Study Report

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

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Preface

This is one of three reports produced as part of the research *project QR12001 Structural insulated panels (SIPs) – durability, seismic and fire performance*. Three project workstreams looked at how SIPs perform long term under New Zealand climate conditions and in the case of an earthquake or fire event. This focus of this report is the long-term performance of SIPs. Other reports are available that summarise research on SIPs subject to seismic loading and their performance in a fire event.

Acknowledgements

We would like to thank the SIP manufacturers who provided very valuable information that has enabled the experimental work described in this report. We also acknowledge the generosity of the building practitioners and homeowners who have welcomed us into their homes and buildings and helped build our knowledge of SIP systems in New Zealand.

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

BRANZ Study Report SR485

Authors

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Abstract

Structural insulated panels (SIPs) are sandwich panels made of two face layers and an insulating inner core. SIPs can be prefabricated and assembled quickly on site and could be used to increase construction speed and reduce overall building cost. Because of their high degree of prefabrication, they offer a potential solution to New Zealand's need for fast, quality and affordable construction. This research aimed to determine which method of ageing and mechanical testing offered the most practical measure of durability for SIPs having timber-based face layers to support the future assessment of these systems in New Zealand. The project also investigated the long-term performance of SIPs in a New Zealand context and the effects of ageing on the seismic performance of SIPs. Experimental testing included ageing SIPs samples in both accelerated ageing and exposed outdoor conditions. A range of mechanical tests were used to measure performance changes due to ageing, including flexure, tensile and shear strength tests. Testing also provided data on the effect of ageing on the seismic performance of SIPs by subjecting aged and unaged connection samples to fully reversed cyclic loading. Results are provided and discussed, along with recommendations made for appropriate methods for evaluating SIPs in the future potentially for compliance with the New Zealand Building Code.

Keywords

Structural insulated panels, SIPs, durability, accelerated ageing.

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Executive summary

New Zealand has an urgent need for quality housing that can be built quickly and affordably. Using structural insulated panels (SIPs) is one possible solution, particularly for residential applications. SIPs are sandwich panels made of two face layers and an insulating inner core. They can be prefabricated and assembled quickly on site for walls, floors and roofs and are one potential solution that could be used to increase construction speed and reduce overall building cost. While SIPs have been widely used overseas, less is known about their performance in a New Zealand context.

SIPs must comply with the relevant sections of the New Zealand Building Code, including clause B2 *Durability*, which sets a minimum durability requirement of 50 years for structural components. SIPs with timber-based panels as the outer face layers have been used in North America for residential construction for several decades. However, they have a relatively short history of use in New Zealand where they have been gaining popularity since around 2010.

The purpose of the research described in this report was to determine which method of ageing and mechanical testing offered the most practical measure of durability for SIPs, which aims to support the future assessment of these systems in New Zealand. As part of this, the research also investigated the long-term performance of SIPs in a New Zealand context and included investigating the effects of ageing on the seismic performance of SIPs.

Experimental work involved ageing SIPs samples in both indoor and outdoor conditions. Indoor climate chambers were used to accelerate the ageing process by exposing small-scale SIPs samples to a range of temperature and humidity conditions. These conditions were selected to replicate realistic in-service maximums that SIPs could be exposed to in New Zealand. Larger-scale SIPs samples were exposed outdoors in both covered and uncovered conditions to replicate their use in a wall cavity and if left exposed during the construction process.

A range of mechanical tests were used to measure performance changes as a result of ageing, including flexure, tensile and shear strength tests. Testing also provided data on the effect of ageing on the seismic performance of SIPs by subjecting aged and unaged connection samples to fully reversed cyclic loading. Results are provided and discussed, along with recommendations made for appropriate methods for evaluating SIPs in the future for compliance with the New Zealand Building Code.

1. Introduction

1.1 Background

Structural insulated panels (SIPs) are sandwich panels made of two face layers and an insulating inner core. SIPs can be prefabricated and assembled quickly on site and could be used to increase construction speed and reduce overall building cost. Because of their high degree of prefabrication, they offer a potential solution to New Zealand's need for fast, quality and affordable construction.

SIP face layers can be made from a range of materials, including boards based on timber or cement as well as metal sheets. Typical core materials are rigid polymer-based foams such as expanded polystyrene (EPS), polyurethane (PUR) or polyisocyanurate (PIR). However, mineral wool, wood-fibre insulation and other bio-based materials can also be used. As well as providing insulation, the core layer of a SIP provides structural stability to the panel by transferring load between the face layers. Therefore, the quality of the bond between the face and core layers is an important factor in maintaining the overall integrity of the system. Core and face layers can be bonded using an adhesive layer or by self-adhesion of the foam.

SIPs buildings need to comply with the relevant sections of the New Zealand Building Code, which includes clause B2 *Durability*. Clause B2 sets a minimum 50-year durability requirement for structural materials, which means evidence is required that they will perform adequately for at least 50 years. SIPs have been used for several decades in other parts of the world such as North America and Europe. However, their history of use in New Zealand is relatively short. As a result of being a relatively new building system in New Zealand, evidence of the long-term performance of SIPs in a local context is not readily available.

Timber-based SIPs for residential construction have seen increasing use in North America, the UK and Japan as an alternative to traditional construction systems. The Structural Insulated Panel Association was established in response to the growing SIPs market in North America and has been involved in developing documentation on the design, detailing and testing of SIP structures. These activities culminated in ANSI/APA PRS 610.1-2018 *Standard for performance-rated structural insulated panels in wall applications*, which provides requirements and test methods for qualification of timber-based SIPs for use within building standards such as the International Residential Code (ICC, 2021). While the inclusion of SIPs in these regulations suggests they will perform adequately, the provisions are applicable to US-based construction where there are no specific durability requirements corresponding to the 50-year requirement in New Zealand.

