CROSS AUS
COLLABORATIVE REPORTING FOR SAFER STRUCTURES

The Institution of Structural Engineers

CROSS Newsletter

CROSS-AUS Newsletter 11 | July 2024

Editorial

This eleventh edition of the CROSS-AUS Newsletter comes amidst interesting times in structural safety.

Nationally, the Safety Reports in this Newsletter remind us of the diligence required in all our endeavours. Internationally, the collapse of the Francis Scott Key Bridge in Baltimore in March highlights the tragic loss of life and economic impacts that can result from significant structural failures. More broadly, the pressing environmental imperative is prompting engineers to revisit established dogmas: What should our floor loadings really be? How does changing loading and degradation alter the risks inherent in our structures? How can we reuse existing buildings and confirm their ongoing safety even though they don't meet today's codes?

I write this introduction as the new Chair of CROSS-AUS. The founding Chair, Mike Fordyce, stepped down at the end of 2023 and, on behalf of the other Directors, the Expert Panels, and all those who've benefitted from his work, I pay tribute to his energy and leadership in bringing CROSS-AUS to this point. Fortunately, Mike remains involved, continuing to share his extensive experience for the benefit of CROSS-AUS.

In some further changes to the CROSS-AUS team, we are pleased to welcome four new additions. David Donnan has joined as a Director of CROSS-AUS, and Iain Hespe, Simon Lovell and Ed Bond have come on board as members of our Expert Panel. For further details please visit **Meet the CROSS-AUS Team>** on our website.

In this Newsletter, Report 1245 underscores the importance of oversight and the checking of contractors' alternative proposals for a retaining wall. Concerningly, Report 1277 reveals that some post-tensioning (PT) contractors are not aware of new requirements in AS3600:2018 (Clause 9.2.2) for the provision of structural integrity reinforcement.

Report 1280 highlights the need for engineers to have a clear load path in mind and ensure that the constructed connections and details achieve this. Finally, Report 1289 concerns the misuse of prescriptive requirements outside their applicable domain. While it is laudable that independent checking engineers discovered the issues, this Report reminds us that every day and for every design, we must apply deep thought to our work and cannot merely seek refuge in beguiling deemed-to-comply provisions.

The Reports in this Newsletter span a range of topics. A particularly positive aspect stands out: the reporters discovered and addressed structural problems that could have impacted public safety negatively. The importance of reviewing, covering the spectrum from formal external proof engineering to informal discussions around the mythical watercooler, could not be more evident. So, in your work, strive to be the "loyal heretic"; review and question everything for the betterment of your team, the project, and for society as a whole.

Dr Colin Caprani

Chair, CROSS-AUS

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Reporting to CROSS

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

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team.aus@cross-safety.org

Unsafe alternative designs for retaining wall

CROSS Safety Report   Report ID: 1245

A contractor proposed a precast concrete design as an alternative to a documented limestone block wall, and engaged a precast supplier to design and construct the alternative design. Several submitted designs, including certified drawings, could have posed a real risk to the community if constructed.

The reporter notes that suppliers regularly state their expertise in the field but this may not always be correct.

Key Learning Outcomes

For clients, project managers and specifiers:

- Alternative options offered by contractors must be subject to appropriate scrutiny as they may have less oversight than the documented design and contractors are often impatient for answers during the construction period
- Ensure that the scope of provision of services during the construction phase includes all professional responsibilities, including those of rejection of submissions and processes that are not compliant with statutory and technical requirements

For Civil and Structural Engineers:

- Recognise that both structural design and stability are integral to the function of structures. Interfaces between soils and structures are complex topics, with high technical levels of understanding of design being required
- Understand the particular requirements of retaining structures including drainage and soil properties. For example, understanding that the angle-of-friction of soil has a significant influence on stability of a retaining wall (high angles-of-friction should be validated with on site testing or specified compaction requirements)
- Provide a comprehensive briefing for any proposed alternative design process
- Ensure that any changes to the structure proposed by others are signed off by the original designer

For contractors:

- Be cautious of suppliers who provide in-house design, and be sure to insist on external design validation and certification as required
- If validation and/or oversight of proposed alternatives is not possible, it may be prudent to keep with documented design solutions

Fire Safety and CROSS-AUS

With the successful expansion of CROSS's remit in the UK to cover fire safety, CROSS-AUS is considering whether a parallel system for Fire should also be established in Australasia to promote understanding and provide a platform to interact with likeminded professionals.

Anyone with an interest in this area who would like to be involved, please send your contact details to **team.aus@cross-safety.org>**.

