BRANZ

ISSUE 695 BULLETIN

STRUCTURAL INSULATED PANELS

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- The range of structural insulated panels (SIPs) commercially available in New Zealand has expanded rapidly in recent years.
- Traditionally seen in cold stores and commercial applications, the use of insulated panels has grown to include more residential construction, including multi-unit homes.
- This bulletin looks at the design, installation and performance of structural insulated panels, with a few notes on non-structural insulated panels.

1 INTRODUCTION

1.0.1 Insulated panels are made up of a low-density insulating cellular core with skins either side. With structural insulated panels (SIPs), the skins are sheets of a rigid material and the panels are used for wall, roof and floor systems. They are usually manufactured with interlocking junctions and are sometimes referred to as sandwich panels. The term 'SIP' has been introduced to the industry relatively recently and mostly refers to structural panels with solid skins.

1.0.2 For non-structural panels, the outside material may be a foil, a laminated film or other non-rigid material and the panels are used mostly to provide thermal insulation. This bulletin focuses on SIPs, with information on non-structural insulated panels in section 7.

1.0.3 SIPs have been used in construction in Aotearoa New Zealand for many years, traditionally in the form of steel-skinned panels used in cold stores and other commercial applications such as long-span roofs. SIPs can also be used as enclosing elements for temperature-controlled spaces or food-processing areas and clean rooms in the biotechnology and pharmaceutical industries or electronics and data-processing industries, where a high level of hygiene and environmental control is required.

1.0.4 There has been a large growth of products and materials available in recent years, with the use of SIPs expanding to the floors, external walls, ceilings and roofs of housing and light commercial applications such as schools and offices. SIPs can be prefabricated and assembled quickly on site and could be used to increase construction speed.

1.0.5 SIPs are manufactured locally, imported or assembled here using overseas and/or local components. They are often proprietary products with their own design guides, engineering calculations and recommended construction methods. Manufacturers typically provide required accessories that may include proprietary fixing components, flashings, caps, mouldings, extrusions, cover strips and so on. Some manufacturers/suppliers require installation by approved contractors while others require training and installer certification for first-time installers.

1.0.6 SIPs are not currently included in Acceptable Solutions or Verification Methods, so Building Code compliance must be demonstrated with an Alternative Solution. Some SIP systems have CodeMark certification.

1.0.7 BRANZ research projects have looked at various aspects of SIP performance (see section 6). For study reports with more detail, see section 8.

1.0.8 It is always important to follow the requirements and recommendations of SIP manufacturers and suppliers to ensure adequate performance and durability are achieved. The systems are often accompanied with supporting information such as Appraisal or CodeMark certificates, technical and installation manuals and details along with specifications, selection and engineering design tables and design checklists. It is important that they are installed within their intended scope of testing or CodeMark or Appraisal certificates.

2 SIP MATERIALS

2.0.1 These are the most common skins in SIPs:

- Metal – lightweight steel or aluminium, which may be corrugated for strength and stiffness. Zinc/aluminium alloy factory-coated steel is a common metal facing.
- Engineered wood panels such as oriented strand board. Timber face layers appear to be the most common option for residential construction in New Zealand and overseas.
- Fibre-cement board.
- Magnesium oxide (MgO) board made with MgO cement, lightweight filler materials and glass fibre mesh reinforcing.

2.0.2 Core materials are most commonly:

- expanded polystyrene (EPS)
- extruded polystyrene (XPS)
- polyurethane (PUR)
- polyisocyanurate (PIR).

2.0.3 The skins are the primary load-carrying components. The insulating core provides structural support, distributing load between the face layers. By preventing buckling within the panel, the core contributes significantly to the bracing capacity of solid skin SIPs. The quality of the bond between the face and core is crucial in maintaining the overall integrity of the system. The core may be bonded to skins with adhesive (the usual process for polystyrene) or may self-adhere if it is injected between skins as a liquid (which is most common with PUR or PIR).

