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Assessing retrofitted external wall insulation techniques

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Abstract

A series of laboratory experiments were performed to investigate retrofit options for timber-framed walls with direct-fixed weatherboard cladding without underlay. These included four different approaches to evaluate water management of walls, following retrofitting insulation: (1) without cavity and no underlay, (2) without cavity and with underlay, (3) with 20 mm separation between insulation and cladding with no underlay and (4) with cavity via drainage plane mesh and underlay. For each option, multiple installation methods for underlay were tested. The performance of the water transfer was investigated using an experimental method based on New Zealand Building Code E2/VM1 with 2.4 x 2.4 m wall specimens. Results of the experiments were assessed using the thermographic image during both testing and disassembly process in the same way as Cox-Smith and Overton (2020).

Results showed that, regardless of the insulation material, without additional mitigation measures, water was transferred from the back of the cladding into the insulation and/or onto the framing. Using inserts of wall underlay before insulation installation (pans) of either kraft paper or synthetic underlay based on recommendations within NZS 4246:2016 *Energy efficiency – Installing bulk thermal insulation in residential buildings* reduced the water transfer, but even with very careful installation, this method was not able to consistently prevent water getting onto the framing or insulation. Creating a separation between the back of the cladding and the insulation as suggested by NZS 4246:2016 limits the thickness of insulation that can be installed or equivalently reduces the thermal resistance (R-value) of insulation and ultimately was not able to prevent water transfer onto the framing. The more effective method was found in these tests to be the use of drainage plane mesh in conjunction with the underlay. Results of this study apply to the retrofitting of external walls with direct-fixed claddings without wall underlay.

Highlights

- The pan method (paper or synthetic) resulted in water getting onto the framing.
- Maintaining a 20 mm separation between the back of the cladding and the insulation was not able to prevent water transfer to the insulation and framing and limited the thickness of insulation installed but was observed to clearly perform

better than the pan method. Maintaining a separation continues to be recommended over the pan method.

- Using drainage plane mesh in conjunction with an underlay was the most reliable method and allows for thicker insulation to be used in retrofitting compared with maintaining a 20 mm separation.

Keywords

Retrofit insulation, timber-framed wall, water management, direct-fixed weatherboard cladding, underlay, thermal imaging.

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1. Introduction

It is estimated that there are over 600,000 houses in New Zealand that lack wall insulation, based on the number of those constructed prior to insulation requirements for new houses being introduced into the Building Code in 1978. Retrofitting wall insulation to these existing uninsulated houses is essential to improving the New Zealand housing stock, providing warmer, drier and healthier environments for the occupants and reducing energy use and environmental impact of housing. BRANZ research together with our National Housing Assessment and House Condition Surveys over the last three decades have consistently shown that a significant proportion of our housing stock is uninsulated and also colder than we would like (Buckett et al., 2011; Clark et al., 2000, 2005; Goodyear et al., 2021; White, 2020; White & Jones, 2017).

The World Health Organization recommends that indoor temperatures should be above 18°C to protect occupants from the harmful health effects of a cold living environment (WHO, 2018). However, our housing conditions are often found to be below the WHO temperature recommendations. More recent analysis of the Pilot Housing Survey and General Social Survey data (Jones & White, 2023a, 2023b) and research carried out by He Kāinga Oranga at the University of Otago have also shown that these poor housing conditions and lower temperatures are having a large effect on the health and wellbeing of occupants.

Although there is a strong desire to provide warmer, drier and healthier environments within our homes, there are a limited number of retrofit wall insulation solutions available for homeowners, particularly for cases that lack building underlay. If we are to improve the performance of our housing stock and make contributions to achieving our 2050 zero-carbon targets, we need a better understanding of these insulation issues as well as the ability to develop solutions to enable us to improve indoor environments and optimise building envelope performance.

Underlays have been a required component in roofing systems and wall systems for decades. Underlays are presumed to perform a number of functions – as a barrier to prevent rain penetration, condensation protection and solar-driven moisture prevention (Cunningham et al., 1995). Current New Zealand Building Code Acceptable Solution E2/AS1 clause 9.4.3 states that a building underlay, as required, shall be installed behind all direct-fixed timber weatherboards or cavity battens for timber weatherboards installed over a drained cavity. In addition, E2/AS1 clause 9.5 states that fibre-cement weatherboard claddings shall be either direct fixed to framing over a wall underlay or fixed over a drained cavity as required.

