BRANZ

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AGGRAVATED THERMAL BRIDGING RESEARCH

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Ordinary thermal bridging in roofs occurs when a framing member connecting roof and ceiling allows heat to be lost to the outside and moisture problems to develop inside.

A more severe form of thermal bridging (aggravated thermal bridging) has been found, particularly in institutional buildings, where serious condensation occurs even though steel framing members are not in contact with the ceiling.

This bulletin focuses on BRANZ research to define the situations where aggravated thermal bridging may occur and evaluate four possible conceptual solutions.

1.0 INTRODUCTION

1.0.1 Thermal bridging occurs when a material that is a good conductor of heat directly connects a building's cladding and lining. Steel roof framing is a good example. It can directly connect the inside and outside of the building and provide a low thermal resistance heat flow path, increasing heat loss from a warm interior to the outside (Figure 1). Cold spots can form on the areas of ceiling directly under the framing, and condensation can form. A typical sign of thermal bridging is condensation, which can lead to mould growth along the colder and damper areas of ceiling, following the pattern of the framing.

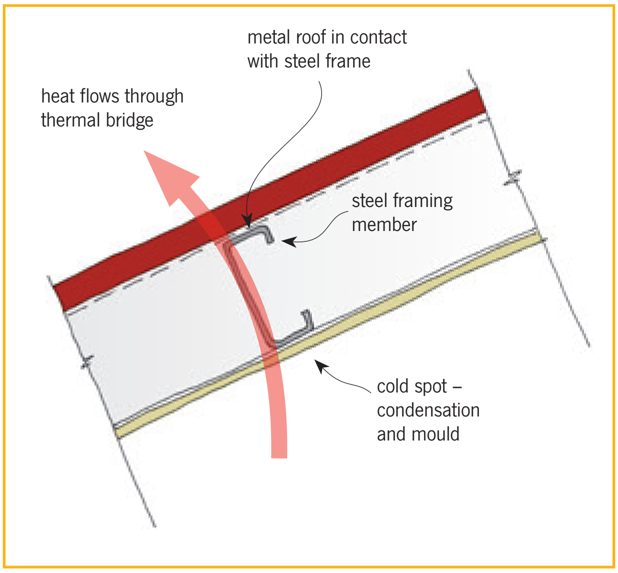

Figure 1 Schematic drawing of thermal bridging (insulation omitted for clarity).

1.0.2 Traditionally, the problem of thermal bridging is addressed by inserting thermal breaks (materials such as polystyrene, timber or insulating board, which are poor heat conductors/good insulators) between building elements to reduce the transfer of heat.

1.0.3 A more severe form of thermal bridging – referred to as 'aggravated thermal bridging' – has been found in the roofs of institutional buildings with steel-framed roofs, even though the steel framing members are not in contact with the ceiling. It can cause severe condensation that ultimately results in corrosion and significant mould growth, which may impact on New Zealand Building Code durability and internal moisture requirements.

1.0.4 This bulletin focuses on BRANZ research to define the situations where aggravated thermal bridging occurs and to evaluate four possible conceptual solutions.

1.0.5 Aggravated thermal bridging typically occurs in gymnasiums, classrooms and halls where:

- a steel framing member is in contact with a low-temperature thermally conductive metal roof (usually with an intervening underlay that is not important thermally) but is not in direct contact with the ceiling
- there is little air movement through the roof
- there is no designed ventilation between roofing and ceiling (no ceiling, ridge or roof ventilators)
- the ceiling is air permeable, such as an acoustic-tiled ceiling, allowing air flow into the ceiling around the edges of the tiles
- the space below the ceiling has frequent high moisture loads, such as occurs from the large number of occupants in classrooms or gyms.

1.0.6 The steel framing members are not in contact with the warm ceiling, and the ceiling material (for example, acoustic tiles) may have some thermal insulation properties. The tiles thermally isolate the steel framing element and the roof-space air from the warm interior, allowing the steel framing to approach the temperature of the cold roof cladding.

1.0.7 Warm moisture-laden air from below passes upwards through the ceiling and condenses on the cold framing steel (Figure 2). With no ventilation to reduce the problem, this can lead to excess condensation, affecting the durability of the roofing elements, corrosion of steel roof components and deterioration of roof underlays, ceiling linings and insulation. BRANZ research that is currently under way aims to provide guidance on how much ventilation should be provided for a range of roof constructions, but no recommendations are available yet.