Feedback on CROSS-AUS Reports

If you have had similar experience to any of our reports, we encourage you to share your experience by simply completing the form at the end of each report or by email to **team.aus@cross-safety.org>**.

Some recent examples of feedback include:

- **Report 956 - Inspection and maintenance of Super-T bridge girders>**
- **Report 1056 - Production of as-constructed drawings>**

R Full Report

The reporter, a construction-phase structural engineer in a company responsible for the detailed design and construction support of a project, identified a safety issue related to retaining structures within the project.

The original design specified a traditional limestone block retaining wall to support a new road with moderate vehicle surcharge. The contractor wanted to adopt a precast concrete retaining wall as it would provide improved constructability and faster construction than the limestone block wall. Accordingly, the reporter's company provided a concept scheme for review.

Typically, concrete retaining walls have bases beneath the retained soil to provide a counterbalance to overturning forces, and increased frictional resistance to sliding due to the weight of the soil imposed on the base. However, the contractor requested the base face away from the retained soil, i.e. on the low side of the wall. This would help with construction sequencing but would also create more onerous design conditions. The scheme provided to the contractor accounted for these design conditions but needed increased cover and an extended retaining wall base.

> **The reporter's company advised the contractor that calculations were essential in order to provide confidence the design solution was adequate**

To avoid longer lead times for custom-designed precast retaining walls, the contractor wanted to use standard panels and chose to engage a precast supplier both to prepare an alternative design and to construct the wall. The design requirements (retaining heights, surcharge, geotechnical conditions) were provided to the supplier. The precast supplier provided two pricing options to the contractor; one provided certified drawings for fabrication, and the other included design calculations as well as the certified drawings. The second option would have an extended lead time. The reporter's company advised the contractor that calculations were essential in order to provide confidence the design solution was adequate.

The first design for fabrication submitted by the precast supplier indicated the base of the retaining wall beneath the retained soil which did not necessarily align with the design requirement. This design had been certified by independent engineers. Feedback was provided on the design, requesting confirmation that the wall stability had been appropriately considered in the design. The supplier stated they had no concerns.

Shop drawings were submitted to the reporter's company for approval without any updates from the design previously provided, and without any calculations. Calculations were later provided and ultimately the proposal was rejected.

Several incomplete design iterations were submitted by the supplier and detailed feedback (outlining areas of concern) at each iteration was provided to the supplier.

The reporter notes contractors regularly propose alternatives which deviate from the original design, and these can involve products and external suppliers' designs that may not undergo sufficient design scrutiny. While suppliers regularly state their expertise in the field, this may not always be correct. In this case, a detailed understanding of the geotechnical/structural interface appeared to be lacking.

This experience greatly concerned the reporter and their colleagues for several reasons. Several submitted designs could have posed a real risk to the community if constructed.

The reporter has particular concern with regard to the following issues:

- The design capability of the precast retaining wall supplier and their certifying engineers
- The general attitude taken by the precast supplier in the face of the feedback received

News & Information

The UK Building Safety Act 2022

The **UK Building Safety Act 2022>** has put in place new and enhanced regulatory regimes for building safety and construction products. There are lessons to be learned from this in Australia and New Zealand. This **resource page>** from the Institution of Structural Engineers gives a good overview of the Act.

IStructE has also provided further information for Structural Engineers, including **Assessing higher-risk buildings under the Building Safety Act: a compendium of structural typologies>**, and **The Safety Case Report: demonstrating safety through systematic structural assessment>**.

Essential consideration of 'soft hazards' on civil and building engineering projects

Civil and structural safety expert, previous Secretary to SCOSS, and ICE Gold Medal winner John Carpenter has written **this check list>** based on his many years of experience to draw the attention of designers to the 'soft hazards' that must be addressed as part of their work.

Australasian Certification Authority for Reinforcing and Structural Steels (ACRS)

Through its certification schemes, **ACRS>** provides traceability of product from manufacturer to end-user. ACRS recent news item, **A call for diligence: Addressing the rise in fraudulent steel certification>** provides an example of this process.

The ACRS June newsletter also contained the following informative items:

- **Responsibilities under the Practice Standard for Professional Engineers Under the DBP Act>**
- **Sustainability in the construction industry: the role of certification schemes>**

C Expert Panel Comments

The reporter is to be congratulated on raising this issue as well as seeking appropriate management and ensuring integrity throughout the design and construction process. This report presents legitimate concerns and recommendations for practitioners facing similar scenarios.

