many witnessed the incident and fortunately nobody was hit by the panel. The reporter was involved in the subsequent investigation, including the condition of the remaining aluminium composite clad elevations. The facade comprised aluminium composite cladding panels, screw-fixed to aluminium framing which in turn was connected back to the primary concrete structure behind.

Investigation of cladding

An inspection of the exposed framing found large holes had been cut into the mullions in certain locations with packers behind the mullion. Given the arrangement of the holes and packers it was expected that structural concrete anchors would be fixed at these holes between the back of the mullion to the structure behind. However generally there were no anchors found at these holes and instead, what appeared to be restraining the framing to the structure were brackets (approximately 1mm thick), which, according to the reporter, were undersized and fixed back to the concrete structure with (non-structural) hammered-in fixings.

The investigation concluded that these were not an appropriate anchorage system for structural purposes. In one instance it was noted that there had been a complete shear failure of a mullion-to-transom bracket which utilised metal of a similar thickness (approximately 1mm thick).

The investigation also revealed several screws across the rest of the aluminium composite clad façade to be loose or missing. A similar situation had been found during an earlier maintenance inspection when all loose screws were reportedly re-tightened into position by a rope access contractor. This suggests that many of the screws had significantly loosened, and dislodged in some cases, since that time. This loosening is suspected to be attributed to the inadequately fixed support framing allowing the framing to vibrate under low winds. The investigation concluded that the failed panel likely had several fixings unscrew due to this vibrating effect, resulting in the panel becoming partially dislodged from its position and then tearing through the final fixing when the panel fell from the building.

As the investigation had revealed several screws across the rest of the façade to be loose or missing, it was concluded that there was significant risk of further panels falling from the building. Subsequently the aluminium composite cladding panels and framing were removed from the facades.

> **The investigation concluded that these were not an appropriate anchorage system for structural purposes**

Maintenance of facades

Although there was an inherent flaw with the construction of the facade, the reporter believes this incident could have been prevented by an adequate facade condition assessment regime. The previous facade maintenance inspections were undertaken by rope-access contractors, with no engineer supervision or review. As such, the earlier observations of extensive loose screws were not diagnosed correctly, leading to failure of the panel.
Additionally, the design and installation of such panels by the relevant designers and contractors (and the incident itself) have the potential to be the subject of investigations by regulatory authorities and result in a variety of legal proceedings.

C Expert Panel Comments

While this report is about the failure of screw-fixed aluminium composite panels, it highlights a general issue with cladding that in many cases it has been regarded as non-structural and therefore not given adequate attention to quality of engineering design and construction. In such cases the design and detailing of the connections have often been left to the installer with little or no structural engineering input.

When the consequences of failure are considered, all elements of building facades require correct engineering design, with clear documentation, good standards of installation, and an on-going maintenance regime.

Cladding panels are typically exposed to the extremes of weather and due attention must be paid to durability of materials, and details such as the use of dissimilar metals.

> **All elements of building facades require correct engineering design, with clear documentation, good standards of installation, and an on-going maintenance regime**

Dynamic effects

When designing for wind, the report notes the importance of considering the dynamic effects under low wind speeds and this is particularly important when relatively lightweight elements are being used. Allowance for movement between elements is always an important consideration and in this case the type of fixings used were found to be inadequate.

Fixing methods

There have been other examples of issues with the installation of aluminium composite panels. In one case, aluminium composite soffit lining panels were fixed with proprietary very high bond double-sided adhesive tape. Although this tape may be an accepted form of fixing for this type of panel, it is very dependent on the quality of on-site installation. In this instance a panel fell from the soffit onto a public concourse and re-fixing of all panels, this time with mechanical fastenings, was subsequently undertaken.

Fasteners into concrete should comply with AS5216: 2018 - Design of post-installed and cast-in fastenings in concrete.

Maintenance

Maintenance (or the lack thereof) is a recurring theme in CROSS reports (e.g., refer to report **AUS-12>**) and is too often neglected by building owners. The maintenance of facades is particularly important, being exposed to all the elements and by introducing a regular maintenance program carried out and documented by a competent experienced engineer and/or suitably qualified and experienced person, not only will safety be enhanced, but significant future remediation costs may also be avoided.

Lessons learned

There have been numerous reports of fixing and anchor failures made to CROSS over the years and these can be found on the website **www.cross-safety.org>**. As with many such cases the example here demonstrates progressive collapse in that an initial failure leads to overloading on adjacent fixings resulting in an unzipping effect.

Refer to CROSS reports numbers 7, 11, 340, 461 and 498 to see parallel situations.

Submit Report

Submit Feedback

The use of cast-in ferrules as structural connections

CROSS Safety Report   Report ID: 993

This report highlights several problems that can arise with structural connections between elements when cast-in ferrules (also known as threaded inserts) are used for the anchorage of reinforcing bars.

