CROSS Safety Report

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

This month's report discusses the structural design of a single storey, timber-framed house in New Zealand.

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 parallel flange channel (PFC) 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 NZS 3604:2011: *Timber-framed buildings* and the GIB site guide (see **Further reading**).

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*. 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 ULS/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.

> **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**

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 NZS 3604
- 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

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 NZS 3604 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 NZS 4229:2013: *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

The full CROSS Safety Report, including links to guidance mentioned, is available on the CROSS website (report ID: 1289) at **www.cross-safety.org/uk/safety-information/cross-safety-report/issues-structural-design-house-highly-1289**.

FIND OUT MORE ABOUT CROSS

SCAN ME

FURTHER READING

CROSS Safety Report:

→| **CROSS Safety Report 1280:** www.cross-safety.org/aus/safety-information/cross-safety-report/load-path-and-detailing-issues-residential-1280

New Zealand Standards:

→| **NZS 3604:2011: *Timber-framed buildings*:** www.standards.govt.nz/shop/nzs-36042011

→| **Acceptable Solution B1/AS1 and NZS 3604:2011:** www.building.govt.nz/building-code-compliance/b-stability/b1-structure/building-structure-documents-changes-in-2011/acceptable-solution-b1as1-and-nzs-36042011

→| **NZS 4229:2013: *Concrete masonry buildings not requiring specific engineering design*:** www.standards.govt.nz/shop/nzs-42292013

Australian Standards:

→| **AS 1684: *Residential timber framed construction*:** https://hia.com.au/resources-and-advice/building-it-right/australian-standards/articles/using-as-1684-for-timber-framing

GIB Site Guide:

→| www.gib.co.nz/assets/Uploads/GIB-Site-Guide-2018-Complete-Manual.pdf

Engineering New Zealand:

→| **Residential portal frames – An engineer's perspective:** https://d2rjvl4n5h2b61.cloudfront.net/media/documents/ResidentialPortalFrames_Sep2020_Final.pdf

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 NZS 3604 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 AS 1684: *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*. This Expert Panel supports the view that it is not good practice, especially fixing into cover concrete in seismic areas. CROSS-AUS 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 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, such as load paths as well as the importance of appropriate detailing, self checking and verification of their work.