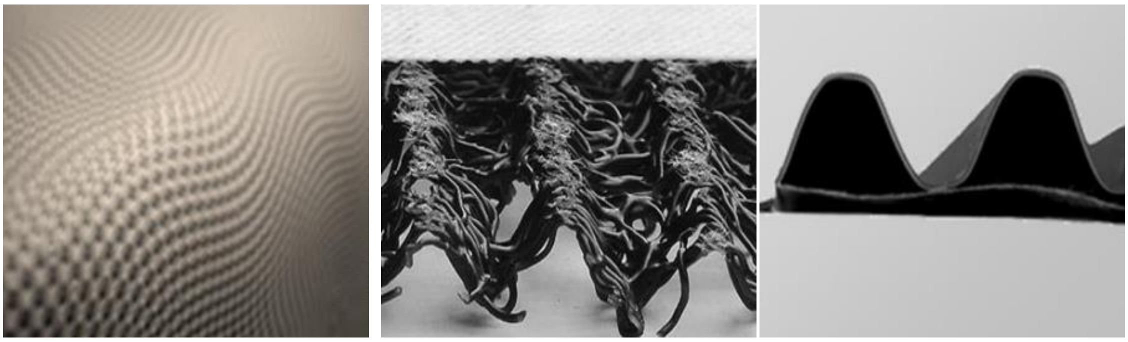
However, many older New Zealand houses without wall insulation also do not have an underlay between the framing and cladding. Although there are recommendations to address the lack of wall underlay, there are still some potential risks or issues with some of the options, and the use of the retrofit insulation is often not optimised. It is critical to investigate how to carry out retrofit insulation to these houses, as adding insulation to the existing exterior wall with direct-fixed cladding and without underlay may potentially change the path of any rainwater leaks and may reduce the drying potential of the wall. There is a need to develop retrofit options that enable the insulation to remain dry and not compromise the drying capability of the framing in the event of cladding leaks.

The retrofitting of wall insulation requires options and solutions for both linings-on and linings-off retrofits. The research described in this report is one of a series of projects aimed at acquiring a better understanding of these insulation issues and providing solutions and guidance around the retrofitting of wall insulation to our older building stock. Some of BRANZ's previous work that has been carried out on the retrofitting of wall insulation has focused on options for insulating walls with underlays. These studies have included options for bulk insulation and involving the removal of wall linings as well as research into blown-in insulation products where the wall linings do not have to be removed. More details on the results and findings of the blown-in insulation work can be found in Cox-Smith and Overton (2020). The series of retrofit insulation projects aim to develop a better understanding of the solutions and the risks for claddings both with and without wall underlay and to provide better guidance frameworks and techniques for the industry.

Some guidance on retrofitting of insulation is provided in NZS 4246:2016 *Energy efficiency – Installing bulk thermal insulation in residential buildings*. The standard describes two key methods for the retrofitting of insulation in exterior walls of existing houses with direct-fixed claddings and without a wall underlay. NZS 4246:2016 clause 2.2.7 states: "Insulation shall not be installed in ways that allow moisture to transfer through or to accumulate in wall, roof, or floor cavities in sufficient quantities to cause condensation, fungal growth, or damage to framing, claddings, or linings." Following this clause, the current options for preventing moisture transfer and accumulation when adding insulation are to either install a pan of underlay before adding the insulation or to provide a separation between the back of the cladding and the insulation. Previous work by BRANZ investigated these techniques as well as the extent to which drainage and ventilation drying can remove water that has leaked through claddings on walls with direct-fixed claddings (Bassett et al., 2015). Some questions were raised around the effectiveness of these systems, which prompted further research. The research outlined within this report aims to extend the work on providing guidance and is solely focused on the installation of insulation to timber-framed walls with direct-fixed cladding.

This research has revisited the use of a 20 mm separation and the use of pans of wall underlay and has also been extended to include the use of drainage plane mesh or drainage mats as a means of keeping a drainage path open and protecting the installed insulation. Drainage plane meshes are water-repellent materials that are located behind the cladding in such a way as to drain water that passes through the cladding back out to the exterior. They comprise a surface next to an air gap that allows water to flow and exist in a variety of forms, ranging from relatively solid plastic channels to entanglements of polymer fibres and also textured building wraps (Figure 1). BRANZ has previously studied how these materials perform and their potential applicability to addressing some weathertightness issues. More information can be found in Overton (2010). The polymer fibre-based drainage plane mesh-type materials were used within this presented study (Figure 1b).