It demonstrates that, if not designed, detailed, and installed correctly, brittle failure can occur rather than ductile behaviour as required by Building Codes and Australian and New Zealand Standards.

Key Learning Outcomes

For civil and structural design engineers:

- Be aware that when cast-in ferrules and similar threaded inserts are used to make structural connections using threaded reinforcing bar, the failure mode may be brittle, and the design may not comply with relevant AS/NZS Standards.
- If cast-in ferrules and similar threaded inserts are to be used when attaching other elements, ensure there is adequate development length and pay particular attention to the load transfer and failure mechanisms.
- There are proprietary systems available that will comply with the relevant AS/NZS Standards for ductile behaviour if installed in accordance with the manufacturer's specification. Talk to the suppliers who can provide technical advice on the tensile and shear capacity of their threaded inserts.
- Check if the structural connection is required to have a fire rating; in which case there may be reduced load capacity.

For construction professionals:

- Where proprietary products are specified, these should be installed strictly in accordance with the manufacturer's technical specification,
- Any proposed changes to the specified connection detail should be approved by the designer.

R Full Report

Introduction

Cast-in ferrules, or threaded inserts, in both in-situ and precast concrete have been used successfully for many years and initially these were for fixing light steelwork and other structures to prefabricated (precast) concrete, and for temporary bracing and propping. In recent years, the reporter has noted a trend to using cast-in ferrules in precast concrete members for the anchorage of dowel bars and starter bars into in-situ concrete. The threaded dowel bar or starter bar is screwed into a cast-in ferrule within the precast concrete and then the in-situ concrete is poured around the threaded bar.

The reporter is aware of several failures with this arrangement where the floors were post-tensioned and the axial shortening of the floor has pulled the ferrule with its associated threaded bar out of the prefabricated concrete walls. The reporter has also seen the failure of cast-in ferrules when impact wrenches have been used with high-strength bolts to fasten steelwork and similar elements to prefabricated concrete members.

Threaded bar

For detailed advice on the use of threaded bars, the reporter refers to a paper published by the Australian Steel Institute in July 2014: **Specification of threaded bar in structural applications>** where it suggests that threaded bar is not an ideal structural member as the cut threads act as notches. Reinforcing bars are not designed to have a thread on them and typically need to be of sufficient diameter to achieve a full thread cut. This means for example, an N24 bar is threaded to fit an M20 ferrule.

Australian Standards

The basic premise of *AS3600*: Concrete Structures is that in an overload condition, the reinforcement must

Reinforcing bars are not designed to have a thread on them and typically need to be of sufficient diameter to achieve a full thread cut

yield in a ductile manner before the failure of the concrete. The Standard states the following: '*the standard sets out minimum requirements for the design and construction of concrete structures and members that contain reinforcing steel or tendons or both.*' Clause 19.3 of AS3600 covers the design of fixings including ferrules and requires the fixings to be designed to yield before ultimate failure in the event of an overload. And Clause 13.1.4 of AS3600 requires the area of the anchor head to be greater than, or equal to, 4 times the cross-section of the bar.

The reporter notes that in *AS3850.1*: Prefabricated concrete elements, a ferrule is defined as an element to take a threaded bolt, not a threaded bar.

The reporter recommends that cast-in ferrules be designed in accordance with the principles in AS3850.1, Appendix B. Cast-in ferrules are available from several suppliers in Australia together with technical data on their tensile and shear capacities. It is important for designers to ensure that the cast-in ferrule complies with Australian Standards and to specify the supplier together with details including length, finish for durability and to ensure that adequate edge distances are achieved so that the full strength of the ferrule can be achieved. Imported ferrules may not comply. Similarly, as many contracts require contractors to construct a structure in compliance with a relevant Australian Standard, it is important for contractors to review a given design to identify and eliminate any potential non-compliance.

As many contracts require contractors to construct a structure in compliance with a relevant Australian Standard, it is important for contractors to review a given design to identify and eliminate any potential non-compliance

As an example of the dilemma facing designers, if one considers an N20 reinforcing bar into an M20 ferrule (and the bar should be an N24 as noted above), the bar has an ultimate tensile strength of at least 500 MPa or about 155 kN at yield. However, a commonly used M20 ferrule has an ultimate capacity of about 100 kN and it will fail before the reinforcing bar in a non-ductile manner. Accordingly, this combination does not comply with AS3600.

Connections of steel members and other elements to prefabricated concrete

Where connections are bolted into a cast-in ferrule, then a Grade 4.6 bolt must be specified rather than a Grade 8.8 bolt so that the bolt will fail in tension in a ductile manner before the ferrule fails. In other words, the capacity of the bolt must not exceed the capacity of the ferrule.