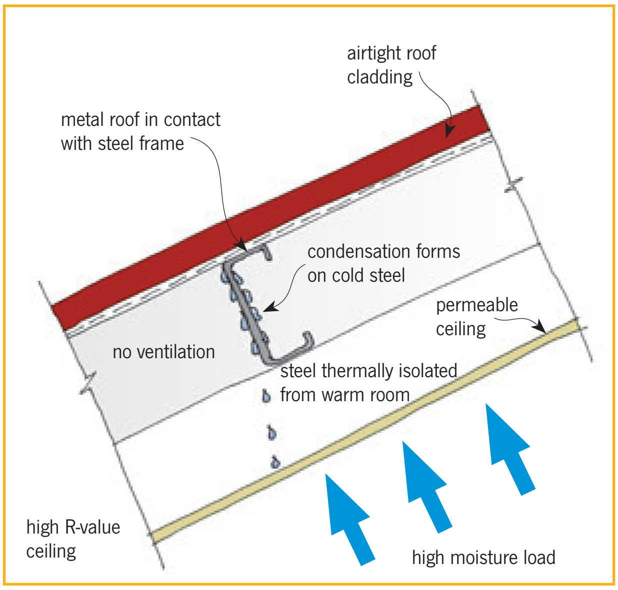

Figure 2 Condensation forms on steel roof framing.

1.0.8 One possible solution to prevent aggravated thermal bridging would be to insert a thermal break of insulating material between the steel member and the roof cladding. However, BRANZ research has indicated that this thermal break is not always sufficient to solve the problem. The air in the roof space – and therefore the steel framing – can still be very cold, and condensation can occur.

1.0.9 Inserting board insulation under the roof cladding across the entire roof area gave a better result than a thermal break above the steel framing members because it causes the air and the steel to be warmer, reducing the risk of condensation. However, this option has potential structural implications in the compressibility and elasticity of insulating board. (Designers also need to consider fire and acoustic issues, but that is outside the scope of this bulletin.)

1.0.10 Placing a high R-value insulating layer, such as a sandwich panel made of plywood and phenolic insulation board, between the steel rafters and the purlin can provide an effective thermal break and has better structural properties than insulating board alone. However, it must remain dry in service so that the plywood and the phenolic insulation are not affected by moisture, as this can result in degradation of the plywood and the formation of pholic acid from the foam, which is corrosive to steel. This can be an expensive option, however, and difficult to build.

2.0 BRANZ TESTING

2.0.1 BRANZ conducted research to test the effectiveness of four different conceptual designs. The testing was limited to four options to determine if those options avoided aggravated thermal bridging, but there are a range of other viable design options that were not included as part of the research. BRANZ constructed a testing rig that would allow accurate assessment of four options yet also be transportable. This allowed the rig to be moved to Dunedin and subjected to a cold winter.

2.1 TEST SPECIMEN DESIGN

2.1.1 The four conceptual roofing specimens were as follows:

1. A timber thermal break between the purlin and roofing underlay under the roofing, with insulation above an acoustic-tile suspended ceiling (Figure 3). (Since this was known not to be particularly effective, it was regarded as a control.)
2. A timber thermal break between the purlin and roofing underlay under the roofing, with EPS polystyrene sheets immediately under the underlay between the thermal breaks, plus insulation above an acoustic-tile suspended ceiling (Figure 4). There are no structural requirements on the EPS in this case.
3. A continuous plywood/phenolic insulation/plywood structural insulated panel (SIP) installed over the purlins and below the roof underlay, with insulation above an acoustic-tile suspended ceiling (Figure 5).
4. A continuous metal roofing/EPS polystyrene/metal SIP panel, installed over the roof underlay and purlins, with insulation above an acoustic-tile suspended ceiling (Figure 6). The panel is also the weathertight cladding in this case.