An advantage of the 7–8 mm thick drainage plane mesh is that it could replace the 20 mm separation and potentially allow 12 mm thicker insulation to be installed without compromising the management of water that gets past the cladding. NZS 4246:2016 clause 5.4.1 states that a gap between insulation and the back of the cladding ensures the drainage path is maintained and the insulation does not come into contact with the cladding. This drainage path also provides a ventilation path to enhance drying.



(a) Relatively solid plastic channel

(b) Entanglement of polymer fibres

(c) Textured building wrap

Figure 1. Typical drainage plane materials.

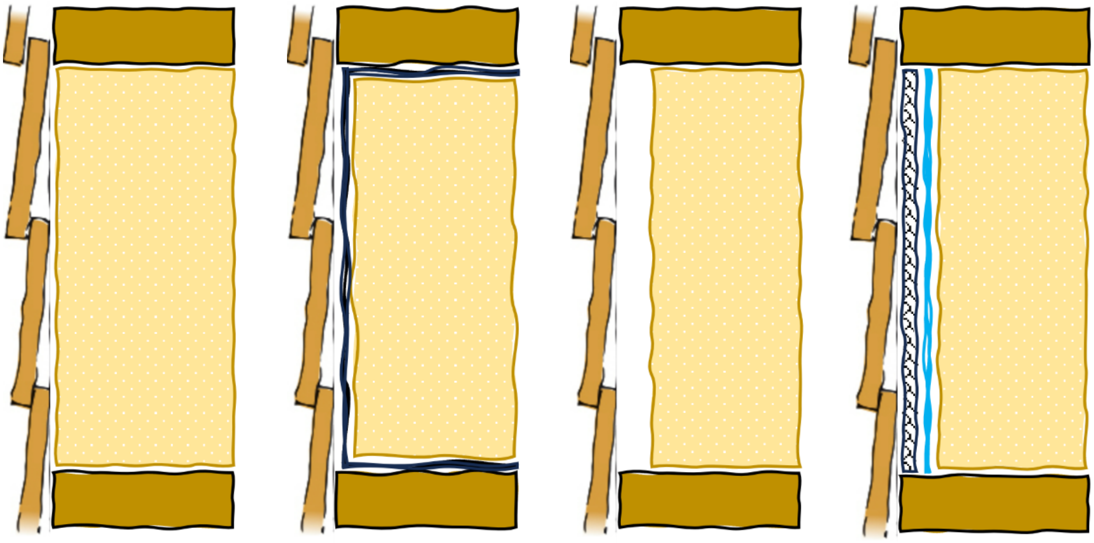
The key research question to be answered by this study is whether the combination of retrofitted drainage plane mesh and underlay could avoid the undesirable water transport to the framing and/or insulation when retrofitting insulation to timber-framed walls with direct-fixed weatherboard cladding and without underlay.

2. Material and experimental set-up

This study aims to assess some techniques for retrofitting insulation in exterior walls without wall underlay with direct-fixed claddings using infrared thermography. Of primary concern was the need for any solutions to prevent any damage by water ingress. The experiments were all conducted at the BRANZ laboratory. The method used in this study is based on the test method developed for the blown-in insulation tests but with some variations. More details around the test method, which is based on the New Zealand Building Code Verification Method E2/VM1, can be found in Cox-Smith and Overton (2020).

A series of experiments were performed with bevel-back weatherboard (BBW) clad panels to investigate the wall retrofit techniques:

- No mitigation before insulation installation (Figure 2a).
- NZS 4246:2016 method – retrofitting inserts of wall underlay before insulation installation (pan method) (Figure 2b).
- NZS 4246:2016 method – maintaining a 20 mm separation between insulation and back of the cladding (Figure 2c).
- Alternative method – replacing the 20 mm separation between the insulation and back of cladding with drainage plane mesh and retrofitted underlay (Figure 2d).