The reporter is aware of several examples where the use of over-torquing using impact wrenches has resulted in cone failure of the cast-in ferrules and emphasises that impact wrenches must not be used for tightening bolts. The ferrule suppliers can provide information on the torque that needs to be applied, and a calibrated torque wrench must be used. The reporter also notes there have been problems with the temporary bracing of precast concrete elements and draws attention to the safety alert issued by WorkSafe Victoria: **Brace footing installations on concrete>**.

Connections between in-situ concrete members and precast concrete

When fully anchored starter bars are used to connect in-situ concrete and precast concrete, if correctly designed the reinforcement will yield in a ductile manner in an overload situation. However, where a cast-in ferrule with a threaded starter bar is used, a typical failure scenario is shown in Figure 1. Where connection loads are minimal and tying together is only nominal, then it may be satisfactory to use a cast-in ferrule with a screwed-in starter bar, but where reinforcement is required for structural strength, then cast-in ferrules should not be used. A typical connection without ferrules is shown in Figure 2.

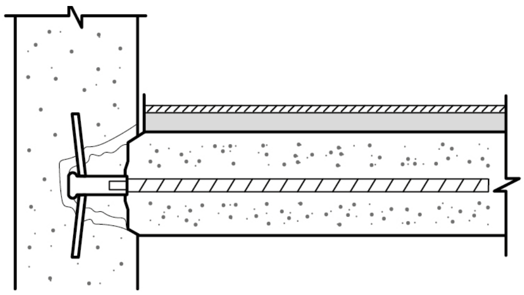

Figure 1: Typical failure scenario where a cast-in ferrule with a threaded starter bar is used

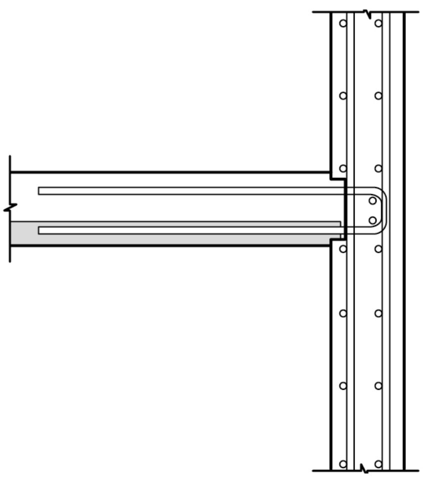

Figure 2: Typical connection without ferrules

C Expert Panel Comments

This report highlights the importance of following basic structural engineering design principles such as ensuring that failure modes of elements remain ductile and avoiding the risk of brittle failure.

When cast-in ferrules are being used, it is important to ensure adequate development length and to assess correctly the local load transfer mechanism between the elements. Otherwise, a local shear failure (pull-out) is likely to occur as shown in Figure 1.

One point often overlooked, when using a connection such as shown in Figure 1, is that although it may be the designer's intention that the dowel bar operates purely in shear, precast walls are often relatively stiff elements that will attract bending moments from the slabs they support. These bending moments are transferred to the walls by the dowels and ferrules and can subject the ferrules to significant axial loads that may be additional to the shrinkage and prestress loads noted by the reporter. There have been reported cases of the slab-to-wall connection 'unzipping' as these brittle failures progress along the wall. While this problem may occur with a single row of dowels, even if the connection is assumed to act as a hinge, it will be exacerbated in the case when two rows are used resulting in some degree of fixity.

There have been reported cases of the slab-to-wall connection 'unzipping' as these brittle failures progress along the wall

New Zealand experience

The use of cast-in threaded inserts has been an issue in New Zealand especially when used in precast panels to connect starter bars into floor diaphragms. Research into these types of connections has found that they perform poorly under seismic load and has concluded that such connections that have a potential breakout failure mode should not be allowed as a structural load path.

Research into these types of connections has found that they perform poorly under seismic load

Further details of this research can be found in the paper **Performance of panel-to-foundation connections in low-rise precast concrete buildings>** by Hogan, Henry & Ingham, published in the Journal of the Structural Engineering Society of New Zealand (SESOC), April 2018, where it states: *It was found that in the out-of-plane direction, current connection details utilising shallow embedded threaded inserts resulted in brittle joint failure and as such do not meet performance criteria in NZS3101:2006.*

Durability and behaviour in fire

For exposed structures or where there is a corrosive environment, the durability of cast-in inserts may be an issue that needs to be considered. In this case, ferrules and threaded inserts may need to be hot-dipped galvanized or stainless steel.

It will often be the case that the structure will be required to have a specific Fire Resistance Level (FRL), and this can influence the connection design. Deformations of the main structural elements when exposed to high temperatures are likely to impose additional loads on the connection. In addition, there may be a direct effect on the behaviour of a cast-in anchor itself if there is a risk that it will be exposed to fire. In such cases the advice of a fire specialist should be sought.