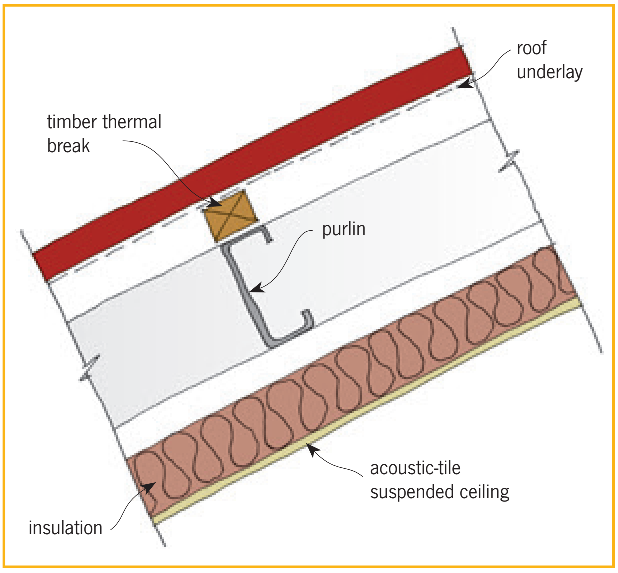

Figure 3 Roof specimen 1: A timber thermal break between the purlin and roof underlay.

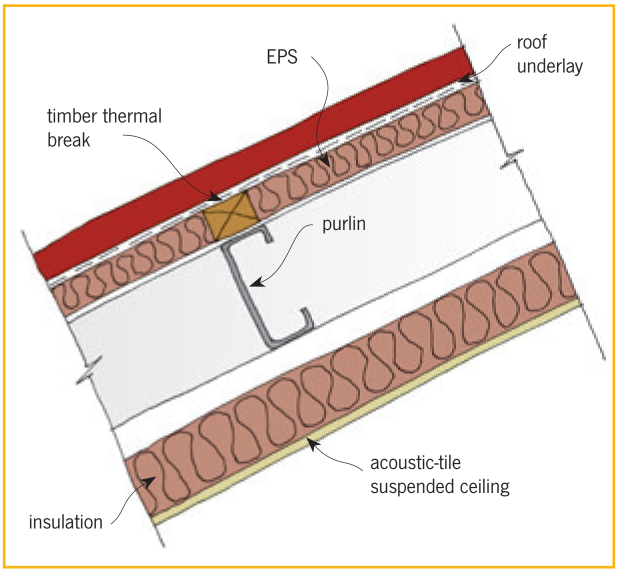

Figure 4 Roof specimen 2: A timber thermal break between the purlin and roofing underlay with EPS polystyrene sheets installed between the thermal breaks and immediately below the roof underlay. The EPS is not structural.

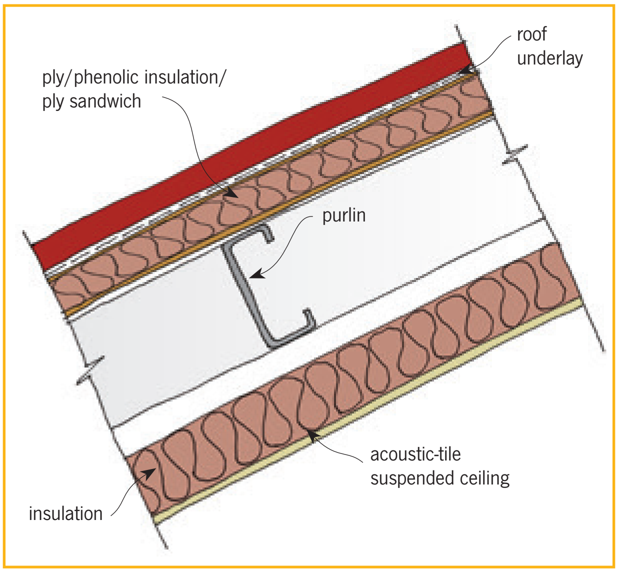

Figure 5 Roof specimen 3: A plywood/phenolic insulation/plywood SIP installed over the purlins but below the roof underlay.