(a) No mitigation – BBW, insulation

(b) NZS 4246:2016 method – BBW, underlay, insulation (pan method)

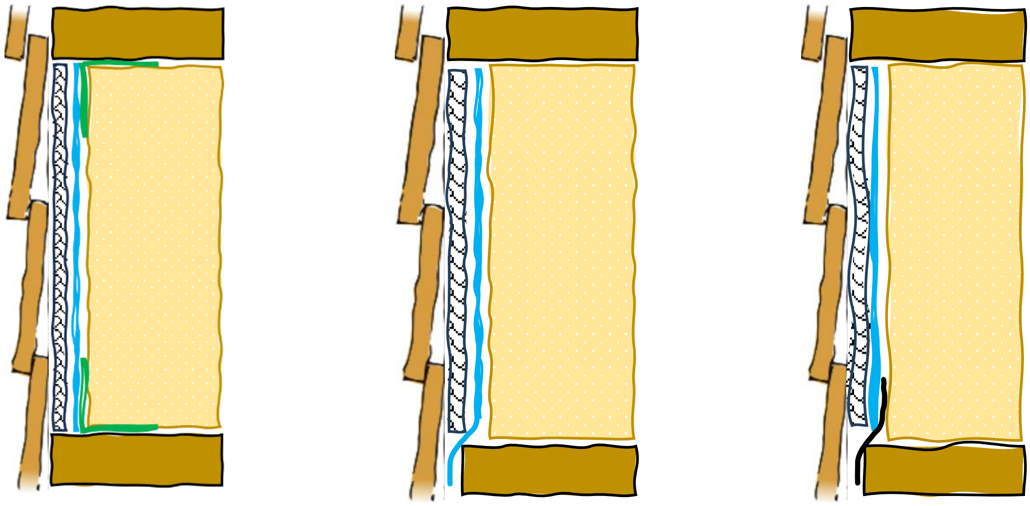
(c) NZS 4246:2016 method – BBW, 20 mm separation, insulation

(d) Alternative method – BBW, drainage plane mesh, underlay, insulation

Figure 2. Investigated techniques for retrofitting insulation in exterior walls without wall underlay with direct-fixed claddings.

The alternative method (Figure 3) was also tested with:

- taping the underlay to framing (Figure 3a)
- tucking the bottom edge of underlay between the framing and the back of cladding (Figure 3b)
- tucking a strip of building paper or underlay into dwangs and the bottom plate (Figure 3c)



(a) Underlay sections taped around top and bottom edges of the framing

(b) Lower edge of underlay sections tucked into dwangs, diagonal bracing and bottom plate; no edge taping used and only lower edge tucked; other edges were a neat fit

(c) Lower edge underlay tuck replaced with an approximately 100 mm high strip of kraft paper

Figure 3. Additional tested alternative methods.

A description of the wall specimens, materials used, experiment set-up, wall configurations and test procedure is given below.

2.1 Wall specimens

Wall specimens (approximately 2.4 x 2.4 m) were constructed using timber framing and direct-fixed bevel-back pre-primed weatherboard cladding by tradespeople following standard trade practices in New Zealand. The framing timber used was 100 mm (90 + 10 mm) dressed framing or 100 mm rough-sawn framing. Figure 4 shows the layout of the test specimen and water flow from leak points within the cladding.

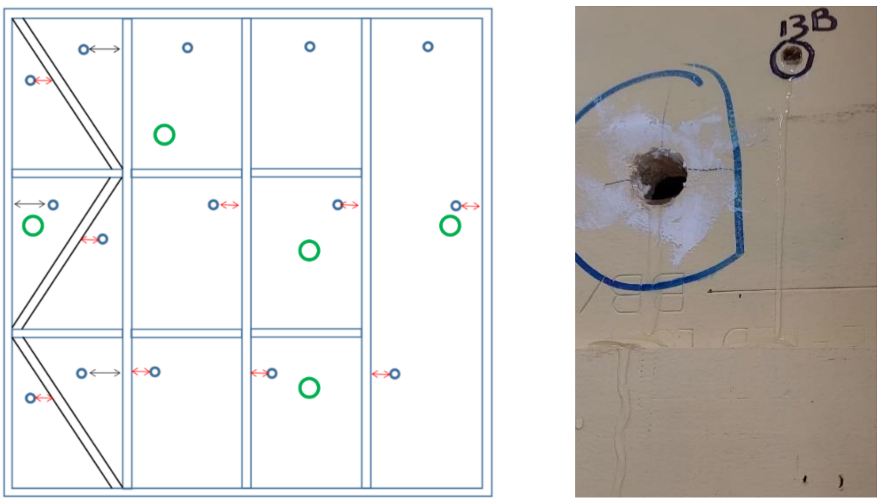


Figure 4. Left: Wall framing layout for test specimen (not to scale); Right: Water flow from leak points within the cladding (back of cladding shown).