Durability provisions in ANSI/APA PRS 610.1-2018 are for the evaluation of foamed-in-place core materials only and do not include methods to assess the SIP assembly as a system including both face and core layers. ISO 22452:2011 *Timber structures – Structural insulated panel walls – Test methods* provides a means for testing of SIP walls that contain at least one timber-based face layer and a core that has sufficient shear strength to cause the face layers to act together structurally. ISO 22452:2011 includes an accelerated ageing method in accordance with ASTM D7446-09(2017) *Standard specification for structural insulated panel (SIP) adhesives for laminating oriented strand board (OSB) to rigid cellular polystyrene thermal insulation core* *materials* and requires that SIPs are subjected to both tensile and shear testing after exposure to the ageing regime.

Previous SIPs research and documentation has focused on SIPs with metal face layers, which have been commonly used internationally and in New Zealand in commercial cold store applications. Methods for assessing the durability of these types of SIPs are included in EN 14509:2013 *Self-supporting double skin metal faced insulating panels – Factory made products – Specifications* and ECCS/CIB Report 257 (ECCS/CIB Joint Committee, 2000), and these methods have been used to test and assess metal-skinned SIPs for use in New Zealand.

Previous BRANZ research sought to develop a method for assessing the long-term performance of SIPs in New Zealand and tested the method on a selection of commercially available and laboratory-made SIPs (Walsh et al., 2019).

This current research aimed to build on the previous work and support the development of an assessment method for SIPs. The work sought to determine an effective method of accelerated ageing and mechanical testing to use for the evaluation of SIPs. An initial review of the SIPs market in New Zealand indicated that, for residential construction, SIPs with timber face layers were most common. Subsequent experimental work involved ageing of timber-based SIPs using commercially available SIPs that were chosen to be representative of those available in New Zealand. As well as supporting the assessment pathway for SIPs, a secondary aim of the project has been to create generic information on the performance of these systems for evaluating SIPs used in New Zealand.

2. Materials and test methods

2.1 Materials

A range of SIP types are available in New Zealand that use different materials as face layers and core materials. This work was focused on timber-based SIPs and aimed to consider the system in a generic way rather than investigating proprietary products. Full-size SIP panels with face layers of engineered wood panels and cores made from either polyurethane (PUR) or expanded polystyrene (EPS) were sourced from two commercial suppliers (Table 1).

Table 1. SIP specimen details.

Specimen ID	Core material	Face material
SIP-1	Engineered wood panel face layers, EPS core	Imported engineered timber panels
SIP-2	Engineered wood panel face layers, PUR core	New Zealand engineered timber panels
SIP-3	Engineered wood panel face layers, PUR core	Imported engineered timber panels

Panels with the EPS core included adhesive to bond the core to the face layers. Panels with the PUR core used the adhesive properties of the foam to bond the core to the face layers. Small-scale samples were cut from full-size (1.2 x 2.4 m) panels in dimensions specified for each mechanical test. All samples had a nominal thickness of 115 mm, where the core was approximately 90 mm thick and each SIP face was approximately 12.5 mm thick. As described in the following sections, different SIP types were conditioned differently and not all types were exposed to the same conditions. This was done based on the objectives of assessing the different test methods and not the specific types of SIPs.

2.2 Accelerated ageing

Accelerated ageing was conducted in accordance with well-accepted methods described in BRANZ Evaluation Method EM4 (BRANZ, 2005) and ECCS/CIB Report 257 (ECCS/CIB Joint Committee, 2000), which are detailed in Table 2.

Table 2. Description of accelerated ageing conditions

Source	Details
EM4 (BRANZ, 2005)	1 cycle consists of: • 6 hours at 30°C, 95% RH • 6 hours at 60°C, 75% RH • 6 hours at 10°C, 50% RH • 6 hours at -10°C, low RH Specimens aged for 30 cycles.
Ageing cycle C1 (ECCS/CIB Joint Committee, 2000)	1 cycle consists of: • 5 days at +70°C (±5°C), 90% (±10%) RH • 1 day at -20°C (±5°C) • 1 day at +90°C (±5°C), RH <15% Specimens aged for 1, 5 or 10 cycles.

These methods aim to expose samples to temperature and relative humidity (RH) maximums that allow for a better understanding of how the products will perform over long periods of time while acknowledging that building products will not necessarily be exposed to such extreme conditions in service.

Small-scale samples were prepared in dimensions required for the mechanical tests described in subsequent sections and were placed into the laboratory climate chambers for different ageing periods (Figure 1) using SIP-1 specimens.

Figure 1. Small-scale SIPs in indoor climate chambers for accelerated ageing.

2.3 Outdoor exposure

In a completed SIPs building, SIPs are protected from the elements by waterproof membranes and cladding systems. However, during construction, SIPs can be exposed for periods of time before the building is made weathertight. The aim of the construction moisture effect testing was to determine the effects of outdoor exposure on the structural integrity of the panels and to compare this to the accelerated aged specimens for a better understanding of how laboratory ageing reflects real-time ageing for SIPs.

At the BRANZ site in Judgeford, New Zealand, one set of large-scale SIP-3 panels (600 x 1200 mm) were fully exposed to the elements in vertical positions as would occur in a wall. This was conducted for 3 years between 2018 and 2021. Another set of large-scale SIP-2 panels (600 x 600 mm) were placed outside but protected from direct exposure to weather in simulated wall cavity enclosures (**Error! Reference source not found.**) in the same location for the same 3-year period as the fully exposed samples. Samples from each environmental condition were visually inspected periodically during exposure. At the end of 3 years, 100 x 100 mm samples were cut from the panels and tensile tested.

Figure 2. SIPs samples in covered outdoor exposure conditions: (left) exterior of the wall cavity enclosures and (right) showing the interior of one enclosure.

