Thermal bridging in external timber-framed walls – part 2

The first part of the *Thermal bridging in external timber-framed walls* project found that the percentage of timber framing in the walls of new houses was much higher than generally assumed. This suggests that designed R-values are not being achieved in practice. Part 2 of the project, outlined in this Research Now, focused on the causes, impacts and potential solutions to the problem.

Finding ways to minimise thermal bridges in walls and ensure our houses are warm has substantial benefits for both house occupants and the country as a whole. Homes with minimal thermal bridging are more energy efficient. They use less purchased energy for heating, have lower carbon footprints and cost less to keep warm and healthy.

Thermal bridges are materials or elements (such as timber framing) that are better at conducting heat than insulating material. Heat flows more easily through timber than insulation materials from a warm interior to a cold exterior. Houses with lots of thermal bridging are harder to keep warm and have increased risks of condensation and mould.

In the first part of the research (see BRANZ Research Now: Warmer drier healthier #2), measurements made of 47 newly constructed houses in Auckland, Hamilton, Wellington and Christchurch found the average percentage of timber framing compared to wall area was 34%. This is much higher than the 14-18% framing content that has generally been assumed by regulators and the industry to be the norm. Such high levels strongly indicate that thermal bridging is compromising the thermal performance of walls and that wall R-values associated with healthy, energy-efficient houses are not being achieved in practice.

Instructions for calculating construction R-values in NZS 4218:2009 *Thermal insulation - Housing and small buildings* apply to what the standard refers to as the "typical" wall area. This "typical" wall area does not account for the full effects of thermal bridging. The definition excludes a significant number of the framing elements that contribute to thermal bridging and heat loss (Figure 1).

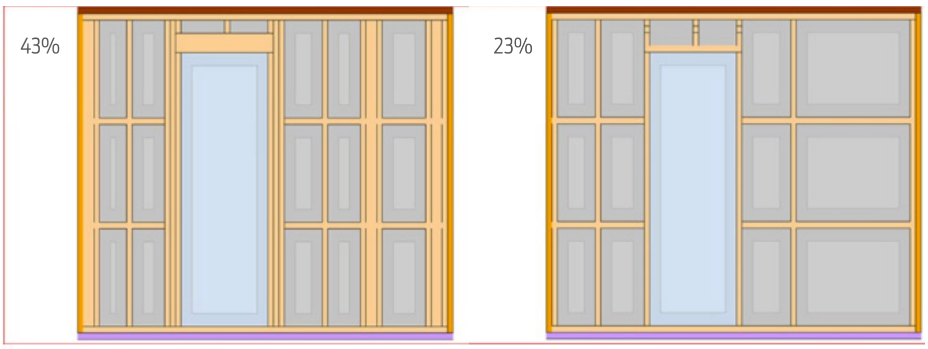

Figure 1. Actual timber framing percentage (left) compared to allowable definitions in NZS 4218:2009 (right).

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It is therefore possible that, at the same time, a house could:

- technically meet the minimum construction R-values of NZS 4218:2009 (and therefore comply with the Building Code) because the standard excludes in its calculations some of the timber framing that provides thermal bridging
- have actual as-built construction R-values that are much lower than the minimums required in the standard, because as-built measurements take account of all the framing.

Part 2 of the project

The second part of the research focused on the causes, impacts and potential solutions to the high rates of thermal bridging found in part 1. The research team:

- worked with frame and truss detailers to identify the drivers of the high percentages of framing and explore optimisation of design and construction
- used modelling to assess and quantify the impact of high framing ratios and weak points on the performance of the thermal envelope
- identified advanced framing and insulation options and held a workshop to explore whether these could be adapted to modify existing commonly used framing solutions.

Exploring drivers for higher framing percentages

A simple standard housing design (Figure 2) was analysed, with variables covering different framing practices, framing spacing and claddings. Analysis found no single factor that drives the higher rates of framing – each variable added small percentages of timber on top of others.

Analysis of current detailing techniques suggests that there is little unnecessary timber being added to framing. Each piece of 90 x 45 mm timber is added for valid regulatory and practical reasons such as structure, weathertightness and fixings for cladding, linings and additional fittings.

