Maximum strength of house bracing walls

A BRANZ research project has investigated load transfer in timber framed buildings – and found a number of potential weak spots.

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Due to New Zealand's unique climate and geology, our houses must be designed to withstand wind and earthquakes. Construction built to NZS 3604: 1999 *Timber framed buildings* is intended to ensure that wind and earthquake loads can be safely carried from the loaded elements, through house bracing walls and into the ground.

However, over the last few years manufacturers have developed stronger bracing wall systems, raising questions about whether the rest of the structure is sturdy enough to transmit forces into and out of these walls. Simple calculations have indicated that the strength of timber foundations, for example, could be inadequate. The real situation is quite complex, due to the load sharing that occurs in buildings.

Potential load transfer limitations

NZS 3604 specifies that wall bracing ratings are to be determined using the BRANZ P21 test. The P21 test investigates isolated walls and evaluates the corresponding wall bracing ratings. Building designers then ensure that the total earthquake or wind bracing demand (as stipulated in NZS 3604) does not exceed the bracing resistance of the sum of the walls used in the construction.

The test walls are fabricated in the same way as those used in actual construction. A horizontal load is applied to the wall top plate, and the test measures the ability of the wall to transmit this load to a foundation beam. The bracing rating that is derived from this assumes that the load can transfer into the top plate, through to the bottom of the wall, and into the subfloor framing or the storey below.

However, there are a range of factors that could potentially cause limitations to the load transfer. These include:

- load transfer limit from the ceiling or roof into the bracing wall
- failure of the mechanical anchors which fix the wall to the foundation. The P21 test uses coach screws or bolts but these are often replaced with various proprietary fasteners in practice, in both timber and concrete foundations
- failure of floor members, such as joists or bearers in timber floors or the concrete slab in concrete floors
- failure of the connection between floor members, such as between blocking and joists, joist and bearers, and bearers and piles.

A three-phase research project

To investigate these potential limitations, and learn more about the real load transfer that occurs in houses, BRANZ has recently carried out a research project. The study consisted of three separate phases. In Phase 1, several isolated bracing walls were constructed on top of a large floor and piled foundation. Testing showed that at low bracing loads failure of the connection between the floor members, or of the floor member themselves, occurred. This was of concern.

This led to Phase II, where a single-storey building founded on piles, with a ceiling but no roof, was racked to enable load sharing to enhance the performance – as is likely to occur in a real building. It also included the theoretical calculations of bracing load at which many potential failures could occur and collated the final recommendations from all test phases.

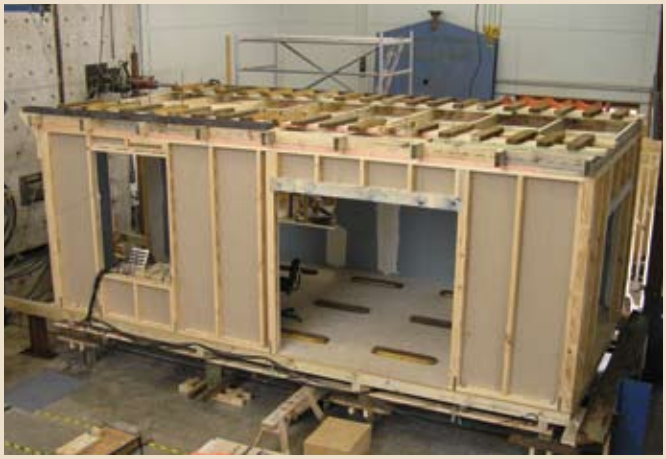
BRANZ also investigated the ability of NZS 3604 type buildings to transfer the vertical loads (which are induced by wall racking) between top and bottom storeys of two-storey buildings. In Phase III of the project (see photo), a two-storey building, with a ceiling but no roof, was racked to investigate the strength of this load path.

Joists and bottom plates failed in flexure, and blocking, joists, bearers and plates separated from their supports. Where internal bracing walls were anchored to blocking between joists, the flexibility of the blocking-to-bearer connection precluded high bracing loads being applied. Joists lifting from their supports also added much flexibility.