3 BUILDING WITH SIPS

3.0.1 SIPs are typically available as panels approximately 1.2 m wide and around 2.4–3.6 m long, with some suppliers offering 7.3 m panels. Metal skinned SIPs can be extremely long, the length effectively limited only by transport restrictions. Panel thickness varies depending on the face layers and core. Panels around 100–120 mm thick are common in metal skinned SIPs, while for solid skinned SIPs, the most common thicknesses are 115, 165, 215, 265 and 315 mm. Weight varies between products and thicknesses. OSB solid skinned SIPs vary from 16 kg/m^2 for a 115 mm thick panel to 21 kg/m^2 for a 315 mm panel. Magnesium solid skinned SIPs are heavier, ranging from 30–35 kg/m^2. Metal skinned SIPs vary from 11 kg/m^2 for a 50 mm panel to 15 kg/m^2 for a 250 mm panel.

3.0.2 SIPs can be used for structural and non-structural components. They can be supplied on pallets and installed one panel at a time on site or be prefabricated off site into wall, roof and floor sections/cassettes with window and door openings already in place.

3.0.3 SIPs are trucked to the site and are generally craned into position. Manufacturers will provide guidance on suitable ways of lifting panels. Some provide dedicated lifting points preinstalled or custom lifting equipment such as plates. Ideally, SIPs should be delivered to site just before installation. If they have

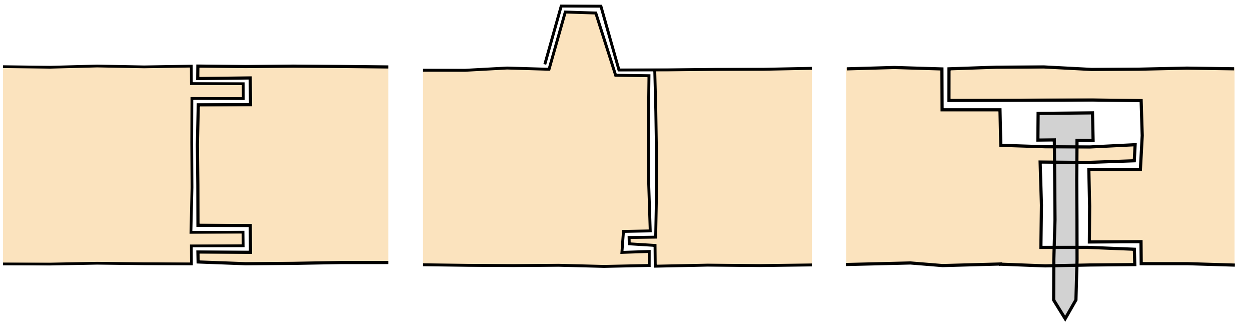


Figure 1. Examples of edge-jointing details in metal-faced panels.

to be stored on site, they should be stacked flat, off the ground or floor, in an area where they will be kept dry and open to air circulation.

3.0.4 The design should take account of the modular standardised dimensions of the products available or the panels should be prepared to the dimensions that are required before delivery to site. SIPs with MgO board skins can be more difficult to cut or shape on site than panels with other facing materials. Care needs to be taken with personal protective equipment, in particular using masks to avoid breathing in the dust.

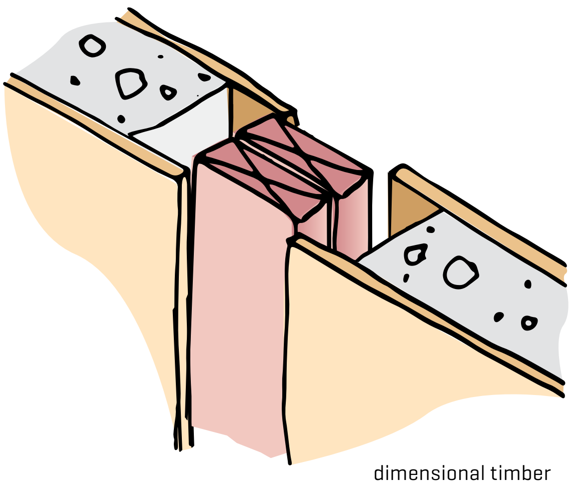
3.0.5 Joints between metal-clad insulated panels are usually formed as tongue and groove-type connections to allow adjoining panels to interlock (Figure 1). Some panels may have extended edge laps along one side of the exterior metal face of the panel to overlap the adjoining panel. Other types of panels may have edge laps formed from both the metal skin and a sculpted portion of the insulating core, which allows for secret or hidden fixings.