2.4 Mechanical properties

Four different small-scale mechanical tests were used to determine which tests were suitable for assessing the performance of commercial SIPs products and to investigate the effect of ageing on different mechanical properties. The tests are shown in **Error! Reference source not found.**. For each different SIP and test method combination, there was also a set of unaged control specimens tested to provide baseline properties for evaluating the impacts of ageing. For most test configurations, sets of 10 replicate specimens were tested. Some test specimen replicates had to be excluded due to testing anomalies, with no configuration having fewer than six replicates tested. All replicate data within configurations was averaged and statistically analysed for comparisons with control groups. Because a main objective of the research was to evaluate the differences among test methods, not all SIP types were used with all test methods. SIP-1 specimens were aged and tested using Tensile-100, Tensile-300, Flexure and Shear methods, while SIP-2 and SIP-3 specimens were only evaluated after ageing using the Tensile-100 method.

Table 3. Mechanical property tests used to evaluate the SIP specimens

Test ID	Specimen ID	Specimen dimensions (mm)	Test method
Tensile-100	SIP-1, SIP-2, SIP-3	100 x 100	EN 14509:2013 A.1 Cross-panel tensile test
Tensile-300	SIP-1	300 x 300	
Flexure	SIP-1	100 x 900	Based on ASTM C393/C93M-20 four-point bend method
Shear	SIP-1	100 x 100	Based on BS EN 12090:2013

After accelerated ageing, samples were weighed immediately and then at intervals until the mass had stabilised under constant climate conditions (21°C ±2°C and 65% ±5% RH) before mechanical property testing. Constant mass was assumed when the change in mass over 24 hours was less than 1% of the total mass. All tests were conducted using an Instron 5699 Universal testing machine with Instron Bluehill software control.

2.4.1.1 Tensile strength

Tensile test samples with nominal surface dimensions of 100 x 100 mm (Tensile-100) and 300 x 300 mm (Tensile-300) were tensile tested in accordance with EN 14509:2013 A.1 Cross-panel tensile test. A 10 kN load cell and crosshead speed of 2 mm/minute (1.7% strain rate) were used. Steel dollies used for loading were thick steel plates approximately 24 x 100 x 100 mm with a threaded hole in the centre for attaching to testing apparatus as shown in Figure 3.

Figure 3. Typical Tensile-100 test specimen with dollies attached.

Dollies were fixed to both outer faces of each specimen and attached to the fixed base and moving crosshead of the Instron test frame for testing. Tests were conducted using different methods of fixing the dollies to the SIP skins, and after some trials were conducted, it was deemed most effective to use an epoxy adhesive when using the Tensile-100 method and screws through the dollies into the SIP skins when using the Tensile-300 method.

Tensile force was applied to the specimens through the dollies due to the moving of the crosshead away from the fixed base at the specified loading rate.

2.4.1.2 Flexural strength

Flexure testing of samples was performed using a four-point bend test based on the method described in ASTM C393/C393M-20.

Samples had nominal dimensions of 100 x 900 mm and were placed on a support span of 800 mm (Figure 4). Load was applied at the one-third points of the support span along the length of the beams at a loading rate of 15 mm/minute.

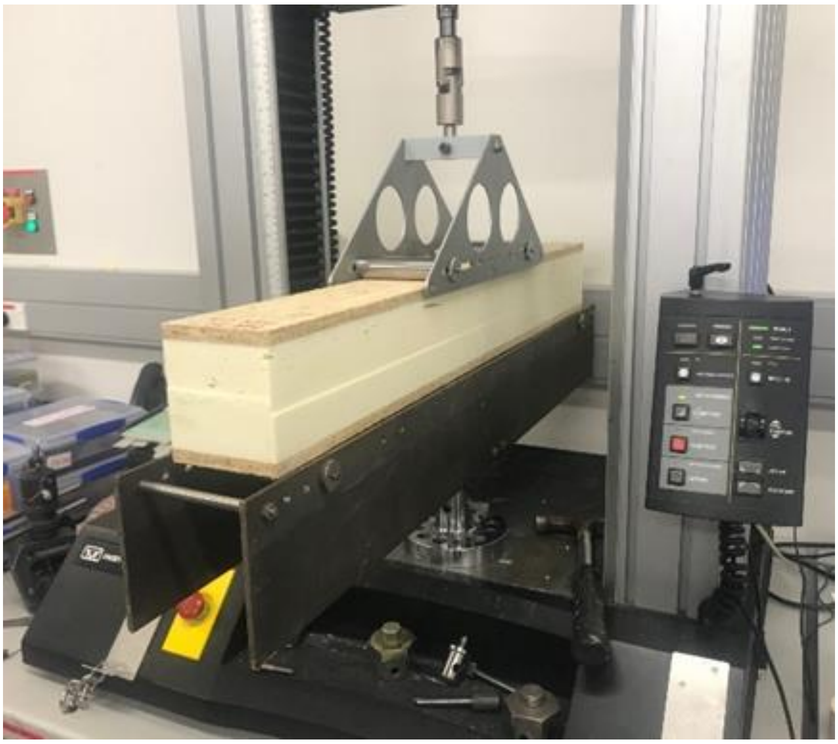

Figure 4. Typical SIP sample in four-point bend test rig.

The apparent modulus of elasticity, *E*, was calculated for each specimen using the following equation from AS/NZS 4063.1:2010 *Characterization of structural timber – Test methods*:

$$E = \frac{23}{108}\left(\frac{L}{d}\right)^3\left(\frac{\Delta F}{\Delta e}\right)\frac{1}{b}$$

where:

L = test span (mm)

d = specimen depth (mm)

b = specimen thickness (mm)

$\frac{\Delta F}{\Delta e}$ = linear elastic slope of the load-displacement graph between 10% and 40% of maximum load (kN/mm).

This apparent *E* was calculated for comparison purposes and was not intended to provide design values for SIPs in bending.

2.4.1.3 Shear strength

A single plane shear test was conducted for pairs of SIP specimens according to BS EN 12090:2013 as referenced in a study by Yang et al. (2011). Samples had a nominal area of 80 x 100 mm with one of the outer skins including a 20 mm projection as shown in Figure 5. The extended timber section of each specimen was clamped by the jaws of the machine crosshead with the remaining cross-section of the panel being restrained from movement. The intention was to assess the shear capacity at the interface between the core and the outer skin. The maximum load (kN) applied in each test was used as a proxy for direct shear strength.