While it is commonplace for contractors to seek alternative approaches to particular construction items, generally for cost and/or programming reasons, it is imperative that alternative designs provided by contractors and subcontractors, and their respective engineers, are subject to appropriate design processes and serious scrutiny. If the reporter had not exercised their responsibility in this case, the outcome may have been disastrous.

> **The reported dismissal of stability concerns and design non-compliances is cause for alarm**

There are two aspects of this report that warrant particular consideration. The first is the level of understanding and apparent lack of appreciation by the sub-contractor and their design engineer for the design constraints and requirements of this structure. The reported dismissal of stability concerns and design non-compliances is cause for alarm. Although the majority of the design issues raised by the reporter involve standard aspects of good design (which ought to be standard practice for any competent design engineer), this lack of understanding identifies the importance of a comprehensive briefing to be prepared in any re-design process.

The second aspect relates to safety and risk; the report demonstrates how pressure can be applied to engineers to accept an alternative that is not to the required standard. Any design change involves risk, and that risk should be carefully considered by all parties involved including the client.

In this particular case, given the wall supports a road, the consequences of failure could well have been more than just the cost and inconvenience of remediating and strengthening the failed structure.

> **This report reinforces the imperative for a full evaluation of any contractor-led alternatives, and the need for thorough independent review of alternative designs**

Other risks involved in entertaining design alternatives during the delivery phase of a project include:

- Time pressure leading to potential error in design and design philosophy
- An incomplete process of developing the concept with appropriate review, and loss of design integrity including inconsistent quality practices, blurred ownership of design, and incomplete capture of all required inputs including those of an interdisciplinary nature (e.g. drainage, architectural, civil, geotechnical)

This report reinforces the imperative for a full evaluation of any contractor-led alternatives, and the need for thorough independent review of alternative designs.

Submit Report

Submit Feedback

Recent guidelines and frameworks from the International Building Quality Centre (IBQC)

The IBQC has recently published new guidelines. The first, **Risk-Based Classification and Inspection Guidelines>** provides a model for government, authors of building codes, regulators and those with a commitment to good practice building regulation, to be considered in the design and ongoing improvement of the building regulatory ecology within their jurisdiction.

The second, **Building Products Performance – Good Practice Regulatory Framework>** sets out a systemwide good practice regulatory framework for building products to enable confidence in product performance by regulators, practitioners, industry and consumers.

Mandatory Inspection Regulations for Ageing Buildings: An Analysis of International Trends

This **very interesting paper>** was presented recently by Nicole Johnston, Director of Strata Knowledge, at the Australian College of Strata Lawyers conference. The paper is an analysis of international trends and poses the question - are these the types of regulations that we may see in Australia?

Code of Practice for Buildings, Construction and Works

The City of Melbourne recently published its **Code of Practice for Buildings, Construction and Works>**.

The Code regulates the conduct of all works that affect public space and commenced on 23rd May 2024.

Structural integrity reinforcement in post-tensioned concrete slabs

CROSS Safety Report   Report ID: 1277

A reporter has found that structural integrity reinforcement in post-tensioned concrete slabs is not being installed correctly by some contractors. They believe that this could result in catastrophic failure of slabs if subjected to earthquake action.

Key Learning Outcomes

For Structural Engineers and designers:

- Recognize the need for appropriate structural integrity reinforcement near the bottom face of concrete slabs and beams to be continuous through column cores to ensure integrity of these structural items in the event of severe events, such as earthquakes
- Check that designs for post-tensioned slabs and beams have sufficient flexural reinforcement continuous through supporting columns and are fully compliant with design standards, even after construction tolerances have been taken into account
- Wide, shallow "band beams" that are susceptible to punching shear should be considered as slabs and slab integrity reinforcement provided in two directions in accordance with **AS3600:2018>**

R Full Report

A reporter has found that structural integrity reinforcement in post-tensioned concrete slabs is not being installed correctly by some post-tensioning (PT) contractors. In addition, several PT contractors known to the reporter do not agree that slab bands should have structural integrity reinforcement in both directions.

Structural integrity reinforcement through column cores is required in both directions within a slab band as stated in **AS3600-2018 Clause 9.2.2>**. This requirement is clearly described in the **Steel Reinforcement Institute of Australia Technical Note 8>** (SRIA TN8) published in November 2022, which states:

"In 2018, based on the lessons learnt from the Christchurch, New Zealand earthquake events in 2011, AS3600 was revised to incorporate many new provisions to safeguard future Australian buildings from seismic events and provide important life safety to the occupants if the buildings are subjected to one of these extreme events. One simple reinforcement detailing requirement that was incorporated into the Standard was structural integrity reinforcement for both beams and slabs. This nominal amount of reinforcement was found to be very effective at preventing the collapse of slabs following punching shear failures in Christchurch, improving the life safety of the building."

