CROSS AUS
COLLABORATIVE REPORTING FOR SAFER STRUCTURES

The Institution of Structural Engineers

CROSS Newsletter

CROSS-AUS Newsletter 7 | **August 2022**

- Modelling of structures
- Construction products- fire test certificates
- Continuously threaded reinforcing bar
- Site testing of post-installed fasteners in concrete

Share knowledge to help create a safer built environment

Editorial

The privilege of aging, which is denied to so many, is coupled with a lifetime of learnings for the older Engineer. The responsibility to impart knowledge and share lessons with the younger Engineering fraternity has never been more critical. The competing pressures and abundance of information at hand for the younger practicing Engineer creates enormous "noise" that can be difficult to manage and prioritize.

The CROSS-AUS board> recognises the importance of sharing the key concept of "lessons learned" with the younger engineering fraternity. For this reason, we have worked with some of our stakeholders to develop plans for engagement with engineering students at university. We want to ensure that talking about failures and near-misses is a natural part of engineering. Our society has morphed into one where mistakes are whispered about in hallways when results are caught up in confidentiality agreements. It has become culturally uncomfortable to share lessons learned and we know this must change. We all have the responsibility to change this for our current and future Engineers.

What can you do to help?

You can help by providing guidance on the key lessons an Engineer requires in their career:

- Fundamental engineering principles,
- knowing what you don't know,
- ethics, and
- learning from failure.

You can also do your bit to create a psychologically safe work environment. Creating a psychologically safe work environment for our engineers is critically important to ensure we keep the best people in our industry, able to deliver their best work.

What is a psychologically safe environment and how do you know if you have achieved it?

Psychologically safe has a number of methods or techniques in place to reduce human error (think spreadsheets, ballpark numbers for verification etc). It has procedures in place such as ISO9001 for verification. It also embraces learning from mistakes and encourages sharing with others.

This last point can be hard to initiate as it requires a cultural change. That's where CROSS-AUS is a great resource. By incorporating CROSS reports into regular technical catch-ups you will slowly change the level of conversation in an organisation. One of the signs that you are well on your way to creating a psychologically safe engineering environment is if your people come to you with their errors instead of trying to hide them. Does the thought of exposing their failure strike them down in fear?

If you would like to join us in being part of this change, we encourage you to get in touch with us. We have CROSS people available to assist by speaking to university groups or presenting to fellow professionals. Maybe you would like a CROSS member to give a presentation in a 'lunch and learn' session with your colleagues. If you would like to learn more about how CROSS-AUS operates and how it can help you and your colleagues - drop us a line at **team.aus@cross-safety.org>**

We trust you will enjoy reading our latest newsletter, which we must point out includes our first Fire Engineering report from Australasia that raises concerns about the inappropriate use of fire test certificates. The other reports in this issue include lessons regarding the modelling of structures, the specification of continuously threaded reinforcing bar and site testing of post-installed fasteners in concrete – all very relevant topics. As with all newsletters, please share them far and wide with your networks and encourage others to sign up so they don't miss the next newsletter. We also encourage everyone to **report your own failures or near misses>** using our simple and fast system.

We also encourage you to join the online discussion about our CROSS-AUS reports. Recently report 960 **"The myth of quality assurance">** has certainly generated some great discussion on **LinkedIn>** and **Engineers Australia's EAX>**.

Karlie Collis

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Director, CROSS-AUS Ltd

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Reporting to CROSS

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Modelling of structures

CROSS Safety Report   Report ID: 994

The reporter is concerned that some structural engineers assume without adequate verification that their computer modelling is correct and accurate; that they do not understand the limitations or basis for their modelling; or that the model chosen may not be appropriate for that structure.

Key Learning Outcomes

For civil and structural design engineers:

- When correctly used, structural modelling can provide the engineer with a solid grasp of the upper and lower bounds to any design on which they are working.
- Always ask the following (as a minimum) when assessing your own work or checking the work of others:
  - is the software selected for the analysis appropriate for the given application?
  - is the model correct and does it correctly and appropriately represent the structure under analysis?
  - how will the structure resist all loads and where are the load paths?
  - will the construction sequence have an effect on the design?
  - has independent verification and validation been undertaken based on the level of risk?
  - have alternatives been modelled to provide a "sense check" in case original assumptions are not correct?
- It is important to verify the results from the model and for the more experienced engineer this may be by "gut feel" and a review of the deflected shape produced by the model. For the less experienced, the very minimum should be self-checking by simple hand calculations.

R Full Report

The reporter is concerned that some structural engineers assume without adequate verification that their computer modelling is correct and accurate, that they do not understand the limitations or basis for their modelling, or that the model chosen may not be appropriate for that structure.

The reporter is also concerned that some engineers may not perform any internal checking and verification within their own office, and for larger projects, no adequate external checking and/or validation has been made of their model and resulting design. On several projects in recent years, the reporter is alarmed that the structural drawings provided to them have not been signed as checked internally.