The team worked with one of New Zealand's most experienced frame and truss detailers to explore how the timber framing content could be reduced within the confines of existing standards, regulations, specifications, cladding types and construction requirements. Even with the skills of an experienced detailer working on a relatively simple one-level house design, the framing percentage could not be reduced below 25%.

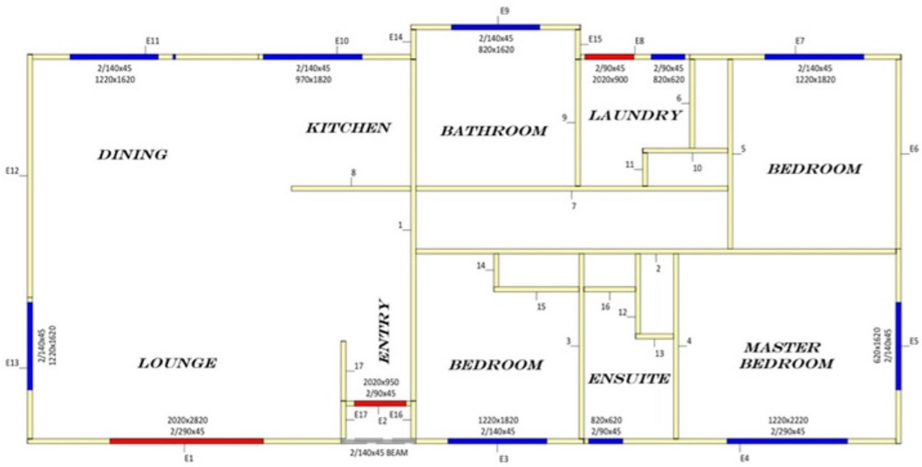

Figure 2. Simplified house plan design for use in detailing analysis (modified from original).

Optimising the percentage of framing in standard 90 mm walls alone will not reduce framing percentages (and thermal bridging) sufficiently to achieve whole-wall construction R-values found in healthy, energy-efficient houses.

The impacts of high framing content and weak points

Part 2 of the research also included modelling of five Building Code-compliant houses to quantify:

- the as-built wall R-values
- the impact of weak points on R-values
- the R-values of a reduced framing percentage of 25%.

Three of the houses assessed were single-storey homes in Auckland, Wellington and Christchurch, while two were 2-storey homes in Auckland. The floor area of the houses ranged from 110–145 m². Wall construction R-values were calculated for each of the properties with R2.0, R2.2 and R2.8 insulation.

The thermal resistance of entire external walls as built was found to be well below the minimum levels in NZS 4218:2009 and below the minimum of R1.5 in Building Code clause E3/AS1.

Weak points include uninsulated corner junctions, uninsulated mid-floors, uninsulated interior-to-exterior wall junctions, uninsulated floor slab edges and areas of timber flashing, timber packing and blocking.

Modelling was carried out to quantify how much construction R-values could be increased:

- The largest single improvement came from insulating the floor slab edge on single-level houses, which improved whole-house wall construction R-value by around 40%.
- Upgrading five identified common weak points produced a smaller increase in wall construction R-values – for walls with R2.2 insulation, the increase was 11%.
- When five weak points and external floor slab-edge insulation were addressed, the increase in average whole-house wall construction R-value was 55% (with R2.0 insulation), 58% (with R2.2 insulation) and 68% (with R2.8 insulation). Most of the increase (80%) was due to the slab edge being insulated.
- Limiting the percentage of wall framing to 25% would only result in an overall wall R-value increase of 6% (with R2.0 insulation) and 8% (with R2.8 insulation). This is still well below the minimum construction R-values in NZS 4218:2009 and only achieves the R1.5 minimum in Building Code clause E3/AS1 with R2.8 insulation.

Reducing framing on its own is clearly a limited strategy. Increasing insulation to R2.8 and applying upgrades of five common weak points on their own will not produce walls with construction R-values over R1.8, even with framing limited to 25%.

Advanced framing and insulation solutions

A number of steps could theoretically be taken together to increase the thermal performance of walls. These include always specifying well-installed R2.8 insulation in 90 mm walls, insulating the slab edge, optimising framing, reducing design complexity, minimising the number and size of windows and doors and placing them to use existing studs rather than adding extra studs. It is unrealistic to expect all these steps to be achieved in reality, however, and ultimately, they do not address the core problem of thermal bridging.