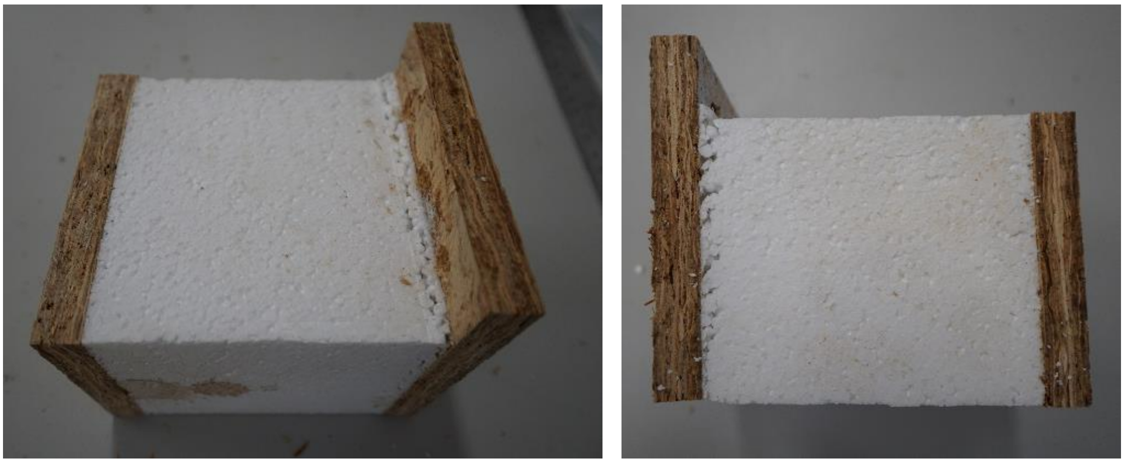

Figure 5. Typical SIP shear test specimens.

2.5 Effects of ageing on seismic resistance

The main mechanism by which SIP buildings resist earthquake loads is usually between the fastenings used to secure the panels to the surrounding structural elements and amongst the panels themselves. SIPs having outer skins using timber-based panels are frequently nailed through the skins to dimensional timber members that serve as top and bottom plates or studs. These timber members are placed in the rebates provided during the manufacture of the SIPs as seen in Figure 6. Nails are driven through the SIP skins and into the timber, which provides a ductile connection that can be used to resist seismic loading. To assess the effects of ageing on these connections, cyclic testing was conducted on unaged and aged specimens as described below.

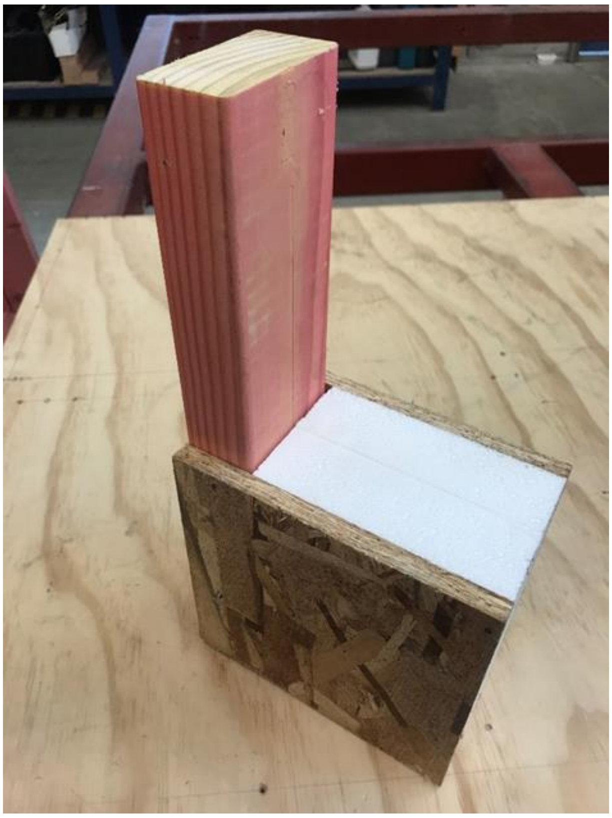

Figure 6. Example of SIP with rebate for connection to timber framing.

Ten cyclic specimens were prepared from both SIP types by cutting 200 x 200 mm samples from the edge of full-scale panels where foam had been rebated on one side by 45 mm. A 90 x 45 mm SG8 radiata pine timber member was inserted into the rebate and connected to the face layers using two 50 x 2.8 mm flathead galvanised nails, one on each side of the SIP (Figure 6). Samples were subjected to fully reversed cyclic loading in accordance with the earthquake testing method in BRANZ Evaluation Method 1 EM1 (BRANZ 1999) based on a set of three static loading tests using the same type of specimen that provided reference displacements on unaged specimens for these tests.

The test set-up for the static and cyclic tests is shown in Figure 7 where the SIP segment was secured to the test frame base and displacements applied to the vertical timber member. The aged tests were assembled prior to ageing to capture any potential degradation of the full connection and not just the SIPs.