Modelling, if correctly done can give very good indications of how structures might perform both under vertical and horizontal loads, especially using sophisticated computer graphics. However,

What should be reported to CROSS?

Structural failures and collapses, or safety concerns about the design, construction or use of structures.

Near misses, or observations relating to failures or collapses (which have not been uncovered through formal investigation) are also welcomed. Reports do not have to be about current activities so long as they are relevant.

Small scale events are important - they can be the precursors to more major failures. No concern is too small to be reported and conversely nothing is too large.

Your report might relate to a specific experience or it could be based on a series of experiences indicating a trend.

common sense and experience are also needed as it is important to understand the background of the software and its limitations.

In a real structure, the behaviour of individual elements under load can be complex, depending on the materials used and many other factors. In analysis, idealised models of the frame or structure are developed to simulate how the real structure may behave. However, it is important to remember that they are just mathematical models and engineers (especially those less experienced) should ask themselves the following:

- is the model correct and does it correctly and appropriately represent the structure under analysis?
- how will the structure resist all loads and where are the load paths?
- was a second opinion obtained within their office on the model they have adopted?
- did they model some alternatives in case the original assumptions are not correct?
- how did they model large penetrations in floors for stairs and the like?

As an example of incorrect modelling, the reporter has reviewed several projects where deflections of concrete floors were an issue, particularly for buildings designed in the 1970s and 1980s. Based on the modelling, these floors appeared to be satisfactory but based on real-life performance they were not. This highlights that there is no substitute for a critical review of the results.

> **There is no substitute for a critical review of the results**

Deflection of concrete floors has been a vexed question for many years (particularly for reinforced concrete floors) and the reporter notes that deflection limitations in Australian Standard AS 3600 are minimal requirements and may not be appropriate for all projects. The reporter is also concerned that designers do not make use of available published information to establish initial sizes before inputting data into modelling programs. For example, the **Guide to Long-Span Concrete Floors>** published by the Cement and Concrete Association of Australia (CCAA), which is free to download and should be taken into account. The reporter further recommends the Institution of Structural Engineers two-day online course on **Understanding structural design>** which extends the principles developed in the earlier **Understanding Structural Behaviour>** course to more complex, real structures and the all-important skills of approximate analysis for checking computer output and member sizing.

On a multi-storey project reviewed by the reporter, the concrete cores were assumed to be cantilevered from the basement and to resist all the lateral load from wind and earthquake. However, the cores were laterally restrained by the ground floor which in turn was acting as a diaphragm connected back to concrete retaining walls. It is more probable that the cores were cantilevering above the ground floor and not from the basement as assumed. Furthermore, in reality, significant additional horizontal loads would be applied to the retaining walls.

When modelling the effects of lateral load, it is important to understand the role of all vertical elements. For example, it is often not sufficient to ignore the effects of other load-bearing elements (such as precast panels or columns) as they may take some portion of lateral load depending on the relative stiffness of each element.

The reporter points out that clause 5.2.3 of the Australian Earthquake Standard for buildings AS 1170.4 requires that all stiff components be considered as part of the seismic force-resisting system and designed accordingly unless they are separated such that no interaction can take place as it undergoes deflection due to earthquake effects. Yet the reporter has seen projects where load-bearing pre-fabricated concrete walls and columns have not been included in the analysis and all of the actions are assumed to be taken by the central core.

Benefits of CROSS

- Share lessons learned to prevent future failures
- Spurs the development of safety improvements
- Unique source of information
- Improved quality of design and constructon
- Possible reduction in injuries and fatalities
- Lower costs to the industry

Supporters of CROSS-AUS

- Australasian Certification Authority for Reinforcing and Structural Steels (ACRS)
- Consult Australia
- Engineers Australia (EA)
- Engineering New Zealand (ENZ)
- Institution of Structural Engineers (IStructE)
- Structural Engineering Society New Zealand (SESOC)

C Expert Panel Comments

Today's structural engineers have a wide range of tools available that allow fast and detailed analysis of different structural forms. However, it is important to clearly understand the assumptions, simplifications and the basis of any software being used for modelling the structure. As the reporter points out, the software used for structural analysis is based on an idealised mathematical model of the structure. There are limits to how accurately the models can represent the real structure in its real environment.

When correctly used, structural modelling can provide the engineer with a solid grasp of the upper and lower bounds to any design on which they are working. Simple models can be used to understand the results of more complex models and all modelling should be considerate of likely construction tolerances, secondary effects, and serviceability implications (vibrations, accelerations, line of sight, etc.). It is also important to consider the effect on structural behaviour from temperature changes, concrete shrinkage, and the possibility of unexpected loads (robustness). If the material response is ductile the consequences of overlooking such effects may be limited, but if the material response is brittle, these effects may lead to failure.