The reporter's concern is that some PT contractors are treating the "slab band" as a "beam" in design. The reporter notes that SRIA TN8 suggests the rule of thumb for a beam is a member with a depth of one and a half to two times its width. Therefore, the majority of these slab bands, in the reporter's opinion should not be

National roadshow on punching shear design from The Concrete Institute of Australia

The Concrete Institute of Australia is **holding a series of events>** across the country in August on punching shear design. This national roadshow brings together two well known concrete design experts, Peter Statton and Peter Burnton, to review the new structural design process for punching shear in slabs. The presentation is based on the work to introduce the process into the Australian Standard AS 5100.5 Bridge Design – Concrete.

There have been several CROSS Reports related to this topic, including our Report 1277 - Structural integrity reinforcement in post-tensioned concrete slabs, featured in this Newsletter (left).

CROSS-AUS is considering possible further publication on this topic, including a discussion on "beams" in slabs. If you have experienced any similar issues or would like to contribute to this topic, we invite your response via the **Contact Us>** page on our website.

considered as beams and should not be designed as such.

The reporter is concerned that without the correct installation of the structural integrity reinforcement, there could be catastrophic failure of slabs under earthquake action.

It is the reporter's opinion that there is a lack of understanding of the importance of this requirement within the post-tensioning industry, coupled with an unwillingness to alter design methods as it adversely affects cost, suggesting little consideration for safety.

The reporter would like to see this issue broadcast as widely as possible so that current design methods change, and that it is factored into the cost by PT contractors when initially pricing jobs.

C Expert Panel Comments

Although it is assumed that this report refers in the first instance to PT contractors who are providing a design and construct service, it applies equally to any design entity documenting post-tensioned slab solutions.

For completeness it should be noted in the context of this report that "integrity reinforcement" refers to reinforcement at the bottom of a slab running continuously through the slab/column interfaces in all spans framing into columns, as well as shear reinforcement.

Integrity reinforcement is required to increase resistance to progressive collapse in accordance with the **National Construction Code (NCC)>** and **AS/NZS 1170.0:2002>**. As reflected in the extract from SRIA TN8 quoted above, experience has shown that the overall integrity of a structure can be substantially enhanced by minor changes in the detailing of reinforcement; in this particular case the provision of "structural integrity reinforcement for both beams and slabs". It is the responsibility of the designer of post-tensioned slabs to comply with the NCC and, in turn, with AS3600-2018, assuming the deemed to comply approach is taken.

As the reporter says, there appears to be a lack of understanding of the requirement for structural integrity reinforcement within the PT industry. It may be that the significant benefit of a relatively small amount of bottom face continuous reinforcement through the column core in preventing catastrophic collapse may not be intuitively obvious to many designers.

> **some confusion exists amongst design engineers regarding the design of wide, shallow "band beams"**

The effect of the structural integrity reinforcement is to produce a much more ductile punching shear mechanism, thus preventing the redistribution of load to adjacent columns (which could initiate progressive collapse) in the event of a punching shear failure. In this sense it contributes to robustness, although it does not satisfy normal robustness requirements which must also allow for the loss of the support. On the other hand, while the PT tendons in the top of the slab over the column cannot be considered to contribute to the integrity solution, they can be used to contribute to the robustness requirements if they are placed within the column core.

It is noted that some confusion exists amongst design engineers regarding the design of wide, shallow "band beams". Some designers and PT contractors assume that these members can be designed as beams, when in the majority of cases they should be designed as thickened slabs. Although AS3600 does not provide a definition for a "beam", in its discussion on slabs the commentary to AS3600:2018 states in Cl. 9.2.2:

*"Integrity reinforcement should be supplied at column or wall connections in all slabs which are **susceptible to possible punching shear failure**. This includes flat plates, flat slabs with drop panels and band beam and slab connections."*

The implication for band beam systems is that if the band beam is wide enough relative to its depth so

Newsletters from other CROSS regions

The UK published their latest Newsletters in March and June. Make sure to **take a look>** for applicable lessons learned from these international safety reports.

Press Roundup

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

1. Simultaneous collapse of balconies in France>

Seven balconies collapsed on one building at same time in the French city of Antibes in April. Press reports are limited with the cause currently unknown. Residents described a "continuous explosion sound", with one also adding, "we have a lot of water damage. We've been warning the mayor for years".