Submit Report

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Design of internal partitions for horizontal loads

CROSS Safety Report Report ID: 1000

This report draws attention to the requirement for internal partitions to be designed for horizontal loads from wind and seismic effects in accordance with Section B of the Australian National Construction Code (NCC).

It discusses that structural testing of some typical panels demonstrated that they were inadequate to resist the anticipated internal pressure from wind.

Key Learning Outcomes

For designers, building owners and managers:

- Be aware that so-called "non-structural" elements such as partitions, ceilings, and the like can be subjected to significant horizontal loads from wind and earthquake actions and require appropriate engineering design and installation by competent practitioners.

For civil and structural engineers:

- Raise the risk of non-compliant design of these so-called "non-structural" elements with other members of the design team.
- Keep informed with developments in codes and standards and ensure you are working to the latest edition.

R Full Report

The reporter is aware that on certain projects light gauge steel-framed fire-rated Inter-tenancy party walls are being specified and that these are being built without noggings. They are concerned that this design does not comply with the requirements of the NCC Section B. Whilst fire-testing of the walls without noggings appears to have been completed and compliance with Section C of the NCC may be attained, the reporter contends that the design does not address the structural requirements of Section B of the NCC.

> **Reporter contends that the design does not address the structural requirements of Section B of the NCC**

NCC Section B compliance

For Section B compliance with the NCC, the Building Importance Level (IL) and design safety events for the building are determined in accordance with Tables B1.2a and B1.2b respectively. Typically, for fire-rated internal partitions the design safety events consist of both wind and seismic, and these will vary according to the Building IL. For wind actions, the NCC references AS/NZS1170.2: Structural Design Actions, and the wind actions on the internal partitions, whether fire-rated or not, are determined in accordance with Clause 5.3.4 of AS/NZS1170.2. Similarly, for seismic actions, the NCC references AS1170.4, and seismic actions on the internal partitions are determined in accordance with AS1170.4 Section 8. The individual actions should then be assessed for the worst-case scenario in accordance with AS/NZS1170.0 as nominated in Section B1.1 of the NCC.

Structural testing

The reporter was involved in an investigation of this type of framing that included structural testing with an independent engineer overseeing the testing and derivation of the design capacities. Four tests were conducted including (1) no noggings, (2) one nogging 100mm below the head track, (3) one row of mid-height noggings and finally (4) noggings at both the head track and mid-height. Two wall systems were tested, a traditional light gauge steel frame readily available in the market and the second a proprietary light gauge steel frame system.

The test results gave the ultimate design capacity for each wall system when subjected to horizontal load, and working back from these internal pressures the reporter could determine the equivalent external pressure and wind speed.

This equated to a maximum building height of 10m and 30m for an Importance Level (IL) 2 building in Terrain Category 2 and 3, respectively. The building height would be further reduced for an IL3 building.

The projects where the reporter has seen such a specification being proposed are significantly higher than this and although they may comply with Section C of the NCC, the design will not comply with Section B. The reporter is concerned that the relevant building approval authorities do not have the necessary understanding of the NCC requirements for non-structural elements to ask pertinent questions in relation to the proposed framing, and this has allowed non-compliant designs such as these to proceed. In such cases, contractors should be wary of their responsibility and the potential consequences for constructing non-compliant designs.

The reporter is concerned that the relevant building approval authorities do not have the necessary understanding of the NCC requirements for non-structural elements

C Expert Panel Comments

This report highlights problems that arise with the use of the term "non-structural'' when applied to certain elements of a building that may not be part of the main structure, such as partitions, ceilings, and external cladding, and yet still have to be designed to resist applied loads, including wind and seismic.

As building size and height have increased, the effects of internal pressures from wind have become much more significant

There was a time when internal partitions were mostly brick or block, and this was generally not an issue. However, with more common usage of lightweight systems, and as building size and height have increased, the effects of internal pressures from wind have become much more significant. As noted by the reporter, all partitions in a building are subject to internal pressures that should be determined in accordance with AS1170.2.

The requirement for these "non-structural" elements to be designed for seismic actions was not generally appreciated in Australia until relatively recently. The ABCB issued guidance in March 2019 on the requirement to design certain non-structural building elements (including walls and partitions, ceilings and services) to resist earthquake forces in accordance with AS1170.4 in its article **Design of non-structural building elements for earthquake forces>**. CROSS-AUS drew attention to this article in its Newsletter 3 of February 2020.

The revised standard **AS/NZS2785:2020 Suspended ceilings - Design and installation>** sets out the minimum requirements for the design, construction, installation, maintenance, and testing of suspended ceilings, and brings the design requirements for wind and seismic into line with the requirements of AS1170 Parts 2 and 4.

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