Three diagonal bracing timbers were included within the wall specimen and the wall was divided into 12 small cavities and one tall cavity. There were 15 small leak points (6 mm diameter holes) and five large leak points (18 mm diameter holes) on the weatherboard cladding. The leak points were made on the cladding to simulate what might happen if there were face leaks through the cladding. The series of five 18 mm leak points were not included in the test method developed for the blown-in insulation tests. They were introduced for this present study to create a significantly higher water load through the cladding. This higher water load was used for testing the retrofitted insulation with cavity via drainage plane mesh and underlay (Figure 2c and Figure 3). In this study, except where indicated, the water load was created by the 15 small leak points (6 mm diameter holes).

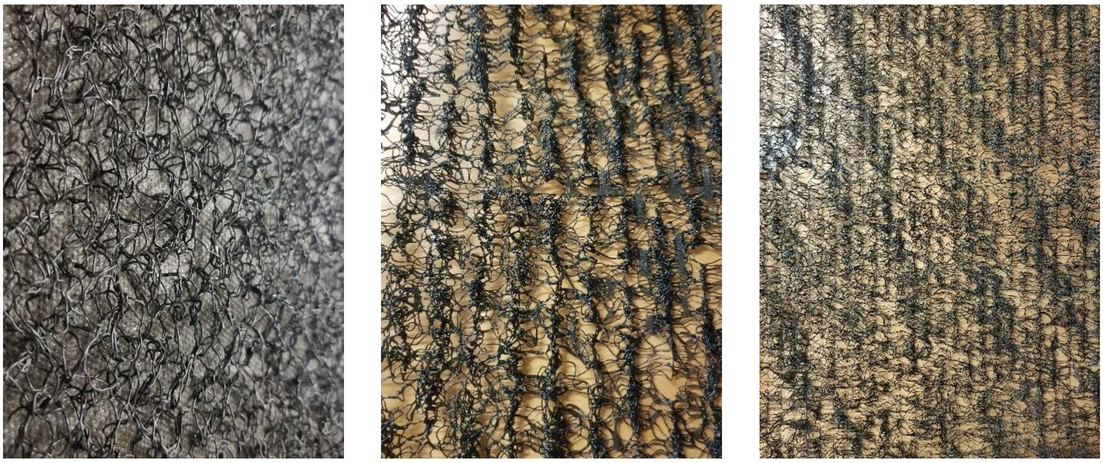
Given the linings-off retrofit process provides the opportunity to thoroughly inspect the framing, wall cavity and back of the cladding and the ability to repair any detected faults, imposed leaks are intended to only represent either undetected leak points or what might infiltrate through the weatherboard overlaps during severe weather events.

2.2 Materials

All materials/products used in this study were donated by manufacturers and suppliers. Brands and logos have been excluded wherever it was practical to do so.

Drainage plane mesh

Three drainage plane meshes from different sources were used in the tests (Figure 5). All were made from polypropylene plastic.



(a) 8 mm, integrated underlay (b) 7 mm, separate underlay (c) 7 mm, separate underlay

Figure 5. Drainage plane mesh used in this study.

Underlay

Four types of underlay were tested – lightweight (200 g/m²) kraft paper, heavyweight (430 g/m²) kraft paper, woven synthetic underlay and non-woven synthetic underlay.

Insulation material

A range of different brands of polyester and glass wool were used. The thickness of the insulation material used and the thermal resistance (R-value) are shown in Table 1.

Tape

Three types of market available tape were used:

- Tape 1 – all-weather flashing tape.
- Tape 2 – multipurpose adhesive flashing tape.
- Tape 3 – high-performance, sticky, acrylic sealing tape.

Table 1. Experimental wall configurations.