> **Inherent inaccuracy of modelling deflections in materials such as concrete**

As noted by the reporter, engineers should be aware of the inherent inaccuracy of modelling deflections in materials such as concrete. Informing a client that a reinforced concrete beam will deflect 21.7mm in the long term would provide a false degree of precision, whereas a more realistic statement would be that the long-term deflection of the beam is likely to be in the range 10 to 30mm.

It is important to verify the results from the model and for the more experienced engineer this may be by "gut feel" and a review of the deflected shape produced by the model. For the less experienced, the very minimum should be self-checking by simple hand calculations to check that the results (e.g. span/depth ratios) are of the right order, and that the total support reactions are equal to the overall loads applied. For complex structures, a very simplified model may be used as a comparison to check the expected load path and to provide a "sense check" for the more complicated model with all elements included.

It is well established that human errors are the cause of most structural failures and a European research project - ***The human factor in structural engineering: A source of uncertainty and reduced structural safety>*** - has studied how subjective decisions, individual knowledge and the use of advanced tools and codes affect structural safety and structural design. This research revealed a large variation (around 300%) in results when a common design task was carried out by different engineers and introduces the term Engineering Modelling Uncertainty (EMU).

Further examples of incorrect modelling of structures that may go undetected are outlined in two investigations of existing bridge capacities that make sobering reading:

- The UK **Highways Agency Contract 2/419 Technical Audit of the Application of BA79 A Review of Bridge Assessment Failures on the Motorway and Trunk Road Network>**. This audit of 249 desk-top bridge assessments that had been carried out by a range of consultants was undertaken to determine why there was an unexpectedly large number of assessment failures. Disturbingly, two of the eight reasons for assessment failures were failures in the desk-top assessment process itself through "inappropriate or too conservative analysis for assessment" and "misinterpretation or inappropriate application of the assessment code".
- The Queensland Department of Transport and Main Roads (TMR) had a similar experience as presented in the paper by Shaw,

News & Information

CROSS-AUS Presentations:

Colin Caprani, Director CROSS-AUS gave a presentation on CROSS in June to the **Association of Consulting Structural Engineers Victoria (ACSEV)>**. As Colin notes "it was extraordinarily positive and I derived great satisfaction from seeing how positively our work is received". If your organisation or workplace would like to learn more about CROSS drop us a line at **team.aus@cross-safety.org>**

Professional Registration in Australia:

If you are seeking professional registration status in the states of Queensland or Victoria you can apply via the IStructE's assessment schemes. Membership of the IStructE is not necessary.

Full details of the application requirements, assessment process and application forms can be found on the **Queensland>** or **Victoria>** pages of the IStructE website.

Engineering New Zealand: Te Ao Rangahau has initiated a new programme called **Learning from Disciplinary decisions>** that is aimed at providing an easy way to learn from the mistakes of others. You can work out what the problem was and then what you would have done differently. ENZ will engage expert engineers to provide their opinion. See if you agree with them and if not, why not?

ENZ is also continuing its **Lessons to be Learnt>** webinar series in 2022 by exploring case-studies of large mistakes as well as examples of smaller, common errors.

Pritchard and Heywood: **Bridge Analysis: are we data managers or engineers?>** TMR conducted an audit of around 500 desk-top bridge assessments that had been carried out by different consultants. This found a range of errors including errors in the use of 3D models, inappropriate software defaults and incorrect load application.

The **CROSS Topic Paper Reflective thinking>** discusses similar concerns. Reflective thinking is a constant drive to ask questions and to make appropriate responses to them. It is characterised by a healthy scepticism about all inputs to processes, the processes themselves and about the outcomes from processes.

To summarise, the risks associated with inadequate modelling include:

- models with assumptions about boundary conditions, element interaction and unrealistic structural behaviour;
- designers not understanding the limitations of software;
- inadequate time assigned to checking of models and independent rudimentary first principle checking for logical output; and
- standards and guidelines may not be suitable to cover the developments in software or communications between designer, detailer, fabricator or builder etc.

These risks can be mitigated as follows:

- ensure the competency level of the modelling and analysis software operator is adequate for the task;
- undertake suitable quality control based on level of risk;
- undertake independent verification and validation based on the level of risk; and
- having a quality control system in place that incorporates the modelling, analysis and model transfers.

The **CROSS>** database contains other examples of the problems associated with incorrect modelling. Attention is drawn to the recent report 1073 **Concern over modelling of concrete frame building for construction stage>**. This report stresses the importance of considering the effect that the construction sequence may have on the design and the need to design the structure through all stages of its life. Failure to ensure that the design and proposed construction methodology are compatible may lead to a structure which is unsafe to build or indeed unsafe in use.