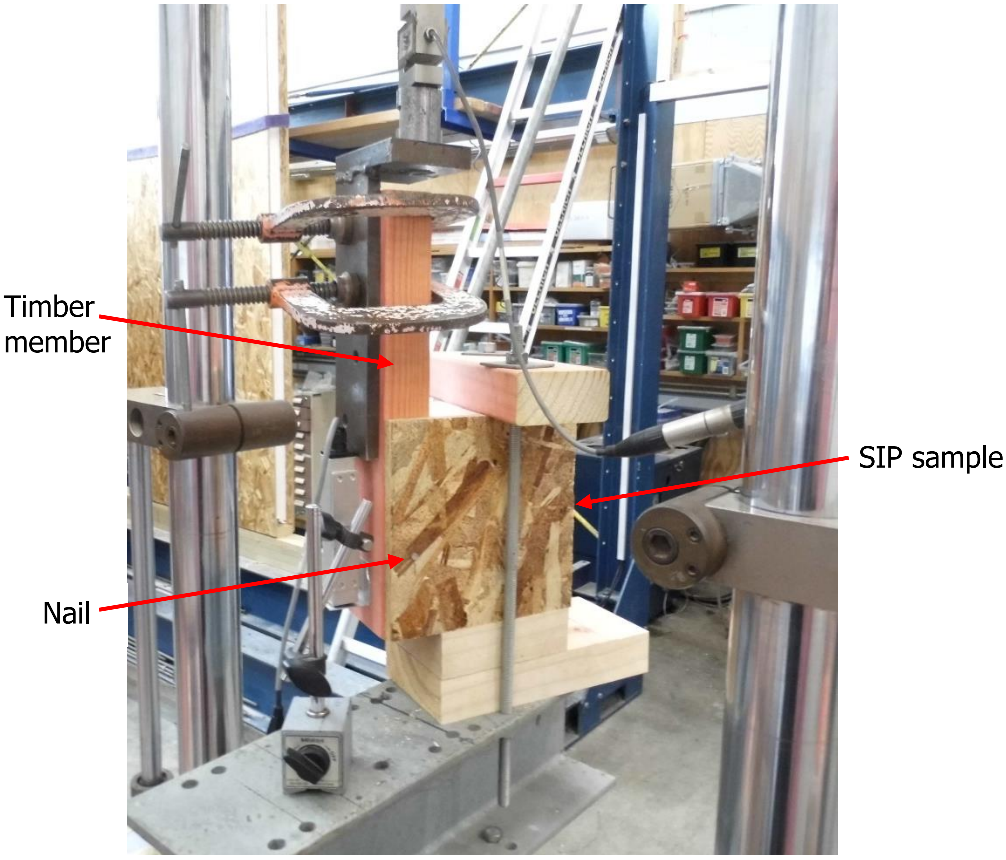

Figure 7. Seismic connection test sample in test rig.

3. Results and discussion

3.1 Accelerated ageing and mechanical properties

SIP samples were subjected to the accelerated ageing conditions C1 and EM4, which are well-accepted methods for assessing durability of materials in New Zealand and have a long history of use. C1 is described in ECCS/CIB Report 257 (ECCS/CIB Joint Committee, 2000) for the assessment of metal-skinned SIPs and involves a greater temperature range than the EM4 method. Both methods involve subjecting samples to repeated cycles of fluctuating temperature and relative humidity extremes and measuring any subsequent changes in mechanical properties when compared with unaged control specimens. SIP-1 samples were exposed to EM4 and C1 ageing conditions for 30 and 35 days (5 cycles) respectively and then mechanically tested to determine the effects of different ageing conditions on a range of mechanical properties. The average strength retentions as a percentage of the control strength for each specimen under different ageing conditions and properties are shown in Figure 8.

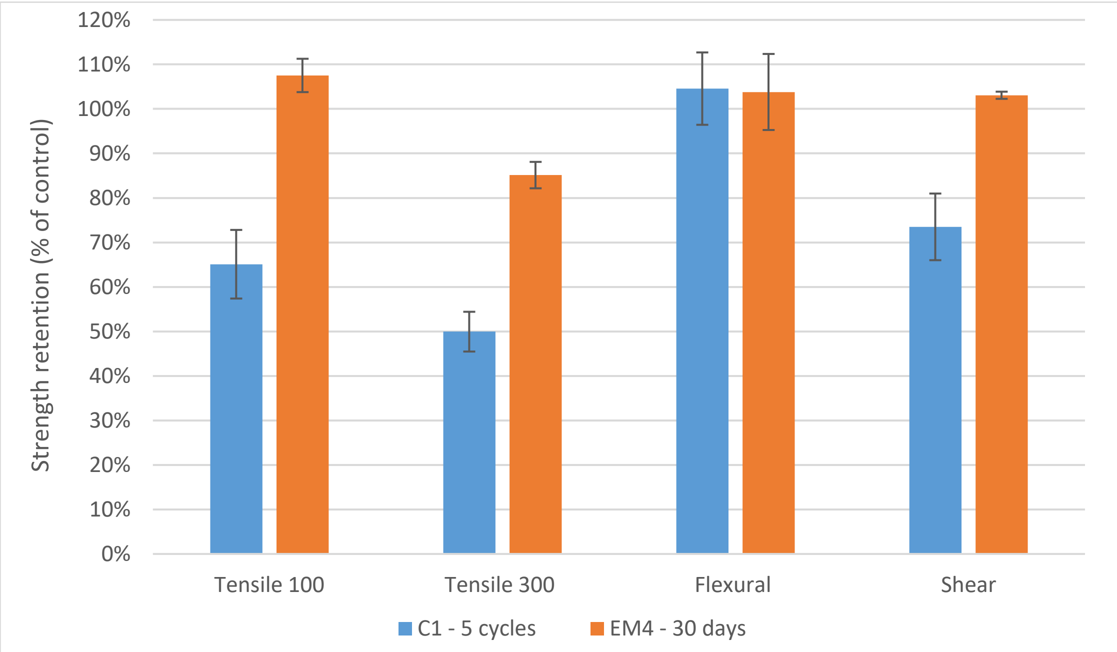

Figure 8. Retention of tensile, flexure and shear strength following ageing under C1 and EM4 conditions.