Name	Wall	Cavity type	Cavity depth (mm)	Underlay	Underlay installation	Insulation, thickness (mm) and R-value
No insulation	Base case	No	n/a	No	n/a	No
Insulation without underlay or cavity	A	No	n/a	No	n/a	Polyester, 90, R2.5
	B	No	n/a	No	n/a	Polyester, 90, R2.5
	C	No	n/a	No	n/a	Glass wool, 90, R2.8
Insulation without cavity and with retrofitted underlay	D*	No	n/a	Lightweight kraft paper	Pan method	Glass wool, 90, R2.8
	E	No	n/a	Heavyweight kraft paper	Pan method	Glass wool, 90, R2.8
	F	No	n/a	Synthetic underlay	Pan method	Glass wool, 90, R2.8
	G	No	n/a	Non-woven synthetic underlay	Pan method	Glass wool, 90, R2.8
Insulation with 20 mm separation and without underlay	H	Separation	20	No	n/a	Glass wool, 70, R2.4
Insulation with cavity via drainage plane mesh and underlay (fit the cavity)	I#	Drainage plane mesh	7	Lightweight kraft paper	Fit the cavity	Glass wool, 90, R2.8
	J	Drainage plane mesh	8	Synthetic underlay	Fit the cavity	Glass wool, 90, R2.8
	K	Drainage plane mesh	7	Synthetic underlay	Fit the cavity	Glass wool, 90, R2.8
Insulation with cavity via drainage plane mesh and underlay, taping underlay to framing or tucking strip of underlay behind framing	L+	Drainage plane mesh	7	Synthetic underlay	Fit the cavity, strip of underlay tucked into dwangs, diagonal bracing and bottom plates	Glass wool, 90, R2.8
	M+	Drainage plane mesh	7	Lightweight kraft paper	Fit the cavity, strip of kraft paper tucked into bottom plates	Glass wool, 90, R2.8
	N+	Drainage plane mesh	7	Synthetic underlay	Fit the cavity, taping the top and bottom edge of the underlay to framing	Glass wool, 90, R2.8
	O+	Drainage plane mesh	7	Synthetic underlay	Fit the cavity, tuck strip of kraft paper behind bottom plate or tape underlay to the bottom plate	Glass wool, 90, R2.8

* see Figure 2a for details; # see Figure 2c for details; + see Figure 3 or additional images in the appendix for the details.

A series of tests were performed using a selection of insulation materials both with and without the underlay and drainage plane mesh. Different ways to install the underlay were also evaluated to compare the water management ability of the walls. Table 1 shows the main experimental wall configurations that have been tested. Where the system worked reasonably well, retests were carried out to establish repeatability. All tests are indicative and not specific products.

During the test, the mesh was attached to the cladding with staples. For the kraft paper, the paper pan was folded with care with overlapped corners and stapled in each corner. The synthetic underlay was stapled against the framing.

2.3 Test procedure and analysis

To evaluate the water management ability of the wall systems, the test methodology recently developed by BRANZ to evaluate the water transfer risk with retrofitted blown-in wall insulation is used in this study. The method is based on NZBC E2/VM1 and that described in BRANZ Study Report SR436 (Cox-Smith & Overton, 2020) with the following variations:

- Test was conducted for 1 hour.
- A series of five 18 mm leak points were introduced to create a significant water load through the cladding for evaluating water management of retrofitting insulation with cavity via drainage plane mesh and underlay. Except where it is indicated, the water load was created by the 15 small leak points (6 mm diameter holes).

Thermal imaging method was used to characterise the water management performance of the wall configuration. Analysis of the performance was visual only, including thermal imaging during both testing and disassembly. No attempt was made to quantitatively measure the amount of water transferred to the insulation or framing. Previous attempts at gravimetric measurements were inconsistent and have not been used in this study.

3. Results and discussion

Four types of underlay (lightweight kraft paper, heavyweight kraft paper, woven synthetic underlay, non-woven synthetic underlay), three brands of glass wool and two brands of polyester insulation were tested. Overall, there was no significant difference in the outcome between the insulation materials or brand of product. In cases where water was transferred to the framing or insulation, it happened regardless of the insulation product. The results are presented below as thermograms with corresponding photographs.

Testing the base case (direct fixed with empty cavities) found that some fine spray/mist caused carry-over onto the back of the lining adjacent to the hole.

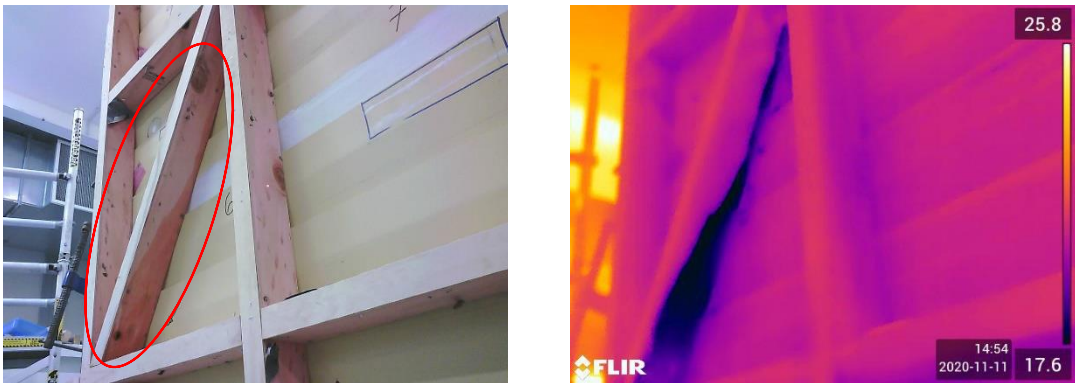
3.1 Insulation without underlay or cavity