In a separate news story, Parisian authorities have **warned that old balconies in the city>** may not be suitable for the size of crowds generated by the Olympics.

that a punching perimeter can form within the width of the band beam, then the band beam is susceptible to possible punching shear failure, and should be treated as a slab in the evaluation of structural integrity reinforcement.

In the absence of a more detailed analysis, SRIA's Technical Note 8 is a good summary of the requirements for structural integrity reinforcement in slabs, as read in conjunction with the AS3600 commentary Cl.9.2.2.

> **ensure that an adequate proportion of the tendons and unstressed reinforcement at the top of the slab are also located within the punching zone**

It is further noted that slabs, including band beams, must also be designed for beam shear in accordance with Clause 9.3.2 (a), which refers to Clause 8.2 of AS3600, where shear failure can occur across the width of the slab or band. Where shear reinforcement is required, the use of open fitments is undesirable. These are often used to assist in steel fixing and laying of post-tensioning ducts. Where open fitments are permitted, closing ties are required to provide effectively closed fitments and to meet the detailing requirements.

Note: The term "fitments" is used here for shear reinforcement that otherwise may be termed ligatures, stirrups, links or ties.

It is worth bearing in mind the need to ensure that an adequate proportion of the tendons and unstressed reinforcement at the top of the slab are also located within the punching zone as required by Clause 9.1.2 of AS3600. This is an issue that is often addressed on the document only to be ignored on site. An additional consideration is that whilst the tolerance for the horizontal location of tendons may be ten percent of the spacing (Cl17.5.3 b) iii), the required proportion may not be met if that ten percent causes tendons to fall outside this zone.

In the interim (until such time as compliance with this requirement becomes commonplace) it may be necessary for the principal designer to place a hold or check point in the construction specifications that requires the contractor to check and record specific reinforcing details including integrity reinforcement.

> **there have been several previous CROSS reports on the subject of punching shear**

Finally, it is noted that this issue should be applied to all structures, not only those subject to seismicity. Failure to provide integrity reinforcement can lead to progressive slab collapses, whether due to accidental overload, fire, or other extreme events. Indeed, catastrophic slab collapses have occurred due to crowd events such as dancing at wedding receptions.

It would appear that requirements for punching shear in slabs are not well understood and there have been several previous CROSS reports on this subject, including:

- **1122 Punching shear in concrete slabs at perimeter columns>**
- **1050 Concerns about punching shear in a flat slab>**
- **950 Inadequate punching shear reinforcement in flat slabs>**
- **906 Missing punching shear reinforcement in concrete slabs>**

CROSS-AUS is considering possible further publication on this topic, including a discussion on "beams" in slabs, in forthcoming communications. If you have experienced any similar issues or would like to contribute to this topic, we invite you to submit feedback via the link below.

Submit Report

Submit Feedback

2. Global high rise fires in 2024 – Spain, Brazil, Russia, and China

There have been a number of high-rise fires reported in the press during the first half of 2024. The first, in a **14 storey residential complex in Valencia>** tragically killed ten people. Investigations into how the fire spread so quickly are still ongoing.

The day after Valencia, sadly 15 people were killed in another **high-rise fire in Nanjing, China>**. Officials suggest that the blaze started on first floor of building, where electric bikes were being stored.

Two further high-rise fires occurred in **Tver, Russia>** and **Recife, Brazil>** in March. Fortunately, both buildings were still under construction at the time and no one was injured in either blaze.

3. Dutch multi-storey car park ramp collapse>

A six-storey hospital car park ramp collapsed in the Netherlands in May. Fortunately, the collapse occurred on a Sunday night, and no one was injured.

CROSS has **a Safety Alert>** and a number of Safety Reports connected to car parks. The **most recent>** was featured in the UK June Newsletter.

Load path and detailing issues with residential construction

CROSS Safety Report   Report ID: 1280

A reporter observed the construction of a two storey residential structure and noted several issues with the design and detailing. The structure comprised a combination of lightweight timber framing, timber joists, and steel portal frames. The reporter was concerned that:

- There were inadequate connections and a lack of sufficient detailing throughout the bracing members
- There was a lack of consideration of load paths
- The design may not have functioned as intended

Key Learning Outcomes

For Civil and Structural Engineers:

- Consider and sketch the load paths in the structure as an integral system prior to commencement of the detail design
- Consider the suitability of the proposed structural system and connection details (including standard details) to achieve the required serviceability, stability and strength
- Clearly articulate on drawings or engineering sketches the connection details that are required
- Locate cast-in anchors inside the zone of reinforcing bars as standard good practice
- Consider any possible construction limitations and specify any necessary hold-points or requirements. This may involve temporary supports or braces, curing times and erection procedures