In general, samples aged under C1 conditions exhibited greater strength loss than samples aged under EM4 conditions. The exception to this was following flexure testing where strength, represented by apparent modulus of elasticity (MOE), was slightly increased after ageing in both conditions. Given the use of more extreme temperatures in the C1 method, a greater effect on strength is not unexpected. C1 conditions were designed for evaluating metal-skinned SIPs and may be excessive for SIPs with timber-based face layers, which are unlikely to experience the same temperature extremes as those with metal face layers. Samples retained at least 80% of original strength in all tests following ageing under EM4 conditions, which suggests they would maintain these mechanical properties adequately following ageing. C1 conditions could provide an indication of performance under more aggressive temperature and humidity conditions and could be used to assess SIPs where this situation is likely in application or where a more detailed picture of durability may be useful.

Tensile strength of Tensile-100 and Tensile-300 samples was affected differently by the different ageing conditions. Strength was reduced to 65% (Tensile-100) and 50% (Tensile-300) following C1 ageing. After EM4 ageing, tensile strength of the Tensile-100 samples was increased to 108% and Tensile-300 samples reduced to 85%. It was not immediately clear why the Tensile-100 specimens increased in strength following ageing. It is possible that, because the EM4 ageing regime was not overly impactful on the test specimens, the typical variation inherent in timber-based materials resulted in what appeared to be improved performance following ageing.

Following flexure testing, the apparent MOE was calculated for each specimen assuming the SIP specimen would behave as a uniform, solid timber beam. While it is recognised that SIPs are a composite structure, the intention was to enable a relatively simple comparison of flexure performance before and after ageing. Therefore, results should be considered as indicative and should not be used as design values. MOE was seen to increase slightly as a result of ageing under C1 and EM4 conditions.

The practicality of conducting each test method to assess commercial SIPs products was considered to determine whether the methods would provide an economical means of assessment for SIPs manufacturers and suppliers. Key factors included the time and complexity involved in sample preparation and testing. The dimensions of flexure test specimens were determined based on the thickness of the panel – a wall SIP of nominal thickness would require a length of at least 800 mm. Therefore, the number of flexure samples that could be tested simultaneously was constrained by space in the environmental chamber.

3.2 Outdoor exposure

Outdoor aged samples included those that had been covered in a wall-cavity enclosure (SIP-2) and those left completely exposed (SIP-3). Changes in tensile strength with ageing of outdoor aged samples were compared with those from samples that had been accelerated aged under the C1 ageing regime for 1, 5 and 10 cycles (Figure 9).

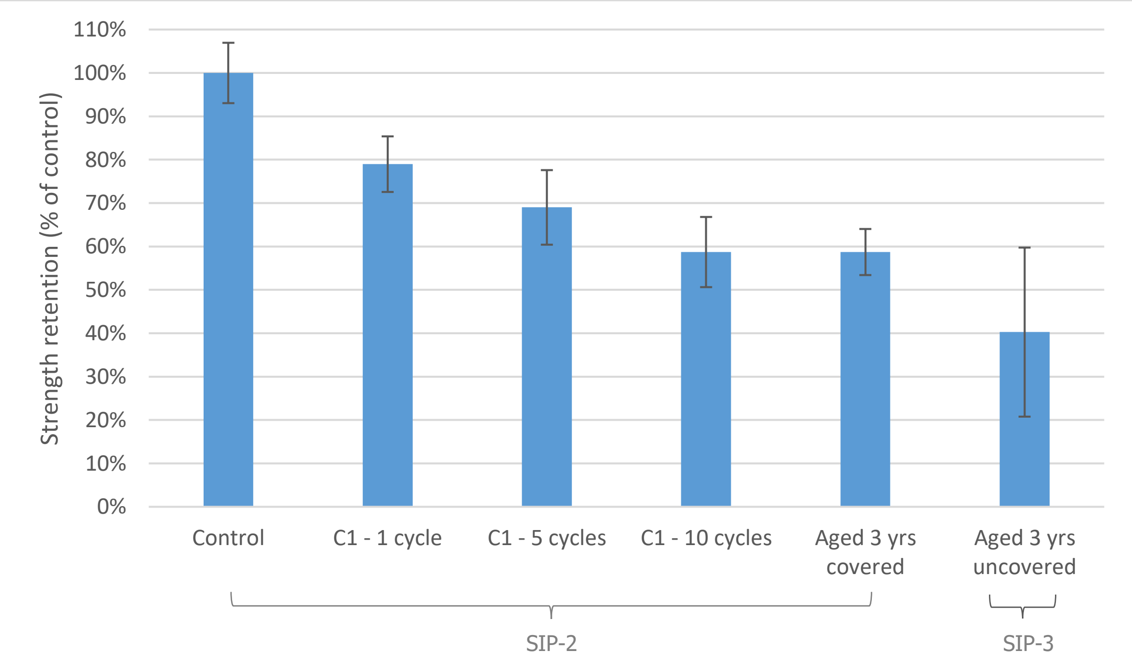

Figure 9. Retention of tensile strength following ageing under laboratory and outdoor conditions. (Note: All comparisons were made with SIP-2 control results.)

The results showed a decline in strength retention with increased ageing. However, the changes in strength between each subsequent ageing period were within acceptable limits of the test criteria provided in the testing standards as shown in Table 4 for SIP-2 specimens. While criteria for the performance of specimens subjected to C1 ageing for 10 cycles is provided in the test standard, it is only required to be considered if specimens have failed the criteria for 1 and 5 cycles of C1 ageing.

Table 4. Comparison of ageing on SIP-2 tensile test results including criteria from the C1 testing standard.

Ageing time (R[weeks])	Tensile strength (kPa)	Comments
R_0	227.95	
R_1	180.02	
R_5	157.31	
R_{10}	133.84	
Acceptance criteria	**Pass/fail**	
$R_1 \geq 0.6*R_0$	Pass	$180.02 \geq 136.77$
$R_5 \geq 0.4*R_0$	Pass	$157.31 \geq 91.18$
$(R_1-R_5) \leq (R_0-R_1)$	Pass	$22.71 \leq 47.93$

Results show that tensile strength was gradually reduced with increasing accelerated ageing duration. The change in strength following 10 cycles of C1 was comparable to samples that had been aged outdoors and covered for 3 years. Uncovered, outdoor aged samples had an average strength retention of 40% and a large standard deviation compared to data for other ageing conditions, as denoted by the error bars in Figure 9.