Submit Report

Submit Feedback

CROSS-AUS report 960 "The myth of quality assurance"> has generated some lively discussion in both **LinkedIn>** and **Engineers Australia's EAX>** on the role of the design engineer during construction and who should be responsible for certifying that the finished works comply with the design.

Attention is drawn to a recent report from the **Insurance Council of Australia (ICA): Climate Change Impact Series: Tropical Cyclones and Future Risks>**. Prepared for the ICA by James Cook University Cyclone Testing Station in association with Risk Frontiers, the report outlines the changes required to building codes and construction standards to improve the cyclone resilience of new homes, and calls for greater investment in the retrofitting of old homes to protect property and lives.

The Bushfire & Natural Hazards CRC has published its **Hazard Note 112: The benefits of strengthening buildings against earthquakes>**. Researchers at the University of Adelaide and Geoscience Australia identified the two most vulnerable forms of construction commonly used in Australia – unreinforced masonry buildings and low-ductility reinforced concrete buildings – and then examined the most cost-effective techniques available to mitigate fatalities, damage, business interruption and heritage structure impacts.

Construction products- fire test certificates

CROSS Safety Report Report ID: 1060

A reporter has notified CROSS-AUS regarding the potentially inappropriate use of regulatory/compliance fire test methods on certain products. This has led, they say, to the circulation of inaccurate test certificates in the market and possibly the use of these products on buildings where they may not be suitable.

Key Learning Outcomes

For manufacturers and suppliers:

- Ensure that products are certified under the appropriate test method for the end-use application
- If uncertain about the testing procedure for a product, engage a suitably qualified independent third party to provide assurance
- Consider withdrawing or amending product certificates that do not provide clear, transparent, or adequate justification for the method that was chosen for testing

For testing facilities:

- To promote best practice, ensure that the appropriate test method is followed and that the test method is genuinely applicable to the considered end-use
- Ensure that system-specific testing certificates are not used (or attempted to be used) to certify individual materials or products without adequate justification and explicit consideration of the need to extend the application of any test result
- Promote transparency in the reporting of testing procedures and results
- Ensure that manufacturer's instructions are followed for the installation of testing specimens
- Publishing a certificate produced from the use of an inappropriate testing method can have subsequent serious implications

For specifiers:

- Fire engineers, testing operatives, product specifiers, and approvers, should be familiar with the relevant testing guidance and its underlying principles
- Check that products, which are proposed to be specified, have appropriate test certificates and reports which are credibly applicable to the envisaged end-use condition
- Communicate such issues with other stakeholders in the design team so that they are aware of possible pitfalls when specifying a product

For Authorities Having Jurisdiction:

- Rigorously review any testing certificate to ensure that only products which comply with the relevant standards are used
- Review original testing reports in their entirety, noting all relevant caveats and limits on application and extension thereof
- Inform the regulator of deficiencies with test certificates, including how they are presented by product manufacturers

R Full Report

This report is about the issue of specifying the fire-related Group Numbers for PVC or uPVC internal wall linings, which are commonly used in commercial buildings, schools, hospitals, airports, hotels, shopping centres, aged care homes, train stations, emergency service buildings, stadiums, and other construction projects.

Background information

The way that linings are specified through the *National Construction Code (NCC)* is, among other restrictions and specifications, through the assignment of a Group Number, says a reporter. This is a value from 1 to 4 – best to worst – and is derived by test. It is used as a representation of how readily a product ignites and releases heat. Depending on factors such as the building classification, location, and sprinkler protection, different Group Numbers are required to meet the Deemed-to-Satisfy provisions.

Section C (Fire Resistance) of the NCC requires that this Group Number is determined in accordance with AS *5637.1:2015 Determination of fire hazard properties—Wall and ceiling linings*. This sets the decision pathway to choose between the two available test methods:

- The first one is *AS ISO 9705-2003 Fire tests—Full-scale room test for surface products*. A room of standard dimensions is constructed from the lining to be tested. Following certain criteria, a Group Number can then be derived. (CROSS panel's note: *ISO 9705 is a system specific testing method, and that the results from an ISO 9705 test cannot – in general – lead to a blanket Group Number assignment which is independent of the specific jointing, mounting, and fixing methods employed in the test. This means that product-specific Group Number assignments are not strictly possible, unless the product is only used in the configuration employed when conducting the ISO 9705 test).*
- The second one is a smaller scale, oxygen calorimeter test. Both the standards *AS/NZS 3837:1998 Method of test for heat and smoke release rates for materials and products using an oxygen consumption calorimeter or ISO 5660-1 Heat release rate (cone calorimeter method) and smoke production rate (dynamic method)* can be used.

The employment of data from the second type of method to derive the Group Number through a prediction method is restricted to certain types of materials. These are outlined in *AS 5637.1:2015* and are only homogeneous materials such as gypsum plasterboard, solid timber, wood products such as particleboard and plywood, and rigid non-thermoplastic foams such as polyurethane. Materials that melt or shrink away from a flame are not to be given a Group Number through the prediction method that employs small scale test data.