For contractors:

- Assess the level of information provided to ensure it contains all connection and load-transfer details from one material type to another, and for stability during construction
- Abide by the requirements of design engineers, including hold-points and stability considerations
- Stop all affected construction if connection details are not provided or are unclear, until these gaps in information are resolved

R Full Report

The reporter observed the construction of a two storey residential development and noted several issues with the structural design and detailing. The reporter raised these with the design engineer, who amended their design and details accordingly. However, the reporter remains concerned that the design as originally documented demonstrated a lack of attention to detail and design

4. Baltimore Bridge>

In March, a dramatic bridge failure occurred in Baltimore, USA, when an errant vessel hit one of the piers and brought about a complete collapse. Bridge and pier impact is a generic hazard which has caused many previous failures, such as the Tasman bridge (1975), Sunshine Skyway Bridge (1980), and the Erskine Bridge in Glasgow (1996).

The National Transportation Safety Board (NTSB) published their preliminary report on the Baltimore collapse on 26 March. **It is available to read on their website>**.

You can read Colin Caprani, Chair of CROSS-AUS's **viewpoint article>** on the collapse in the May edition of *The Structural Engineer* magazine, or listen to his interview on **The Briefing podcast>** episode, *An Australian engineer explains the Baltimore bridge disaster.*

5. Sydney apartment blocks at risk of collapse>

A four-tower retail and residential development in north-west Sydney is “at threat of collapse” after defects in the load-bearing concrete were identified by the state building commission.

6. Two engineering firms prosecuted in landmark case in South Australia>

Two engineering firms are the first in South Australia to be successfully prosecuted over an unsafe structural design, which led to an incident in November 2021 where two workers were injured when a roof structure collapsed.

The South Australian Employment Tribunal fined the two firms a combined $70,000. The decision was the first successful design related prosecution by SafeWork SA.

considerations, and the problems with the process of quality control.

The structure involved a combination of lightweight timber framing, timber floor joists, and steel portal frames. The reporter was concerned the original design would not have functioned as intended as there were inadequate connections and a lack of adequate detailing throughout the bracing system. Although a catastrophic failure may have been unlikely, there could have been excessive damage to the structure in an Ultimate Limit State event and possibly higher-than-acceptable levels of damage in a Serviceability Limit State event.

The reporter noted the following in particular:

- There was no consideration of load transfer from the timber floor diaphragm through to the packing on the steel portal frame. Although the timber joists were detailed, there was no continuous, robust load path to the packing
- The spacing of bolts connecting the timber packing to the portal frame was too great. The design engineer accepted this and altered their details
- The steel portal frame was designed as having a fixed base. However, this is very difficult to achieve without buttressing and the reporter was concerned that the connection would not achieve full fixity
- Even if the connection could have achieved fixity, it was detailed with a weak mortar packing compound under the stanchions that may have crumbled, causing a pin joint to form, as well as introducing combined bending and shear in the anchor bolts
- The cast-in anchor bolts were set outside the steel reinforcement in the foundation beam (i.e. in the cover concrete). The design engineer stated they had considered the ability of the concrete to transfer the load. Although the reporter acknowledged that this is possible under the relevant Standards, they did not consider this to be a robust design

It is the reporter's opinion that the design engineer should have considered in more detail the load path. Too much focus was given to the mathematics and computer modelling. The assessment of the overall structure also needed to be taken into account. The reporter suggests this could easily have been resolved by sketching the load path on the structural drawings and providing sketches with the calculations.

C Expert Panel Comments

Experience suggests that residential design is often poorly detailed, most likely as it is very much a fee-driven market with tight margins, serving clients with little or no capacity to judge the quality of the documents, and often with nobody responsible for overall control of the design. There tends to be separate design/supply/erect sub-contracts with no co-ordination resulting in problems of overall stability and trouble at interfaces.

Documentation for timber framing is typically produced by 'design' services using the relevant Standard, with minimal or no further engineering involved in the design process. In New Zealand, *NZS 3604:2011 - Timber-framed building* provides methods and details for the design and construction of timber-framed structures not requiring Specific Engineering Design (SED). In Australia, *AS 1684 - Residential Timber Framed Construction* is a four-part Australian Standard covering design criteria, building practices, tie-downs, bracing and span tables for timber framing members. By complying with this Standard, designers are Deemed-to-Satisfy the requirements of the Building Code of Australia. In practice, the *Part 4 - Simplified* version of AS 1684.4 and the member size/spacing tables contained therein are commonly used by building designers. These New Zealand and Australian Standards contain limitations on the size and type of building that designers must be aware of.