All uncovered, outdoor aged samples were taken from the bottom edge of a large-scale panel that had taken up water from the concrete base. Timber-face layers had been visibly affected by water uptake, with timber strands having delaminated. All samples failed in the timber face-layer except one that failed in the core. No samples failed at the bond line between core and face layers.

3.3 Effects on seismic resistance properties

Control and aged SIP connection specimens were subjected to fully reversed cyclic loading to investigate the effect of ageing on typical SIP connections with timber members. Samples were tested in accordance with BRANZ EM1 (BRANZ, 1999), which is referenced in NZS 3604:2011 *Timber-framed buildings* and is usually thought of as being specific to buildings constructed in accordance with the standard. Because residential dwellings built with timber-based SIPs typically follow the principles of NZS 3604:2011, it was considered reasonable to use EM1 to evaluate the connections of these systems. It is important to note that the connection test is intended to give an indication of seismic performance and does not produce bracing ratings for which testing of full-scale panels would be required.

In Figure 10 and Figure 11, the averaged 1st cycle peaks provide an indication of the ultimate strength of samples at that displacement level. The averaged 4th cycle peaks show the effect of repeat loading and are intended to represent the type of loading that SIPs could experience during a seismic event. Both peaks were included in this analysis to investigate the effect of ageing on performance under repeat loading.

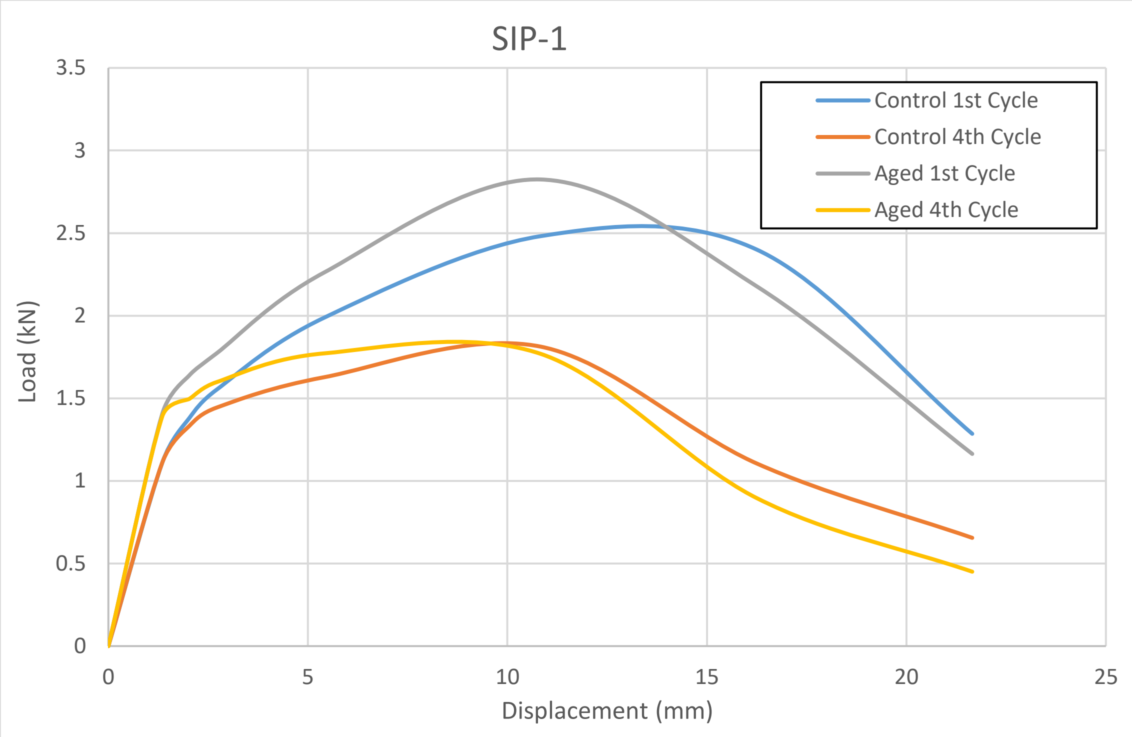

Figure 10. Load/displacement curves for connections of control and aged SIP-1 specimens.