PVC and uPVC are thermoplastic materials, given how they become mouldable when heated above a specific temperature. This means that *AS ISO 9705-2003 Fire tests—Full-scale room test for surface products* should, says the reporter, be followed for the derivation of a Group Number.

Cause for concern

The reporter is of the mind that some of the suppliers of internal PVC wall vinyl or rigid PVC wall protection trading in Australia might be doing so without the correct Group Number certificates. It is possible, in the opinion of the reporter, that suppliers are either unaware of the guidance, or are actively seeking to obtain a test certificate through a smaller scale, thus cheaper, test method. This is exacerbated by the fact that the test houses may accept samples to be tested and then use a method that is not suitable for their type. Finally, architects, engineers, builders, installers, and certifiers also do not know what to look for in a compliant Group Number certificate, nor interrogate the completeness and validity of the information provided there.

The concern is founded on the uncertainty surrounding this situation. If these materials are tested correctly, then they can potentially have an acceptable result and the linings may be compliant with the requirements of the NCC. If these materials have not been tested with the appropriate method, or when submitted for testing the testing process did not follow the manufacturer's installation instructions, there may be a question of compliance with the NCC.

Through their position, the reporter noted test certificates where the Group Number of PVC or uPVC internal wall linings was derived "in accordance" with *AS/NZS 3837:1998*. Based on the argument above, this can be misleading as it does not follow the guidance outlined in *AS 5637.1:2015*. These certificates are then provided to architects, builders, engineers, and building certifiers. Because these end-users look only for a test certificate that references AS 5637.1:2015 at the top, they may be accepted as valid without further questioning.

The reporter has found that how test certificates are worded can vary between test houses. It was also noted that some companies are quoting British or American Standards without any evidence of expert assessments accompanying these certificates, which should state that the foreign certificates are the same or better than the Australian Standard or test method.

The reporter is worried that if the concern they raise is correct, some buildings in Australia have been lined with a material that may not necessarily be compliant with the fire requirements set out in the NCC. If that is the case, the reporter considers it vital to see all industry stakeholders educated further on this topic, and some action put in place to catch 'bad' certificates.

C Expert Panel Comments

The reporter is to be congratulated on their stance and recognition of the issue. The panel recognises that the concern appears to be valid and genuine, both in Australia and New Zealand.

It is important to have current test certificates and test reports from the National Association of Testing Authorities (NATA/IANZ) Accredited facilities, fully and freely available for scrutiny by building professionals. These include Fire Safety Engineers, Architects and Building Surveyors/Certifiers tasked with ensuring compliance. This is critical to establishing trust and compliance in the supply chain. A testing report contains more information than a certificate, and the NCC considers a report from an Accredited Testing Laboratory as one of the requirements to provide Evidence of Suitability for a specific product.

Reliance on marketing material for safety decisions must not be the established practice going forward. It is vital to ensure that products are being specified, designed, and installed in a manner that is within the limitations of any testing reports, assessment reports, or relevant test or classification standards.

> **vital to ensure that products are being specified, designed, and installed in a manner that is within the limitations of any testing reports**

For this reason, all suppliers must make test certificates and reports readily available and be more transparent with building professionals relying on such material for their designs. Professionals must satisfy themselves with the suitability of the chosen solution by using more robust evidence than what may be available in marketing literature.

The specific concerns raised in this report regarding incorrect test application for establishing the Group Number of wall linings have previously been raised by the Australian Building Codes Board (ABCB) and are **covered in their guidance note>**.

AS 5637.1:2015 is very clear on the decision pathway it outlines. However, this is stated as "guidance", and the option is available to adopt cone calorimeter results when the Group Number can be "confidently predicted" with an appropriate mathematical model. Under this standard, the reporting of the Group Number results using the cone calorimeter only requires a statement "that it was valid to test the material in the cone calorimeter for the assignment of the NCC group number". The panel is of the opinion that a more detailed statement setting out how it was determined would be more transparent. It is also observed that the Group Number certificates provided to CROSS by the reporter do not contain this statement.

To the panel's knowledge, the current trend is that Certifiers are increasingly aware of this problem, with some only permitting the use of test results obtained through *AS ISO 9705* testing. However, more awareness is no doubt necessary and associations for accredited certifiers and building surveyors are encouraged to do more to raise this issue with their members.

Certifiers should also review the ISO 9705 testing standard to ensure that they properly understand the test standard's view on extension of application of ISO 9705 test results on products using specific forming and mounting configurations (as is required in an ISO 9705 test) to other, different, system configurations.

Designers, specifiers, producers, and certifiers should also consider what is actually being assessed via any given regulatory/compliance fire testing method, and decide if the fundamental thermal physical underpinnings of the test method may be violated by any particular building product. Many such test methods may have originally been derived to assess specific materials or surface treatments, however, they may now be applied to products which have the potential to violate various aspects of the testing philosophy. The distinction between 'materials', 'products', and 'systems' should always be borne carefully in mind.