Water was transferred to the framing and/or the insulation regardless of the insulation material used when there was no separation or underlay between the back of the cladding and the insulation (Table 1, walls A–C). The orientation of the fibre grain had some effect on how much water was transferred but it was difficult to achieve a consistent orientation without wasting some of the material. When the polyester was in smaller pieces, there were more joins and more edges where water could track into the insulation. It highlighted the importance of installing the insulation with as few joins as possible.

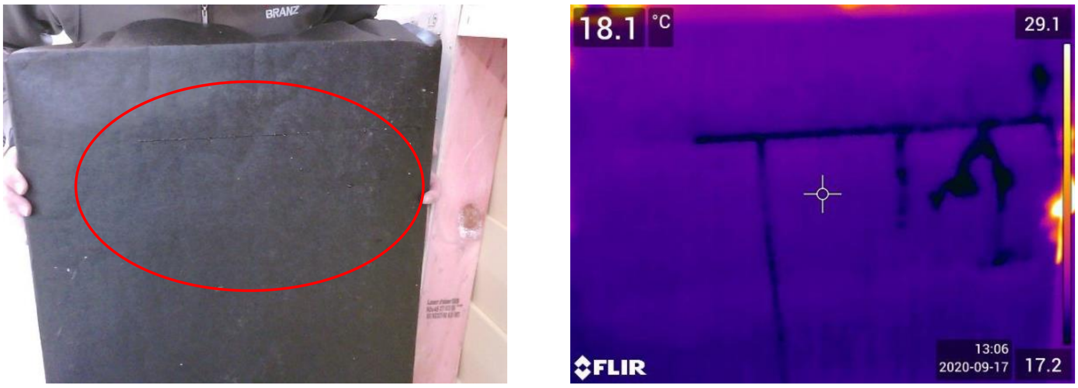
3.2 Insulation without cavity and with retrofitted underlay

There were some differences in the way the water drained between the back of cladding and the various retrofitted underlays when there was no cavity (Table 1, walls D–G). However, the outcome was always the same with some of the water being transferred onto the studs, dwangs, bottom plate or diagonal bracing. Figure 6 shows some of the test photos. One possibility is that water was trapped between the retrofitted underlay and studs/dwangs, potentially reducing the ability of the latter to dry. Therefore, while insulation might have been unaffected, the outcome is still undesirable.

With the diagonal bracing, the water was able to run down the underlay to the bottom corner and onto the framing (Figure 6a). With the rectangular cavities, the underlay appeared to block the water from running down the back of the cladding and instead the water was trapped along the top edge of the weatherboards. Water was then transported along the top edge to the fold in the retrofitted underlay against the side of studs. From there, the water ran down the vertical edge of the stud (the edge nearest to the cladding) and eventually onto the bottom plate in the corner against the stud or sometimes onto the dwangs (Figures 6b–6d).



(a) Water was transferred to diagonal bracing



(b) Water was transferred to back of underlay

(c) Water was directed onto framing behind folded underlay edges

(d) Water was transferred onto framing and back of cladding

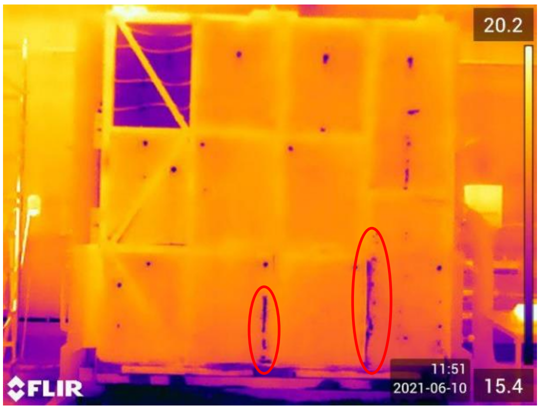
Figure 6. Walls insulated with underlay and without cavity where water transfer occurred.