An interactive online webinar in October 2020 with nearly 100 participants from industry and government considered possible solutions and real-world examples of systems that have been designed, consented and built.

Most of the construction approaches attempted to overcome issues relating to thermal bridging through the application of a second skin of insulation over a reasonably standard 90 mm stud wall (Figure 3 shows one example).

BRANZ External Research Report ER64 *Thermal bridging in external walls: Stage two* includes details and drawings of walls from existing houses with two layers of insulation.

Two layers of insulation offer a range of benefits:

- The approach is readily compatible with design from NZS 3604:2011 *Timber-framed buildings*, which is well known.
- The 45 x 45 mm batten technique uses commonly available materials.
- Frame and truss manufacturers could calculate and order the battening timber as part of their standard approach to manufacturing and delivery.
- The additional inside layer can be used to run services, further protecting the thermal performance of the overall building envelope. This may also reduce the labour costs of installing services.
- The additional layer of insulation reduces the thermal bridging across the entire external wall (i.e. the whole wall), providing a consistent thermal envelope with few weak points.
- A secondary layer of insulation running counter to the first may also reduce air movement, improving the rated performance of the insulation in either layer.
- A second layer of insulation would help compensate for weak points in current framing and insulation practices and would help to compensate for poorly installed insulation in either layer.

It would be worthwhile looking into the additional work required to deliver a two-layer insulation option as an Acceptable Solution. For this idea to be adopted widely and achieve uptake at scale throughout New Zealand requires broad industry/government collaboration.

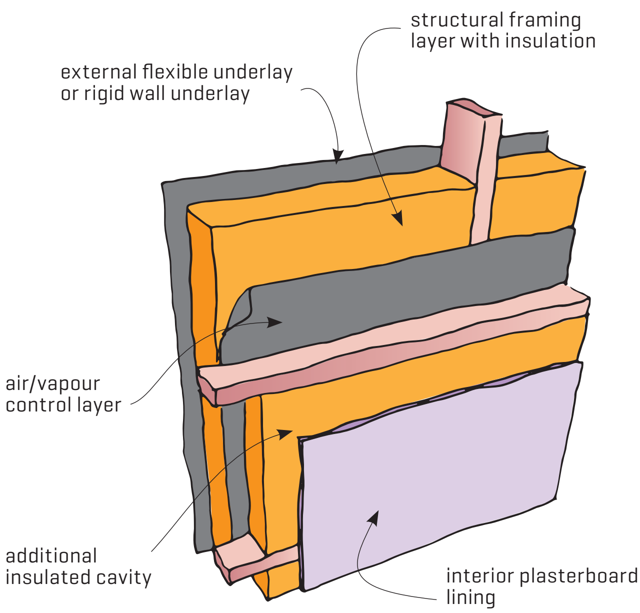

Figure 3. Schematic drawing of timber-framed wall with an insulated timber-batten cavity constructed on the inside face of the structural framing.

Conclusion

This research found that standard 90 mm timber-frame construction complying with the Building Code produces new-build houses with actual whole-wall construction R-values that vary between R1.2–R1.4, even with R2.8 insulation installed. This highlights a sizeable performance gap between what is achieved in reality and the R-values calculated to meet Building Code compliance of R1.9/R2.0 in NZS 4218:2009.

The research found little unnecessary timber in wall framing – each piece is added for valid regulatory and practical reasons. Even one of New Zealand's most experienced frame and truss detailers working on a simple design could not reduce the framing percentage below 25%. Optimising the framing percentage alone will not achieve actual entire wall R-values that match those of minimum construction R-values for wall areas in NZS 4218:2009.

A number of homes already built or currently under construction have overcome the problem of thermal bridging by using a second layer of insulation. This creates a thermal break between the timber framing and the external environment as well as providing space to increase the thickness of the insulation.

The results of this research could contribute to improvements in building regulations, including the New Zealand Building Code and standards. Follow-up work in this area is being developed.

More information

BRANZ Research Now: Warmer drier healthier #2 *Measuring the extent of thermal bridging in external timber-framed walls in New Zealand*

BRANZ External Research Report ER53 *Measuring the extent of thermal bridging in external timber-framed walls in New Zealand*

BRANZ External Research Report ER64 *Thermal bridging in external walls: Stage two*

BRANZ Bulletin 660 *Residential walls with high thermal performance*