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Designing houses with unevenly distributed bracing

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While the bracing requirements in NZS 3604:2011 *Timber-framed buildings* suit most buildings, the distribution rules of clause 5.4.7 are too lenient for some complex designs. During earthquakes, some Building Code-compliant buildings may move or flex, causing extensive damage. BRANZ research found which buildings are affected and suggests changes.

WHEN A building shakes during an earthquake, it is being loaded very differently from the usual downward load of gravity. Predicting precisely how much buildings will move (and suffer damage) during earthquakes is difficult, particularly for buildings with irregular or uneven bracing layouts.

Irregular or unevenly distributed bracing in plan usually results from large window openings to capture a view or open plans with large room sizes, thus reducing the amount of bracing that can be fitted into one part of the building.

Irregular bracing can cause problems

Irregularly braced buildings will not only flex from side-to-side during an earthquake – they can also twist and rotate in plan. These separate types of movement can combine and be amplified in some parts of the building, causing severe damage. The building can literally end up shaking itself apart.

Damage to Christchurch houses varied

To investigate how Building Code-compliant buildings performed, BRANZ visited hundreds of houses after the earthquakes in Christchurch. Most light timber-framed (LTF) houses performed reasonably well with minor damage, provided there were no other issues with the site, such as liquefaction.

However, houses with ambitious designs with large windows and interior open spaces, which often have irregular bracing distributions, generally experienced the most damage, even though their designs were Code-compliant. The damage to some of these houses was so severe they were uneconomical to repair.

Extensive damage to a light timber-framed house following the Canterbury earthquakes.

BRANZ found underperforming houses

The current standard NZS 3604:2011 *Timber-framed buildings* gives requirements for the bracing needed for LTF residential buildings. The standard provides the likely demand on the building (wind and earthquake), as well as specifying the capacity of the bracing required to meet the demand.

Section 5.4 of NZS 3604:2011 sets up the rules for the design of the bracing and allows LTF housing to have irregular bracing arrangements within certain limits:

- It requires that lines of bracing in any storey shall be spaced at no more than 6 m apart in each direction (clause 5.4.6).
- It prescribes the minimum bracing capacity for each bracing line across the building (clause 5.4.7).

BRANZ designed a research project to find out the effect of the irregular bracing arrangements permitted in the standard on LTF houses during earthquakes. The study involved two parts.

The first was full-scale laboratory testing of plasterboard timber walls and the rigidity of plasterboard ceilings, which are responsible for distributing bracing loads. (New Zealand is the only country that considers plasterboard walls and ceilings as a part of the building structure.)

The second part of the study involved 3D computer simulations of LTF buildings that were designed in line with the standard but with different irregularities in their bracing layouts. This allowed the study of the effect of permissible irregularities on the seismic performance of LTF houses.

NZS 3604:2011 bracing too lenient

In the laboratory tests and computer simulations, BRANZ found that the bracing distribution requirements in NZS 3604:2011 are too lenient. The lateral side-to-side deflections of buildings with irregular bracing layouts could be many times greater than that of regular buildings.

This explains why LTF houses with irregular bracing arrangements, which were allowable by NZS 3604:2011, experienced such significant damage during the Christchurch earthquakes.

Changes needed to bracing distribution

Tightening the current limits for irregularities in bracing arrangements in NZS 3604:2011 is needed to achieve more-resilient housing stock.

This study showed that increasing the current minimum bracing requirements in the standard along the perimeter walls by 50% could reduce lateral movement by about 40% and would keep the overall movement of buildings during earthquakes within levels that won't cause as much damage.

If there is any doubt about your bracing design, consult a structural engineer, particularly if the layout is near the bracing distribution limits prescribed by NZS 3604:2011.

More information

Further information on this project is available from www.branz.co.nz/pubs:

- BRANZ Research Now: Seismic resilience #1 *Performance of irregular seismic bracing in light timber-framed buildings*
- BRANZ Study Report SR337 *Design guidance of specifically designed bracing systems in light timber-framed residential buildings*
- BRANZ Study Report SR404 *Seismic effects of structural irregularity of light timber-framed buildings*.