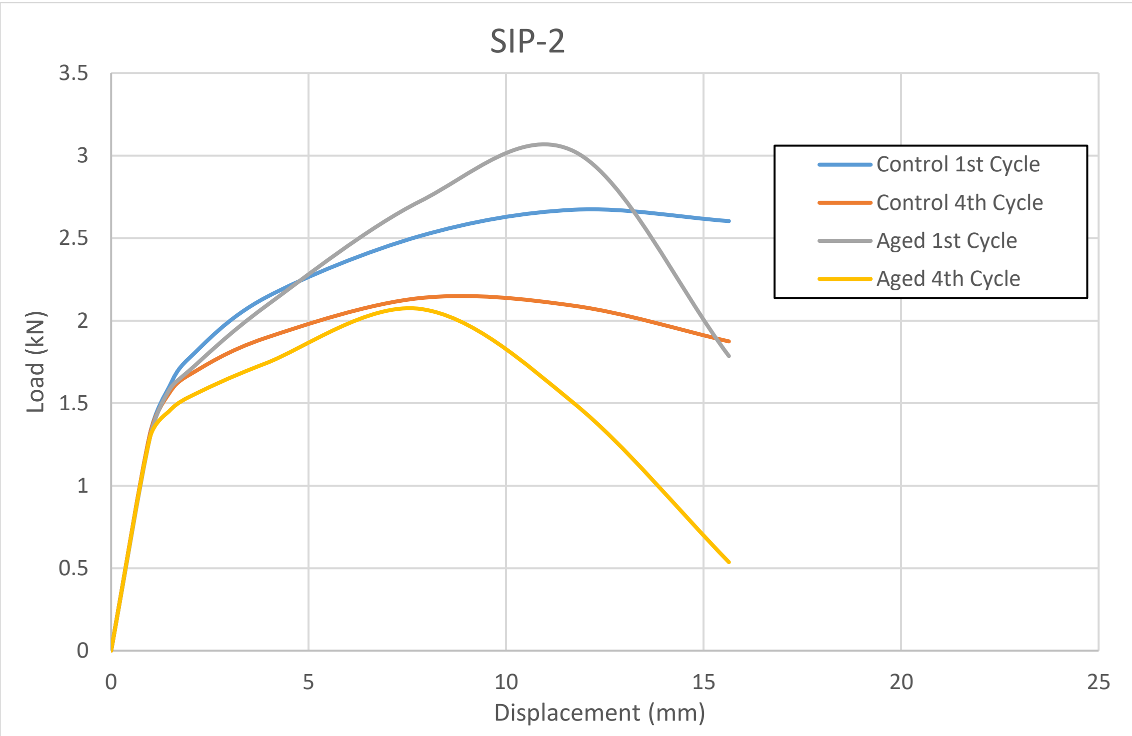

Figure 11. Load/displacement curves for connections of control and aged SIP-2 specimens.

For SIP-1, aged samples showed greater resistance than unaged samples for at least the beginning of both the 1st and 4th cycles. In both cycles, aged samples showed a greater drop in resistance after the peak than unaged samples. It is possible that ageing under C1 conditions leads to an increase in the stiffness of the timber-face layer, which would explain the high initial strength shown by aged samples, and greater drop-off post-peak load. However, testing of more samples would be required to make conclusions more confidently.

Aged SIP-2 specimens showed slightly lower initial resistance. However, similarly to SIP-1, they showed significant drops in resistance following peak loading for both the 1st and 4th cycles. The drops in resistance for aged samples were more significant than for the unaged samples. In general, for both SIP types, the variability of the tested samples was greater than the statistical difference between aged and control samples. Overall, the results were inconclusive with respect to the effect of ageing on repeat loading resistance. The difference in maximum displacement levels for the two types of SIPs was due to the results of monotonic testing used to establish displacement levels for cyclic testing as described in section 2.5.

4. Conclusions

This research project aimed to determine which method of ageing and mechanical testing offered the most practical measure of durability for SIPs having timber-based face layers to support the future assessment of these systems in New Zealand. Experimental work was conducted that aimed at simulating the range of conditions that SIPs may be exposed to during in-service conditions and thereby understand how SIPs are affected by long-term ageing under New Zealand climatic conditions. Mechanical testing on unaged control specimens and aged specimens provided data on how mechanical properties were impacted through different ageing procedures. The effect of ageing on SIP connections within light timber-framed buildings to simulate their seismic performance following ageing was also investigated.

This work supports previous BRANZ research on SIPs that developed an evaluation method that included test procedures for evaluating the component parts of SIPs made from different materials as well as the complete panel assembly (Walsh et al., 2019). The evaluation method indicated that panels should be aged using the accelerated ageing regimes given in section 5.1.4 of ECCS/CIB Report 257 (C1) and/or the cycle detailed in BRANZ Evaluation Method EM4 and then tensile tested. The focus of this current research was investigating whether any alternative mechanical testing methods may be appropriate for the evaluation of SIPs given the types of loading SIPs would be exposed to in service. A range of mechanical testing methods were tried and assessed in terms of the feasibility of using them as methods of assessment for commercial SIPs. Findings suggested that tensile testing of samples having cross-sectional dimensions of 100 x 100 mm provided adequate indications of the effects of ageing on the durability of samples. It was also considered an economical method because of the number of samples that can be accelerated aged and tested in a given time. In particular, tensile testing highlighted potential changes in the performance of the bond between face and core layers of the SIP samples before and after ageing. Results of seismic testing of aged samples were inconclusive due to the variability of the results.

This study has provided quantitative and qualitative data on the effects of ageing on the performance of SIPs using engineered wood panels as the outer skins, considering different natural and accelerated ageing conditions across a range of mechanical and seismic properties. Test methods have been investigated and the recommended evaluation methods include using the C1 and EM4 test accelerated ageing regimes with 100 x 100 mm tensile test specimens for comparisons with control specimens.

The intent of this research was not to specifically evaluate the ability of SIPs with timber-based outer faces to achieve the 50-year durability requirement of the New Zealand Building Code for structural building elements but rather to consider what test methods would be suitable for evaluating these systems. Based on the criteria provided in the C1 testing standard for 1 and 5 cycles, the panels tested would have “passed” but it is not clear how this would directly relate to a number of years these systems would provide adequate service. It was observed that none of the aged specimens delaminated or failed at the interface between the core and the skins, and therefore it is suggested that information on the durability of the core and face materials can be considered when evaluating the potential life span of these systems. Most SIP applications include cavities and provide sufficient protection from the weather such that the panels will not be exposed to outdoor conditions for extended periods of time, but it is always important to follow recommendations from manufacturers and suppliers of SIPs to ensure adequate durability and performance.

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Standards

ANSI/APA PRS 610.1-2018 *Standard for performance-rated structural insulated panels in wall applications*.

AS/NZS 4063.1:2010 *Characterization of structural timber – Test methods*.

ASTM C393/C393M-20 *Standard test method for core shear properties of sandwich constructions by beam flexure.*

ASTM D7446-09(2017) *Standard specification for structural insulated panel (SIP) adhesives for laminating oriented strand board (OSB) to rigid cellular polystyrene thermal insulation core materials.*

BS EN 12090:2013 *Thermal insulating products for building applications. Determination of shear behaviour.*

EN 14509:2013 *Self-supporting double skin metal faced insulating panels – Factory made products – Specifications*.

ISO 22452:2011 *Timber structures – Structural insulated panel walls – Test methods*.

NZS 3604:2011 *Timber-framed buildings.*