> **A clearly defined, robust load path must be established and designed, with appropriate and well-documented connections**

More from CROSS

Request a CPD talk from CROSS-AUS

The CROSS Team is available to give presentations to firms and organisations. These give insight into the work of CROSS and include examples of failures and the lessons that can be learned. To request a talk, please email us and we will be in touch to organise: **team.aus@cross-safety.org>**

Accordingly, residential building 'design' often involves a lack of appreciation of load paths and connections, particularly for lateral loads. A clearly defined, robust load path must be established and designed, with appropriate and well-documented connections. For example, with multi-level buildings it is critical for structural designers to understand that lateral loads must be resisted from the roof to the suspended floor. This is usually by some form of shear wall action which in turn uses the suspended floor as a diaphragm to carry the loads into lateral systems, including any steel framing or shear walls, and finally to the ground. The identified load path needs to allow for collector loads associated with the maximum lateral actions and each individual element, including associated connections, checked for this corresponding load.

> **Critically important is displacement compatibility for lateral loads**

The reporter notes the adoption of a portal frame solution, with attending issues, in this structure. Portal action in housing is often difficult to achieve. Critically important is displacement compatibility for lateral loads. This is often neglected, and damage to timber framing can be extensive before the resistance from the portal frame system becomes effective. This was noted in damage caused by the Canterbury/Christchurch, and other recent, earthquakes in New Zealand where mixed bracing systems of plasterboard-lined bracing walls and steel portal frames did not perform well. Plasterboard or ply linings, or diagonal bracing, which are relatively stiff compared to steel portal frames, are therefore recommended for timber-framed residential construction. The **Building Research Association NZ>** (BRANZ) has published technical papers and recommendations on this topic.

> **The observations made in this report are likely to be widespread**

Where portal frames are deemed suitable for adoption, careful consideration should be given to restraint of the frames, particularly at knee braces, and to details of restraints at bases. Full base fixity is difficult to achieve without appropriate detailing and competent site construction; where it is assumed but not achieved, deflections and member actions will exceed those calculated, exacerbating any compatibility issues.

Grouting to baseplates of portal frames should use high strength non-shrink flowable epoxy mortars. Anchorage of holding-down (HD) bolts in cover concrete is not considered good practice, especially in seismic areas. In addition, the capacity of anchor bolts in the zone of concrete cover will be severely limited by edge distance considerations, and shear loads in HD bolts are likely to be high due to portal action spreading and other lateral loads.

The observations made in this report are likely to be widespread. It is very concerning that, if these details had not been observed on site by an experienced practitioner who intervened, they may have been built-in and covered up as construction proceeded. This raises serious concerns about the level of experience of designers in this area of the construction industry, the checking and review of designs, and the quality of construction in residential structures.

Note: Reference should also be made to **CROSS Safety Report 1289 - Issues in structural design of a house in a highly seismic zone>** which covers similar issues with the design of timber-framed residential buildings.

Submit Report

Submit Feedback

Issues in structural design of a house in a highly seismic zone

CROSS Safety Report Report ID: 1289

A review of the structural design of a house in a highly seismic zone revealed several deficiencies with its design and detailing.

Key Learning Outcomes

For Civil and Structural Engineers:

- Be mindful of situations which lie outside the scope of prescriptive solutions, in this case **Acceptable Solution document NZS3604:2011 >**
- Take all necessary steps in quality control to ensure that the design is robust, especially when a mix of material types is used
- Ensure that all connection details are well considered and communicated clearly. Adequate base fixings, lateral restraint, load path and transfer all need to be detailed by the engineer
- External chimneys need consideration, especially high and/or heavy chimneys, as do heavy walls. Out of plane fixing of chimney structures and heavy walls is required, with an appropriate and clear load path to transfer loads to the in plane bracing system

R Full Report

This report raises several concerns about the structural design of a single storey house located in a highly seismic zone in New Zealand. The house was under construction when the design documents were sent to the reporter for review. The design review raised several issues that were communicated by the reporter to the original design engineer.

The house is of timber frame construction braced by a combination of plasterboard bracing walls and ceiling systems (for example, **GIB bracing systems>**) acting in conjunction with several steel portal frames fabricated using PFC (Parallel Flange Channels) members. These bracing systems are commonly used in timber framed residential construction in New Zealand and the design and installation should be carried out in accordance with **NZS3604:2011 Timber-framed buildings>** and the **GIB Site Guide>**.