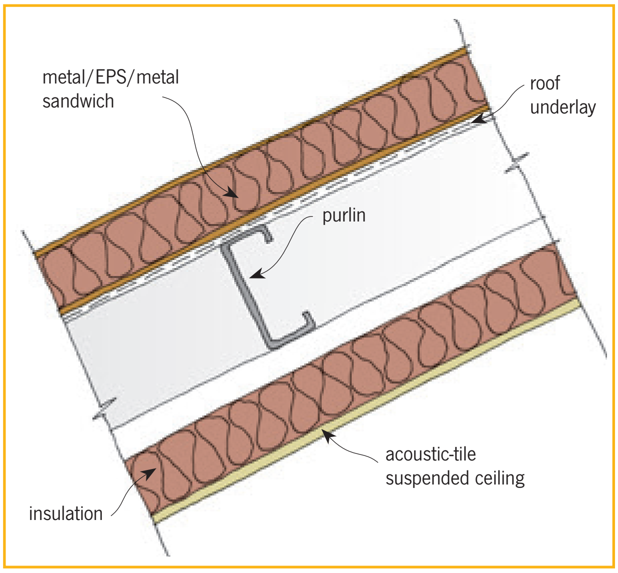

Figure 6 Roof specimen 4: A metal roofing/EPS polystyrene/metal SIP panel installed over the purlins and roof underlay. The roof panel is the weathertight building cladding.

2.1.2 Relative humidity (RH) was measured at a number of points in the specimens over time to determine what impact the different options had on moisture in the roof space. (Relative humidity is the amount of water vapour in the air compared to the maximum amount of water vapour the air can hold at a particular temperature. For example, an RH of 90% means that the air contains 90% of the moisture it can possibly hold at that temperature.) Very high levels of relative humidity bring a higher risk of condensation and therefore corrosion and damage.

2.2 TEST RESULTS

2.2.1 The relative humidity levels on a frosty night for a building with a high moisture load and a temperature around the flanges of around 0°C are shown in Figure 7. They show the following results:

- For the timber thermal break alone (roof specimen 1), the relative humidity was over 95% around the steel member – the 'upper flange' on the chart (relative humidity was over 97% for more than 17% of the time). This is high enough for substantial amounts of condensation to form and become a serious problem.
- For EPS (roof specimen 2), the relative humidity percentage was in the 80s – generally acceptable. (Although relative humidity rose to 97–98% on extremely cold nights, this happened for around only 1% of the time. The condensation that occurred on such nights would be unlikely to result in long-term problems.)
- For the SIPs (roof specimens 3 and 4), the relative humidity percentage was in the 70s – acceptable.

2.2.2 The research shows that a timber thermal break running along the top of steel framing members may not be enough in itself to reduce the relative humidity in the roof space and, therefore, to reduce the risk of condensation forming.

2.2.3 The research shows that sheet insulation under the whole of the roof cladding, whether it is EPS or a sandwich (SIP) of plywood/phenolic insulation/plywood or metal/EPS/metal, reduces relative humidity to an acceptable level.

