Timber-based hybrid buildings

BRANZ is developing guidance that will support designers to incorporate a range of hybrid solutions in light timber-framed buildings, supporting the growing popularity of low-rise and mid-rise housing.

BY ANGELA LIU, BRANZ SENIOR STRUCTURAL ENGINEER, AND DAVID CARRADINE, BRANZ SENIOR STRUCTURAL RESEARCH ENGINEER

NEW ZEALAND HAS AN EXTENSIVE history of using light timber framing (LTF) in residential houses due to its many advantages. These include local availability, a high strength-to-weight ratio and good performance during earthquakes. As the demand for higher-density housing continues to grow, it has led to more LTF use in multi-storey buildings beyond the scope of NZS 3604:2011 *Timber-framed buildings*.

A recent BRANZ publication, *Multi-storey light timber-framed buildings in New Zealand: Engineering design,* has guidance on multi-storey LTF buildings. Through the development of this guidance and other related research, it became apparent that combinations of stiffer and stronger structural systems could be beneficial for the seismic performance of multi-storey LTF buildings.

Combination systems seismically vulnerable

Buildings using a combination of systems as bracing elements such as LTF plasterboard or plywood wall systems, steel systems and concrete systems are considered to be hybrid structures as they have mixed bracing systems. The seismic vulnerability of residential houses with these systems was highlighted in the BRANZ Canterbury Earthquake Survey. They were found to perform far worse than their single-material counterparts, including buildings made of LTF plasterboard walls only (see BRANZ Bulletin 551 *Learnings from the Canterbury earthquakes)*.

Timber-based hybrid multi-residential dwellings under construction.

The concept of hybrid buildings is not a new one, and many precedents exist for buildings whose lateral load-resisting systems are a combination of LTF walls and other materials. BRANZ Study Report SR400 *State of the art of timber-based hybrid seismic-resistant structures* describes various timber-based hybrid buildings and discusses the pros and cons of these within the context of earthquake performance.

Understanding deformation compatibility

However, little guidance exists for these combinations, and there are several issues that require consideration for their effective design. As different systems respond differently to earthquakes in terms of strength and stiffness, it is critical to understand how they will respond when they are connected to each other and expected to act together in a building system.

Some systems tend to move very little during an earthquake but are brittle when pushed too far. Conversely, other systems can move significantly during an earthquake and do so without collapsing yet result in permanent damage to the building.

These different responses to earthquakes need to be considered for the design of these systems, and this is particularly important where different systems are connected together. Deformation compatibility is the term used by engineers for the situation where they consider how joining systems respond differently to the same force. Understanding this concept is part of the puzzle that requires investigation in order to understand how hybrid buildings should be designed and constructed.

Project to develop design guidelines

A current project, *Seismic design of low-rise and medium-rise hybrid residential buildings,* is aimed at providing adequate guidance to inform the design and construction of timber-based hybrid structures for increased seismic resilience, nationwide consistency and associated economic benefits.

This project builds on a previous project partially funded by EQC and conducted at BRANZ, which looked at how hybrid structures perform in earthquakes, especially the compatibilities between hybrid systems, and how to design them. This project was primarily done at an elemental/component level. See BRANZ Study Report SR337 *Design guidance of specifically designed bracing systems in light timber-framed residential buildings*.

Looking at specific seismic issues

The current project will investigate the specific seismic issues of low-rise and mid-rise hybrid residential buildings using LTF construction combined with specifically designed bracing elements incorporating other materials at a system level. The common hybrid combinations of residential buildings will be investigated using structural modelling and experimental testing along with desktop analyses of performance and feasibility.

The following work will be conducted:

- Computer simulations based on the most feasible combinations of bracing systems found to identify the critical aspects in load paths.
- Component tests to establish load-deformation models of critical components.
- Cyclic tests on subassemblies consisting of hybrid bracing systems, timber walls, connections and floors to calibrate the developed models.
- Three-dimensional seismic analyses of whole buildings, based on the developed models, to gain insights into the load distributions between bracing systems.

Stakeholders help focus on common systems

The project began in April 2020 and will continue through to October 2023. A project advisory group formed to help includes stakeholder representatives from regulatory organisations as well as Engineering New Zealand technical groups and practitioners. The project team is undertaking targeted stakeholder engagement to obtain a better understanding about typically used combinations of hybridised bracing systems in different building typologies.

This will ensure that resources are focused on the most common hybrid systems, increasing the impact of the project. The major output of the project will be design guidance for hybrid bracing systems with low-rise and mid-rise residential buildings incorporating LTF. This guidance will build on previous projects and provide methods for design that allow designers the freedom to incorporate a range of hybrid solutions within LTF buildings.

Help designing low-rise and mid-rise residential buildings

There is significant interest from stakeholders such as MBIE, the NZS 3604 revision scoping committee, Engineering New Zealand and councils to develop adequate guidance to inform the construction of hybrid structures to increase seismic resilience, nationwide consistency and the associated economic benefits.

Looking forward, the proportion of new builds that are hybrid residential buildings will grow as demand for higher-density housing increases and demand for bespoke designs continues.

Currently, there is very little design guidance available for use in the construction of these buildings. This research project will help by developing engineering principles that can be used in designing low-rise and mid-rise residential buildings of mainly LTF construction with hybrid bracing.

These will enhance the technical tools available to provide seismic resilience and consistency nationally. Additionally, design and consenting costs may be lower while increasing build quality. They will also provide the foundation for developing an engineering basis for the potential expansion of the Acceptable Solution standard NZS 3604.

Note The BRANZ publications and study reports mentioned are available from www.branz.co.nz/pubs.