3.0.6 Panels with timber-based faces can be connected with timber or LVL splines (rectangular elements that fit into a groove), a foam block or mini-SIP splines and OSB splines (Figure 2).

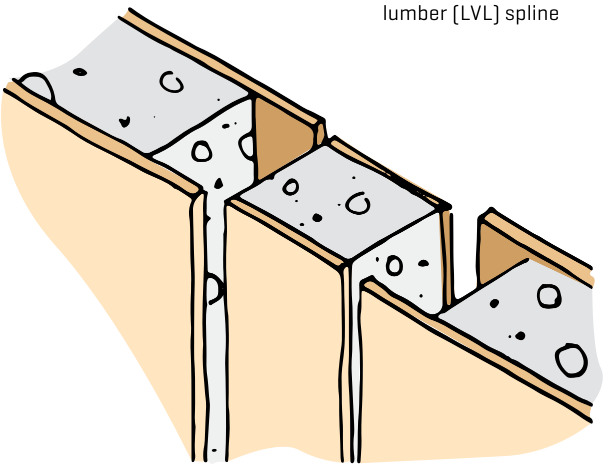
3.0.7 There are often solid timber or LVL members running along the top and bottom – the top and bottom plates (Figure 3). These plates allow SIP walls to be connected to the roof, ceiling or floor systems, which may or may not be a SIP themselves. The bottom plate can be used as the connection between wall panels and the foundation.

3.0.8 Embedded timber framing that includes solid lintels is used as supports for loadbearing elements, including at window and door openings.

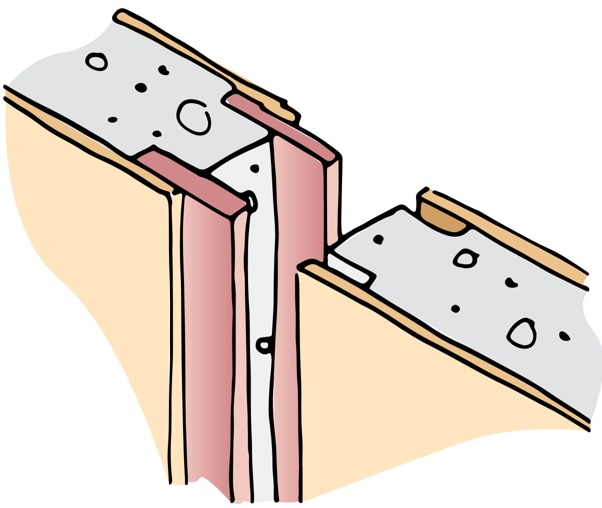
3.0.9 Some manufacturers recommend a cavity batten system for claddings. Some also recommend battens on the internal walls, providing a cavity for electrical wiring behind the plasterboard lining. With others, the face layer can be used as the interior wall surface, either left exposed, painted or plaster skimmed and painted.



dimensional timber
or laminated veneer
lumber (LVL) spline



foam block or mini-spline



OSB thin spline

Figure 2. Examples of connections between SIPs.