In conclusion, the panel considers that given the guidance from the ABCB on this matter, all building professionals should be aware of the risks entailed when accepting a Group Number obtained through the cone calorimeter results that do not satisfy the relevant sections of *AS 5637.1:2015*. Where this is the case, they should be requesting a clear robust explanation from the testing authority as to their justification and what empirical testing was used to form the basis of the prediction, otherwise only an *AS ISO 9705* test – suitably limited in application based on the forming, mounting and fixing methods actually used in the test, as is explicitly required by the ISO 9705 testing standard – should be accepted. It is important that the process of setting up tests is open and that test results are stated as being system specific.

The CROSS panel would encourage further reporting on this subject.

Submit Report

Submit Feedback

Continuously threaded reinforcing bar

CROSS Safety Report Report ID: 1074

This report highlights the difficulty of inspecting continuously threaded reinforcing bars to ensure that they have been adequately inserted into the cast-in ferrules.

When using such devices, it is very important to follow the manufacturer's advice and recommendations.

Key Learning Outcomes

For structural design engineers:

- Specify inserts or couplers for which the design capacities are well established by testing that is relevant to the application
- Specify control measures that site inspectors and construction contractors should use to confirm compliance with their design intent

For site engineers and inspectors:

- When checking threaded bars installed into cast-in ferrules, be sure to check that they are fully wound into the insert
- Maintain records of all such inspections

For construction professionals and contractors:

- Follow the guidance provided by designers, product manufacturers, and suppliers
- Ensure that couplers and inserts are quality-assured and keep records of quality control of threaded depth of all coupling devices
- When installing continuously threaded bars into cast-in ferrules, these should not be tied to the slab reinforcement until after the pre-pour inspection has been completed by the engineer and/or site inspector

R Full Report

When conducting pre-pour inspections of reinforced concrete structures, the reporter has found several examples where continuously threaded reinforcing bars have been tied into the slab reinforcement layer at the slab-to-wall joints. As a result, the reporter was unable to verify whether the threaded bars had been adequately wound into the cast-in ferrules within the wall. After the reporter had the tie-wire cut to check the adequacy, the threaded bars were found to be not fully wound into the ferrule on a number of occasions.

The reporter is concerned that there is a high risk of failure of the structure if threaded bars are not adequately wound into the cast-in ferrules as these bars provide direct shear support for the slab element.

Winding in threaded bars into ferrules can be labour-intensive. Reducing the time taken to undertake these construction activities may have been a contributing factor to the circumstances observed by the reporter at the time of inspection.

C Expert Panel Comments

Although this report specifically refers to the use of continuously threaded bars with cast-in ferrules, it could apply equally to the use of threaded bars with couplers and other splicing or joining devices and inserts.

When using such devices, reference should always be made to the manufacturer's literature for the correct specification and installation of the particular product. For example, when using continuously threaded bars, such as Reid Bar, with couplers, the **ReidBar design guide>** states: '*Tests show that to achieve the ultimate strength of the connection the thread engagement must be at least 80% of the maximum thread depth available in the fitting. Correct bar insertion is critical to the performance of the ReidBar™ system and it is recommended that good practice requires the user to mark the bar at half coupler length back from the inserted end so that a visual check is available.*'

Thus, when selecting this type of connection, the design engineer should satisfy themselves as to the minimum thread length that has to be engaged to achieve the required performance, and the specification should require the bars to be clearly marked at the required distance back from the end of the bar. It would appear that this had not been done in the examples found by the reporter.

When determining the required performance of the connection, designers should take into account the particular location. For example, at floor slab-to-wall joints the bars are likely to be subject to a combination of shear and axial loads as they transfer bending moments to the walls.

As the reporter notes, winding in these bars is a labour-intensive operation and any grit or cement dust on the threads or inside the ferrule can make them difficult to install to the full depth. Keeping protective plugs in the ferrules until just before they are used and keeping the threads of the bars well protected will go a long way to eliminating this particular problem.

Threaded reinforcing bars

It is important to differentiate between continuously threaded bars which provide full capacity of the bar and those which rely upon a cut thread which reduces the bar capacity unless a proprietary system is used, such as **Ancon reinforcing bar couplers>**. Again, it is very important to follow the manufacturer's recommendations when using such items.

CROSS report 844 **Defects in tapered thread reinforcement bars for coupling>** highlights the importance of good quality control procedures on site for the inspection of safety critical elements being delivered to ensure they meet the required standard. In this report reinforcing bars were observed to have visually different tapered threads cut into the bars after delivery to site and the reporter recommends the removal of couplers and visual inspection of threads for randomly sampled bars when delivered to site.