Recommended changes to NZS 3604

Based on the results of the research project, BRANZ made the following recommendations for changes to NZS 3604:

- Removing the option for connecting bearers to normal piles with just four skew nails, leaving only the option of two skew nails plus two wire dogs.
- The minimum requirement for fixing boundary joists to the plate below should be a single power driven 90 x 3.15 mm skew nail at 100 mm centres from joist-to-wall top plate along the length of the boundary joist. NZS 3604 does not stipulate what this connection should be.
- Blocking should be fixed to the joists and joists fixed to their supports with a 6 kN connector in some instances.



Phase II testing of a single-storey building on piles.

Phase III with a two-storey building.

- Double joists should be used below bracing walls in some instances.
- Full depth blocking should be used between joists in some instances.

Recommended maximum bracings

From the results of the study, new recommended maximum bracings were calculated. These are based on:

- bracing loads when failure occurred in the three large constructions tested
- calculated bracing rating based on connection strengths measured in elemental tests, calculated mean member strengths and estimated wall axial loads.

Care was taken to ensure the findings were not too conservative since complex redistributions of load can occur and performance is based on average rather than characteristic strengths.

WALLS FOUNDED ON TIMBER FLOORS

Based on the results of this project, the recommended maximum wall bracing rating is 110 BU/m (5.5 kN/m) for construction on timber foundations, approximately 25% less than industy expectations. This recommended limit is expected to prevent foundation failures from earthquakes or wind in most houses. Where established bracing ratings exceed this limit of 110 BU/m, specific engineering design would be required if the value used was higher than 110 BU/m.

WALLS FOUNDED ON CONCRETE FLOORS

Calculations showed that it is unlikely that concrete foundation slabs will fail in flexure due to vertical load transfer from wall bracing elements. However, to transfer the load into a bracing wall, a limit of 180 BU/m was calculated. Wall bottom plate failure is expected at 137 BU/m for bottom plates bolted to the foundation 100 mm from the end of the bracing element. This value will vary with the actual bracing wall hold-down system used.

A wide variety of anchor strengths are commercially available, some of which meet most common bracing demand uplift loads. Consideration was given to proposing a strength limit to the NZS 3604 Revision Committee for concrete foundations formed using conventional formwork and another for masonry block formwork which would take into account the capacity of commercially available anchors. However, no specific limit for the maximum wall bracing ratings for walls on concrete foundations has been made to date.

To apply bracing ratings from a P21 test the concrete anchors substituted for the hold-down bolts used in the test must be shown to be adequate. The project report gave a methodology for achieving this.

It may be difficult to achieve high bracing ratings for internal walls if wall anchors are limited in depth to meet durability requirements and to ensure the damp-proof course is not penetrated. It is recommended that the NZS 3604 Revision Committee consider this problem.

Other conclusions

Wall deflections increased by factors between 2 and 5 due to subfloor flexibility, particularly for internal walls. Thus, walls built on the more rigid parts of the subfloor structure may carry a disproportionate share of the racking load and others may be only lightly loaded. The recommendations given in this article will help provide useful subfloor stiffening.

Coach screws used to fix bracing wall bottom plates to double joists may currently be at the adjoining faces of the joists. Should this occur, the pull-out strength is expected to be compromised. Methods to ensure these fixings are into solid timber need to be addressed.

Various alternatives to solid timber floor joists are now commonly used in buildings. The strength of the fixing of bracing walls to these joists, and the connection strength of these joists to the structure below, is outside the scope of NZS 3604 and requires specific design.

The findings of this research have been forwarded to Standards New Zealand for possible incorporation into the next revision of NZS 3604.

For more details see the three BRANZ Study Reports SR162, SR163 and SR164 which can be downloaded from www.branz.co.nz, under Free information.

This work was funded by the Building Research Levy. Winstone Wallboards Ltd, Auckland, donated the wall linings used in the testing.