The reporter had the following concerns relating to the steel portal frames:

- baseplates of some PFC portal frames were fixed by a single chemical anchor into cover concrete only. This detail is not in accordance with good practice as set out in **Engineering New Zealand>** publication **Residential Portal Frames – An Engineer's Perspective (October 2020)>**. The suggested detail uses two bolts or anchors, notes that hold downs must have sufficient edge distance, and that epoxied bolts should not rely on cover concrete. With a single anchor, the offset from the shear centre of the PFC to the bolt would induce torsion, which the reporter considers could not be accommodated with a single anchor
- horizontal members of portal frames in the external walls will be subjected to wind loads acting in the weak direction of the PFC. The reporter requested that the design of these be checked for ultimate limit state (ULS) and serviceability limit state (SLS) loads for bending about the minor axis of the PFC, and suggested a stiffening detail if required
- lack of detail for the connections of the portal frames to the rest of the structure, including the lateral restraint of the portal frames; how these were tied back; and how the earthquake and wind loads were transferred to the portal frames

The reporter also had concerns regarding the balance of the design including:

- a very heavy veneer on external walls and scant details provided for the framing of the timber wall to accommodate this heavy veneer
- the house layout involved some large span diaphragm ceilings that were beyond the scope of NZS3604 and the standard GIB bracing details. The reporter was concerned that there was no clear horizontal load path to transfer out of plane wall loads back to the steel portal frames. The reporter suggested that this might require details similar to those used in **NZS4229:2013 Concrete masonry buildings not requiring specific engineering design>** when connecting a masonry block wall to a ceiling. Although these details are very onerous, they would give a good indication of what is required
- the design of two high, heavy chimneys located in an external wall of the house. It appeared that the engineer had not considered the out of plane behaviour of these as there were no details showing how these were tied back to the building

C Expert Panel Comments

It is encouraging that the various design issues were found during an independent review, although it is noted that construction had already commenced before the documents were sent to the reporter.

One of the important issues raised by the reporter relates to the scope limits of prescriptive standards. The concept of fully understanding the limitations of any prescriptive design approach is very basic but often overlooked. Knowledge of NZS3604 and what does and does not conform to this building standard is not universal among Structural Engineers in New Zealand. This is perhaps evident in the findings of this report.

In proposing to adopt this code, the designer needs an understanding of it and its limitations in order to enable them to determine their scope and responsibilities, and whether the prescriptive solution is applicable to the situation in hand, or whether first principles/bespoke engineering is required.

These gaps in scope are not necessarily found during the building consent approval process, nor does the approval process act as part of the engineer's verification processes to identify these errors and omissions.

Although this report refers to New Zealand practice, the principles are the same in Australia and the use of AS1684, Residential Timber Framed Construction to comply with the deemed-to-satisfy requirements of the building code of Australia. Again, the scope limitations must be understood by the designer and that the standard is for conventional timber framed buildings of one or two storeys, with limitations on building geometry and wind classifications.

On another matter, the reporter records the adoption of a single chemical anchor fixing for a baseplate into cover concrete only, and holds that this detail is not in accordance with good practice as set out in Engineering New Zealand publication **Residential Portal Frames – An Engineer's Perspective (October 2020)>**. This Expert Panel supports the view that it is not good practice, especially fixing into cover concrete in seismic areas. **CROSS-AUS Safety Report 1280 - Load path and detailing issues with residential construction >** refers in this respect, and has application also, to issues relating to steel portal frames in residential construction, including the question of displacement compatibility for different materials (in this case steel portal frames and masonry walls).

As intimated by the reporter, any heavy walling such as precast concrete, stone, or feature masonry walls, including chimneys or parapet walls, needs careful assessment and design for seismic and wind actions.

Further, careful consideration needs to be given to all load paths in the structure, and connections should be sufficiently detailed in the documentation. As noted in **CROSS-AUS Safety Report 1280>**: *"A clearly-defined, robust load path must be established and designed, with appropriate, well documented connections… It is critical for structural designers to understand that lateral loads must be resisted from the roof to the suspended floor, usually by some form of shear wall action, which in turn uses the suspended floor as a diaphragm to carry the loads into lateral systems, including any steel framing or shear walls and finally to the ground".*

> **In short, engineers should remind themselves of the fundamentals of structural analysis and design**

In short, engineers should remind themselves of the fundamentals of structural analysis and design, such as load paths as well as the importance of appropriate detailing, self checking and verification of their work.

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