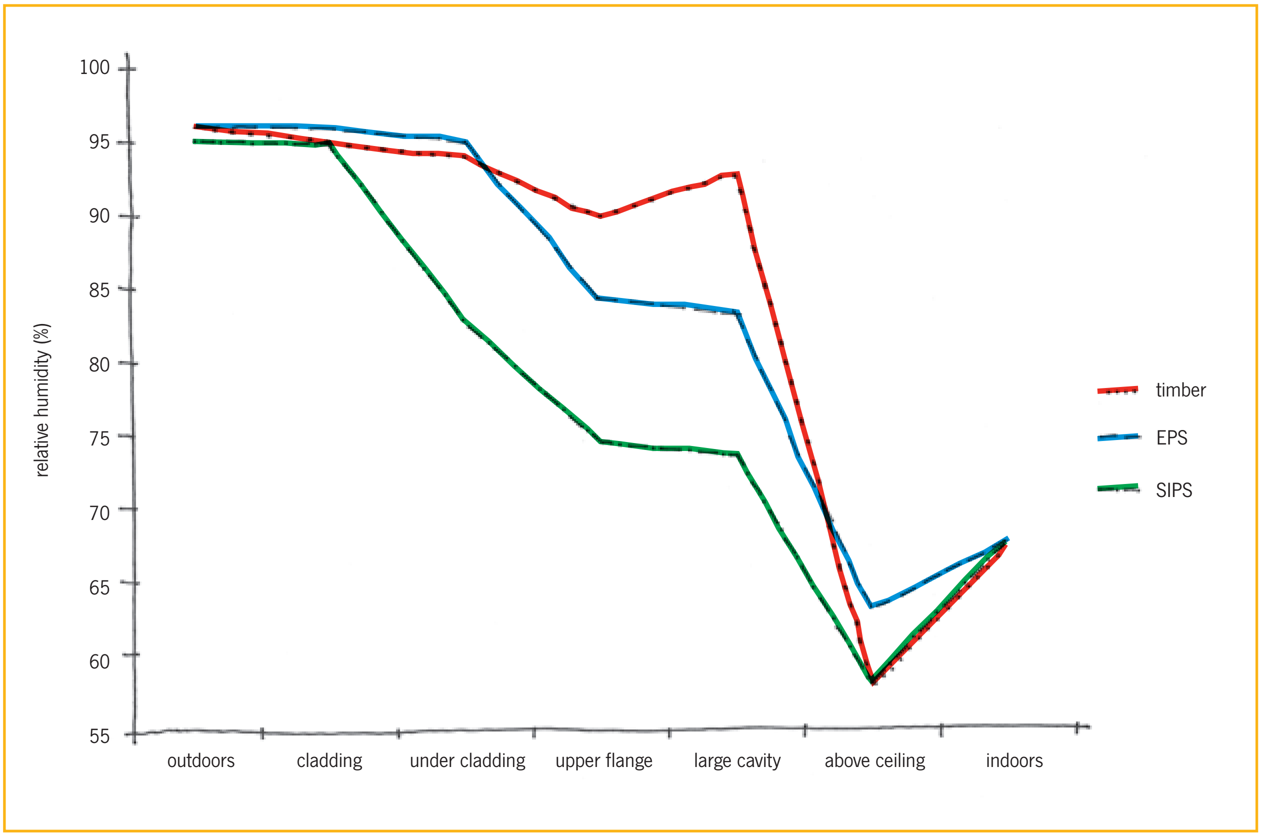

Figure 7 For the roofs studied, a timber thermal break does not significantly reduce relative humidity around the steel framing ('upper flange'). EPS and SIPs are more effective.

3.0 DESIGN AND INSTALLATION CONSIDERATIONS

3.0.1 Designers working on an institutional building where there is likely to be a high moisture load inside, especially where a tiled ceiling system with steel roof framing is being used, should be aware that aggravated thermal bridging may be a design risk. Employing a specialised consultant with experience in this area to provide design input and/or review documentation is recommended.

3.0.2 Concepts that have been shown by the research to be effective for high internal moisture loads and colder climates include:
- non-structural EPS polystyrene sheet under the roof cladding
- plywood/phenolic insulation/plywood SIPs under the roof cladding
- metal/EPS/metal SIPs.

3.0.3 Other factors to consider during design include:
- providing ventilation to the roof space, particularly in skillion roofs; however, no specific ventilation rates are available yet for different types of roof construction in New Zealand conditions
- considering the inclusion of an air barrier or air control layer at ceiling level (particularly for skillion roof construction) to restrict the movement of moist air into the roof spaces
- considering the inclusion of a vapour check layer at the ceiling level (which may also perform as an air barrier)
- ensuring the access and construction detailing allows the insulation to be effectively installed to ensure there are no gaps.

3.0.4 The NZ Metal Roofing Manufacturers *NZ Metal Roof and Wall Cladding Code of Practice* is currently being revised and the revised edition (Version 3), when published, will contain more recommendations and prescriptive requirements for roof ventilation.

4.0 ON-GOING RESEARCH

4.0.1 Much of the material in this bulletin is based on recent BRANZ research into this type of thermal bridging and condensation risk. This work is on-going together with BRANZ research on roof ventilation requirements, and future findings will be reported in BRANZ publications.

5.0 REFERENCES AND RESOURCES

NZ METAL ROOFING MANUFACTURERS INC.
NZ Metal Roof and Wall Cladding Code of Practice

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'Aggravated thermal bridging', Malcolm Cunningham, *Build* 127 (pages 52–53), December 2011/January 2012

Building Basics *Steel Framing*, April 2012.

Remediating condensation problems in large-cavity, steel-framed institutional roofs, Malcolm Cunningham and Luca Quaglia, BRANZ Study Report SR289, 2013.

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