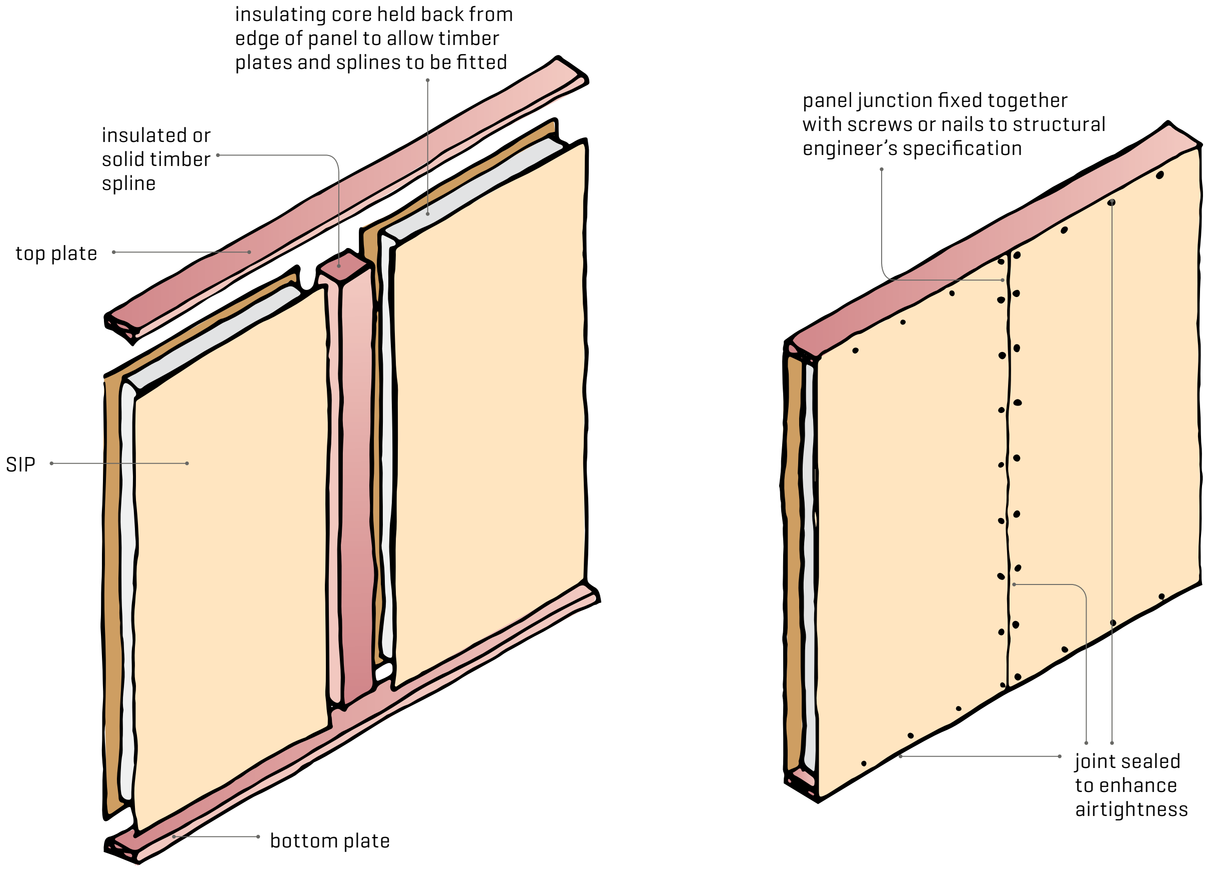


Figure 3. Typical timber-faced SIP wall assembly.

3.0.10 While some SIP systems run cables (or conduits) through a cavity between the SIP and the interior lining, others can have chases precut in the core. With EPS cores, either non-migratory cable must be used, or when using standard cable, a conduit or sheathing is required to prevent contact between cables and polystyrene.

3.0.11 Some manufacturers cut plumbing chases through the core, but many recommend that plumbing pipes are not run through the core.

3.0.12 Suppliers of SIPs with timber or wood-based components often require that these have a moisture content of not more than 18% when they are enclosed.