CROSS report 993 **The use of cast-in ferrules as structural connections>** raises several issues with this type of connection and notes 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. In this case, the design may not comply with relevant AS/NZS Standards, such as the ductility requirements in AS3600. Furthermore, AS 3850.1: *Prefabricated concrete elements*, makes it quite clear that only bolts should be fixed into such ferrules for fixing items such as lightweight architectural framing, temporary bracing, and the like.

National Precast Concrete Association Australia (NPCAA) has produced a very informative Tech Talk (Webinar): **Code Compliant Reinforcing Connections>** (February 2022) on this subject.

As the Steel Reinforcement Institute of Australia (SRIA) notes in its newsletter bearing issue number 43/4 of December 2017 on "Mechanical Splices for Joining Reinforcement": '*There are a number of proprietary systems available to mechanically splice reinforcing bars in Australia, including both coupler and coupling sleeve systems (both mechanically bolted and grouted), and specific design and detailing parameters for the various systems can be found via the links on our web site to our Associate Member manufacturers of these products. Detailers should consult the manufacturer's websites and examine the details to satisfy themselves on the type and detail they should use and how to specify them. In some cases, mechanical splices are designed specifically for proprietary bar types, or to splice proprietary bars to 'normal' deformed reinforcing bars.*'

Submit Report

Submit Feedback

Site testing of post-installed fasteners in concrete

CROSS Safety Report   Report ID: 1091

This report describes a situation where site testing of post-installed fasteners in concrete was undertaken by a contractor as an alternative to adopting the design data from the manufacturer in an attempt to justify an increased design capacity for the fasteners. This led to proposed design capacities which were about 3 to 5 times greater than the safe design capacities determined in accordance with AS5216. Since these fasteners are located in a safety-critical application, the reporter considered whether this may have resulted in an unsafe condition.

Key Learning Outcomes

For civil and structural design engineers:

- Safe design of post-installed fasteners and compliance with NCC2019 and AS5216 is best achieved by specifying a fastener selection for which a current European Technical Approval/Assessment (ETA) is available for the fastener and installation method, and by adopting the design parameters documented in the ETA for the design of the post-installed fastener
- The design resistance of post-installed fasteners should not exceed the values of design capacities published by the manufacturer without approval from that manufacturer

For contractors and construction professionals:

- The purpose of site testing, when undertaken, should generally be to identify any gross errors in the quality of the installation of the anchor

R Full Report

The reporter encountered an issue where site testing of post-installed fasteners in concrete was undertaken by a contractor as an alternative to design data produced by the manufacturer. This was undertaken to justify increased design capacities for the fasteners which were approximately 3 to 5 times greater than the safe design capacities determined in accordance with AS5216: *Design of post-installed and cast-in fastenings in concrete*. Since these fasteners are located in a safety critical application the reporter considered whether this may have resulted in an unsafe condition.

A contractor had substituted post-installed chemically anchored threaded rods in place of cast-in holding down bolts specified in the design documentation. When the design capacity of the post-installed anchors was subsequently checked using design data supplied by the manufacturer of the fasteners, the values were found to be inadequate. The design capacities provided by the fastener manufacturer were based on extensive laboratory testing and evidenced by a **European Technical Assessment (ETA)>**.

ETA assessment usually involves the testing of a large number of specimens under various conditions over a minimum period of 3 months, some of which are mandatory and some which are optional to qualify the product. For example, the mandatory conditions include testing for sustained load, variable loads, robustness and changed environmental conditions. These are extremely difficult to replicate on-site, and on-site testing cannot produce the same rigorous requirements as laboratory testing.

The reporter notes that site testing, including ULS proof testing, is generally undertaken to identify any gross errors in the quality of the installation of the anchor. However, in order to address the shortfall in design capacity the contractor in this case used the results of the on-site installation tests as the basis for establishing the design capacity of the post-installed anchors. This resulted in calculations for the design capacities of the fastener which exceeded the values of capacity based on the manufacturer's Technical Data Sheet (TDS) and/or ETA by a factor of between 3 and 5.

Independent opinions were sought from two professional chartered engineers who also expressed the opinion that the site testing could be relied upon as prototype testing to AS1170.0 Appendix B to permit the use of a design capacity 3 to 5 times higher than the design capacity established by the manufacturer's ETA. However, the reporter notes that these site tests are not equivalent to the suite of tests that are required by the European Assessment Document EAD330499, which includes assessing effects of concrete cracking, epoxy aging, long term loading, etc.

The reporter notes that the Australian Engineered Fasteners and Anchors Council (AEFAC) **Technical Note AEFAC-TN05-Site-testing-Vol 3>** advises that the characteristic strength obtained from site testing should not exceed capacities determined in the ETA; and that clause **B1.4 Determination of structural resistance of materials and forms of construction>** in the National Construction Code NCC2019, Volume 1, Amendment 1, requires that post-installed and cast-in fastenings comply with AS5216: *Design of post-installed and cast-in fastenings in concrete*.