3.0.13 Penetrations through SIPs should be avoided wherever possible. Where necessary, check with the manufacturer's documents for guidance first and take extreme care to ensure that the penetration is weathertight from the outside and airtight from the inside.

3.0.14 Any part of the insulating core that is exposed must be protected from deterioration from environmental conditions, moisture, fire, physical damage by birds and vermin, vandalism or unintentional damage.

3.0.15 Specific design and construction requirements may apply to cold storage and other specialist facilities where vapour control, insulation continuity and other considerations are more critical.

4 THINGS TO CONSIDER WHEN USING SIPS

4.0.1 The main advantages of SIPs:

- Construction of homes with SIPs produces a high level of airtightness and higher thermal performance than can typically be achieved with 90 mm timber-framed exterior walls.
- Where SIPs are made into wall, floor, ceiling or roof sections off site and craned into place on site, construction can be faster than using conventional materials and methods. The benefits would be especially considerable for developers who are building multiple homes, with significantly reduced construction times possible and resulting savings in labour costs.
- Metal-clad insulated panels can self-support over longer spans than some conventional roof cladding and lining materials.

4.0.2 Other factors that require consideration:

- Because SIPs are different to conventional construction, it is necessary to have a complete understanding of the system, including the details, to ensure the work is done properly.
- SIPs often cost more than conventional building materials. This may be offset by lower labour costs if sitework takes less time and lower operating costs where the SIPs have high thermal performance.
- Not being covered by an Acceptable Solution may mean that demonstrating compliance with the Building Code

requires more work and outside consultants may need to be engaged to assist with this.
- Some SIPs such as those with a core of polymer-based foams have higher embodied carbon than some other construction materials. (Using bio-based materials instead can reduce this.)

5 BUILDING CODE COMPLIANCE

5.0.1 SIPs are not currently included in Acceptable Solutions or Verification Methods, so demonstrating Building Code compliance must use an Alternative Solution:
- For clause B1 *Structure* (and potentially clause B2 *Durability*), this requires an engineering assessment. Many SIP suppliers provide engineering calculations – project-specific engineering assessment may not be required where products are used within scope of the supplier's calculations.
- Compliance with clause C *Protection from fire* may require a fire engineer/consultant assessment.
- Compliance with clause E2 *External moisture* may require a weathertightness expert/consultant assessment.

5.0.2 Some SIP products have CodeMark or BRANZ Appraisal certificates.

5.1 B1 *STRUCTURE* AND B2 *DURABILITY*

5.1.1 Under clause B2, SIPs wall, roof or floor sections must have a minimum durability of 50 years where the application is structural. If their role is just as insulation in roof and/or walls, the durability requirement is 15 years provided failure would be detected and the system is not difficult to access or replace. 50-year durability is required if failure to comply with the Building Code would go undetected during both normal use and maintenance of the building (where the building elements are hidden from view with no provision for inspection access and failure would not be apparent until significant damage had occurred to other building elements).

5.1.2 The structural performance of SIP systems – the interaction between the outer skins and perimeter timber framing members – is similar to a timber-framed wall with plywood cladding. Residential dwellings built with timber-based SIPs typically follow NZS 3604:2011 *Timber-framed buildings* as well as they can. Bracing ratings for wall systems used with NZS 3604:2011 can only be determined using the P21 test method.

5.1.3 The findings of BRANZ research (see section 6) may be used as a consideration in design and to support demonstration of Building Code compliance.

5.2 C *PROTECTION FROM FIRE*

5.2.1 In all current fire compliance documents, there are specific reaction-to-fire requirements for building systems that include foamed plastic or combustible insulation. All SIPs that include these products (which is most of them) are subject to these requirements.

5.2.2 Acceptable Solution C/AS1 can be applied to low-rise stand-alone or multi-unit dwellings where each unit is independent of all other units (classified as risk group SH). C/AS1 requires that wall or ceiling systems that include foamed plastics or combustible insulation materials (which would apply to SIPs with a foamed plastic core) must achieve a Group Number of not more than 3. The foamed plastics must comply with the flame propagation criteria as specified in AS 1366 *Rigid cellular plastics sheets for thermal insulation* Parts 1–4 for the material being used. SIPs used in locations requiring a fire separation (such as inter-tenancy walls) or for external walls close to a boundary may also require a 30-minute fire resistance rating in SH buildings.

5.2.3 In dwellings, plasterboard encapsulation is often used as a means of achieving adequate fire resistance.

5.3 E2 *EXTERNAL MOISTURE*

5.3.1 This clause applies where panels are used as roof or wall claddings. Take particular care around effectively detailing and constructing with metal SIPs.

5.4 H1 *ENERGY EFFICIENCY*

5.4.1 The thermal performance of SIPs depends on component material and thickness. Manufacturers claim R-values of around R2.3–R2.8 for 100–115 mm thick panels with a standard EPS core to as much as R9.0 for panels over 300 mm wide with EPS that includes graphite.

5.4.2 The inherent airtightness of SIP buildings means that SIP manufacturers often recommend the installation of mechanical ventilation such as heat recovery ventilation.

6 BRANZ RESEARCH AROUND SIPS

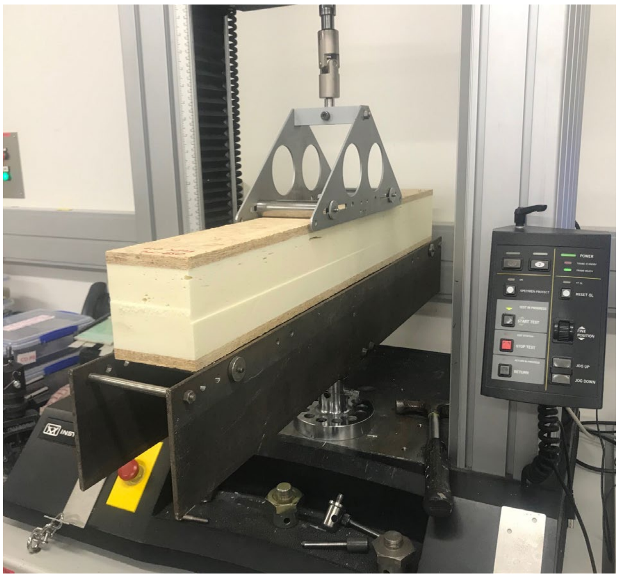
6.0.1 BRANZ has carried out a number of research projects around SIPs. One aimed to address the need for a robust, reliable test method to predict the durability performance of SIPs. Other work has involved tests of timber-faced SIP samples and also of components such as MgO boards. One of the objectives of this work is to support the development of compliance pathways for the use of SIPs in New Zealand.

6.1 TESTING OF TIMBER-BASED SIPS FOR STRUCTURAL INTEGRITY

6.1.1 One programme of tests involved ageing samples of commercially available timber-based SIPs in indoor and outdoor conditions (Study Report SR485). The tested samples included cores of polyurethane (PUR) and expanded polystyrene (EPS). Indoor climate chambers were used to accelerate the ageing process, exposing small-scale SIP samples to a range of temperature and humidity conditions.

6.1.2 Larger-scale SIP samples were exposed outdoors in both covered and uncovered conditions. SIPs are commonly protected from the elements by waterproof membranes and cladding systems in a completed building. However, during construction, they can be exposed before the building is made weathertight. The testing aimed to determine the effects of outdoor exposure on the structural integrity of the panels.

Small-scale SIP samples in indoor climate chambers for accelerated ageing.



A typical SIP sample in a four-point flexure test set-up.

6.1.3 A range of mechanical tests were used to measure performance changes as a result of ageing, including flexure, tensile and shear strength tests. The primary intent of the research was to consider what test methods would be suitable for evaluating SIPs and not to specifically evaluate whether they would be likely to achieve the required 50-year durability. However, it is useful to note that none of the aged specimens delaminated or failed at the interface between the core and the skins.