Appendix A to AS5216 sets out the mandatory requirements for testing and assessment of fasteners, and requires these to be assessed in accordance with the European Assessment Documents **EAD330232 (Mechanical Fasteners for Use in Concrete)>** and **EAD330499 (Bonded Fasteners for Use in Concrete)>**. Clause 1.1.2 Application in AS5216 also notes that *"the design parameters and product specifications required for use with this Standard may also be obtained from a current European Technical Approval/Assessment for the relevant fastener"*. Alternatively, the same suite of tests that would be required by the European Assessment Document EAD330499 can be undertaken by a Registered Testing Authority (RTA) in Australia and assessed by an Assessment Body which should be independent of both the manufacturer of the fastener and the RTA. This involves a large suite of tests and would not normally be undertaken at project level.

The higher design capacities based on site testing of ULS if adopted would, in the reporter's opinion, result in the use of unsafe design capacities not compliant with the minimum safety requirements of NCC2019.

When a site pull-out test of an anchor is undertaken it is easy to understand how these test results might be accepted as representing an accurate assessment of the anchor capacity accounting for the specific project site conditions. However, these site tests are generally undertaken in uncracked concrete for loads of short duration without aging and environmental effects, and are unlikely to represent the true design conditions.

The reporter notes that although the provisions for prototype testing in AS1170.0 mention that these effects must be taken into account using separate factors, there appears to be less awareness of the extent to which these affect the design capacity of post-installed fasteners.

The reporter also notes that the requirement for post-installed fasteners to comply with AS5216 is relatively new (that is circa 2019), and there appears to be little awareness of the testing and qualifications of anchors required to satisfy AS5216 to ensure the safety and reliability of post-installed fasteners.

In summary the reporter notes:

- Appendix A of AS5216 as referenced by the NCC2019 is a normative (i.e. mandatory) requirement which requires that the testing of post-installed fasteners for suitability and admissible service conditions be performed in accordance with EAD330449;
- guidelines in AS1170.0 and AS4100 for the use of test data for design are not satisfactory evidence of compliance with AS5216 (and NCC2019). These guidelines advise that there are several qualifications for the use of test data obtained in accordance with these referenced standards which require variables or conditions not covered by test procedures to AS1170.0 and AS4100 to be taken into account separately. These additional effects are explicitly included in the EAD330499 approach required by AS5216 (and NCC2019) and include:
    - loading scenarios (such as dynamic, sustained and combined loading);
    - substrate conditions (such as cracked and uncracked concrete);
    - durability and effects of aging;
    - age and duration of loading;
    - environmental conditions; and
- in accordance with the advice from the Australian Engineered Fasteners and Anchors Council (AEFAC) it is recommended that characteristic strengths obtained from site testing should not exceed capacities determined in the ETA.

The reporter further recommends that the design resistance of an anchor should not exceed the values of design capacities published by the manufacturer without approval from that manufacturer.

In conclusion, the reporter considers that the simplest way to ensure safe design of post-installed fasteners and compliance with NCC2019 and AS5216 is to specify a fastener selection for which a current European Technical Approval/Assessment (ETA) is available for the fastener and installation method, and to adopt the design parameters documented in the ETA for the design of the post-installed fastener.

C Expert Panel Comments

The Panel fully endorses the reporter's comments along with the recommendations contained in the report.

Concrete cracks under all types of loading including restrained concrete shrinkage, thermal loads, foundation settlement, dynamic loads, and extreme live loading. Testing anchors after installation is a poor indicator of their capacity at the time when the anchor may be subjected to critical loading. It is considered that the primary purpose of the pull-out test [as envisaged by AS5216] is to verify that there have been no gross errors in the physical installation of the anchor, not as an abrogation of the responsibility to design the anchor.

Anchor design in accordance with design values provided by the manufacturer makes assumptions on several variables (e.g. concrete strength), and assumes unreinforced conditions. If the anchor is found to require additional capacity, it may be possible to refine the accuracy of the variables whilst maintaining the integrity of the standard design process

With respect to the advice on prototype testing in AS1170.0, this requires that separate account should be taken for those variables or conditions that are not covered by the test procedures (items which are in fact covered by the EAD330499 testing regime). Further, Appendix B3 of AS1170.0 states that the prototype test method is not applicable to the establishment of general design data.

In addition, particular attention needs to be paid to the acceptability of chemical anchors in fire conditions, and in such a situation as indicated by the reporter (i.e. change from cast-in to post-fixed anchors), an application to the building certifier for material change in system may be warranted.

It is the considered opinion of the Panel that any decision to circumvent compliance with AS5216 (as described in this case by the reporter) may create unacceptable and avoidable risk, which, in the very worst-case scenario, may lead to injuries and/or fatalities.

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