6.2 TESTING TIMBER-BASED SIPS UNDER SEISMIC LOADING

6.2.1 Other research (funded by EQC) examined how SIP structural bracing systems perform when subjected to seismic loads and how the performance aligns with New Zealand requirements for structural systems in buildings primarily for use with NZS 3604:2011 and using the P21 test method.

6.2.2 Additional tests were also carried out using bracing systems commonly used in New Zealand residential buildings (Table 1). The seismic performance of the timber-based SIPs was compared with the seismic performance of the other systems. This was done to assess the ability of SIPs to be used in conjunction with other bracing systems as well as to compare critical performance parameters between SIPs and more common bracing systems.

6.2.3 The seismic performance of the four non-proprietary SIP systems tested was considered good in general and was consistent with the expectations of commonly used bracing systems:

- The SIPs provided suitable energy dissipation, ductility, strength and stiffness for prescriptive and specific engineered wall bracing designs.
- Damage observed during cyclic loading was less for the SIPs than most of the more commonly used bracing systems.
- Energy dissipation and ductility were provided through nail bending, which is considered a reliable and effective method.
- There were no indications that panel delamination was an issue in relation to seismic performance on the unaged specimens that were tested.

6.2.4 Additional indicative testing was conducted where a specimen was tested, and further fastenings were included to show that, after seismic loading is applied

Table 1. Configurations used in seismic testing using the P21 test method.

Test configuration	Side 1	Side 2	Hold-downs
BPB1	Bracing plasterboard	NA	Yes
BPB2	Bracing plasterboard	Bracing plasterboard	Yes
PLY1	7 mm plywood	NA	Yes
PLYPB	7 mm plywood	Standard plasterboard	Yes
FC	6 mm fibre-cement	NA	Yes
SIP-PS-NHD	NA	NA	No
SIP-PU-NHD	NA	NA	No
SIP-PS-HD	NA	NA	Yes
SIP-PU-NHD	NA	NA	Yes

Notes: PS = polystyrene, NHD = no hold-downs, PU = polyurethane core, HD = hold-downs.

and removed, there is potential for refixing the SIPs to timber framing to provide further seismic resistance following an earthquake.

6.3 TESTING MAGNESIUM OXIDE BOARDS

6.3.1 Some SIP systems use MgO boards as the facing boards on either side of the insulation core. These boards are typically made up of MgO cement, lightweight filler materials and glass fibre mesh reinforcing. BRANZ tested four different MgO boards.

6.3.2 The findings from the BRANZ study (Study Report SR472) show that there is variability between how MgO boards from different suppliers perform under New Zealand conditions. Variability in performance is related to variability in composition.

6.3.3 Compositional analysis identified two subsets of board based on differences in chloride concentration. Some key results of the testing:

- Boards containing more chloride did not perform as well in the freeze-thaw or soak-dry tests. Their bending strength was reduced compared to the other boards.
- Boards with more chloride also tended to corrode their fasteners under the conditions tested. Stainless steel screws were not affected.
- None of the MgO boards performed well after soaking them in warm water. The fibre mesh delaminated and the cement was degraded in some boards.
- All four boards transmitted water vapour to some degree and absorbed water when soaked for just over 48 hours.

6.3.4 Testing also assessed performance of MgO boards compared to fibre-cement boards. Again, variability of MgO boards under some conditions was observed. In both soak-dry testing and freeze-thaw testing, the fibre-cement and two MgO boards retained around 90% strength, easily meeting the minimum acceptable performance requirement of 75% strength retention. Two MgO samples composed of an oxychloride cement only retained 40% strength.

6.3.5 After soaking for 24 hours, the MgO boards generally retained over 90% of their equilibrium condition strength while the fibre-cement boards retained around 70% strength. All boards easily met the minimum acceptable performance of 50% strength retention (from AS/NZS 2908.2:2000 *Cellulose cement products – Flat sheets*).

6.3.6 The results highlight the importance of:

- considering the likely in-service conditions when assessing the suitability of a given MgO board for a given application
- knowing the composition of the MgO board and being aware that different MgO board compositions can behave differently.

6.4 REVIEWING THE LITERATURE ON SIP FIRE PERFORMANCE

6.4.1 BRANZ investigated the fire performance of SIPs in residential buildings through a literature review (Study Report SR468). This found that the choice of materials for the core and face components and the choice of connections and assembly methods can influence the behaviour of the system in reaction to fire.

6.4.2 In some countries where SIPs have been used for several decades, guidance documents have been developed that suggest SIP buildings can meet fire safety regulatory requirements with the use of suitable lining materials where specific fire resistance ratings are specified. The inclusion of SIPs in overseas building codes further indicates confidence in their use in those jurisdictions. Much of the overseas information and documentation is relevant to New Zealand.

6.4.3 The Insulated Panel Council Australasia is a non-profit industry body. It has published a Code of Practice with a key objective to increase firefighter confidence when fighting fires in structures made of insulated sandwich panels. The Code does not mitigate any Building Code requirements and is not intended to be used in conjunction with a fire engineered alternative solution.

7 NON-STRUCTURAL INSULATED PANELS

7.0.1 Non-structural insulated panels are used as thermal insulation in roofs, walls and floors.

7.0.2 As with SIPs, there is a range of materials and specification options available. Commercially available products in New Zealand usually have cores made from extruded polystyrene (XPS) or polyisocyanurate (PIR) foam. The sheet material facing includes aluminium foil, fibreglass/aluminium, laminated film or glass fabric.

7.0.3 Some manufacturers of metal-faced SIPs recommend their products as cladding rather than providing a structural element to the building.

7.0.4 Sheet sizes are typically around 2.4 x 1.2 m, with thicknesses of 20–150 mm with an R-value up to around R7.0.

8 MORE INFORMATION

BRANZ

SR485 Assessing the long-term performance of structural insulated panels (SIPs) in New Zealand (2024)

SR472 Performance of magnesium oxide (MgO) boards in New Zealand (2022)

SR468 Fire performance of structural insulated panels (SIPs) for residential buildings (2022)

SR429 Testing an evaluation method for structural insulated panels (SIPs) (2019)

Webinar: Assessing SIPs in New Zealand

Research Now: Materials #2 Fire performance requirements for structural insulated panels (SIPs) in

New Zealand residential builds (2022)

Research Now: Materials #3 Performance of magnesium oxide boards in New Zealand conditions (2023)

Research Now: Materials #4 Comparing the performance of magnesium oxide and fibre-cement (2023)

NATURAL HAZARDS COMMISSION TOKA TŪ AKE (FORMERLY EQC)

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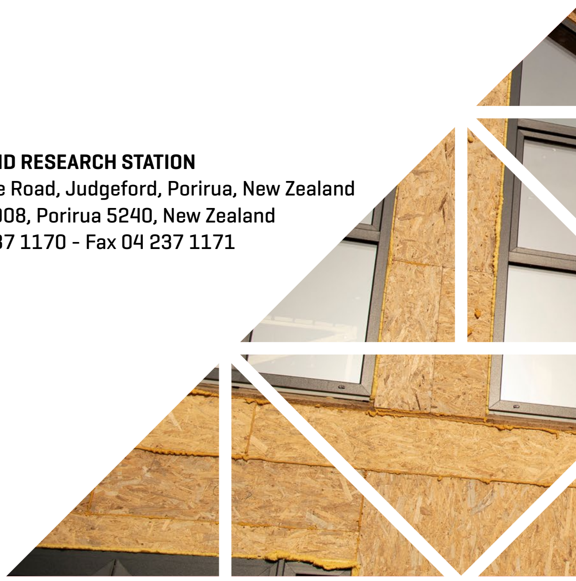

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