3.3 Insulation with 20 mm separation and without underlay

The purpose of the tests was to evaluate the water management of retrofitted wall insulation with a 20 mm separation and without an underlay (Table 1, wall H). Initial tests were conducted following the NZS 4246:2016 guidance where the semi-rigid insulation (glass wool) was held in place with horizontally installed strapping. The strap was installed horizontally at intervals no greater than 300 mm centres by stapling into the wall studs (Figure 7). The strapping chosen was a stiff woven type rather than the more flexible type. As a result, it was difficult to staple with a 90-degree corner and precise positioning. This difficulty in fixing resulted in a less even separation than shown in NZS 4246:2016.

Figure 7. Walls insulated with 20 mm separation via strapping holding the insulation and without underlay.

Installing strapping entailed extra work. However, this technique did not prevent water being transferred onto the insulation materials, stud, dwang and bottom plate (Figures 8 and 9). In some areas, excessive water was observed on the insulation materials (Figure 8a) and the side of the stud (Figure 9 left). Since there was a separation between the insulation and the back of the cladding, water was able to run down the back of the cladding instead of trapping along the top edge of the weatherboards. Repeat tests showed that water was able to transfer to the insulation through direct spray from the leak points and onto dwangs and the bottom plate through drips falling from the lips of the weatherboards.



(a) Water was transferred to the insulation material

(b) Water was transferred onto framing and back of cladding

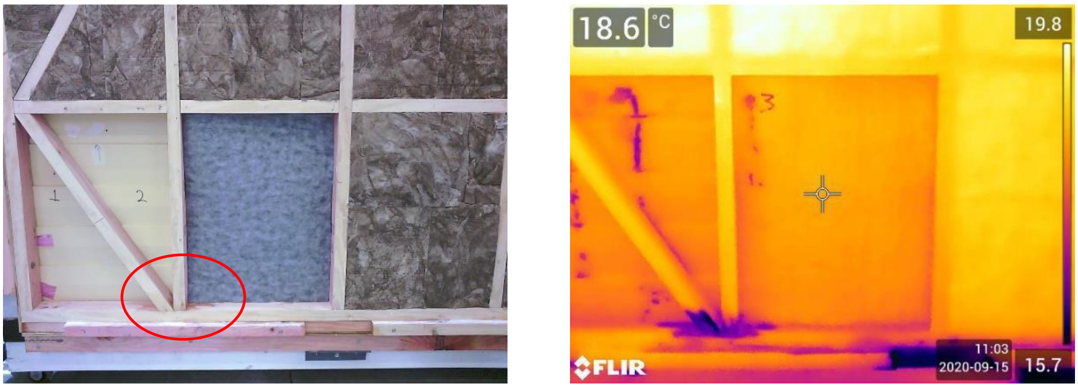
Figure 8. Walls insulated with 20 mm separation via strapping holding the insulation and without underlay where water transfer occurred.

Figure 9. Close-up view – walls insulated with 20 mm separation via strapping holding the insulation and without underlay where water transfer occurred (circled).

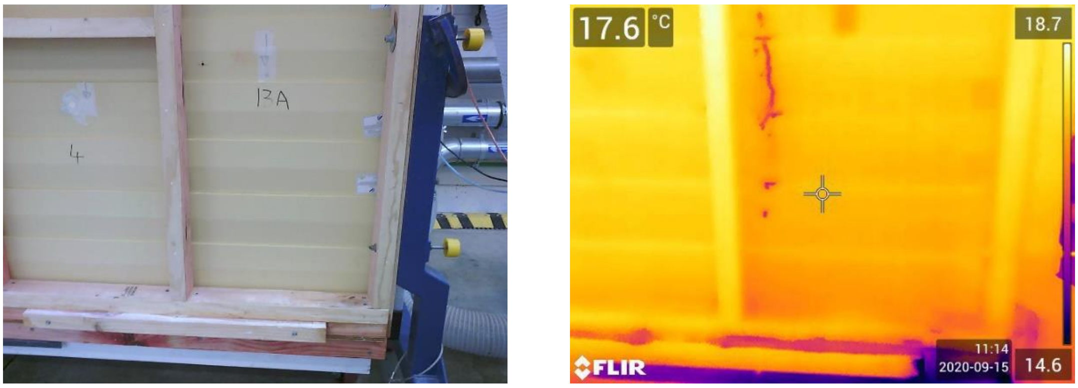
3.4 Insulation with cavity via drainage plane mesh and underlay (fit the cavity)

One of the drainage plane mesh products was supplied with an underlay already attached (Figure 5a) so there was no opportunity to add folds to the edge of the underlay (pan method). For the other two drainage plane meshes, there were no underlay attached (Figures 5b and 5c) so it would have been possible to use an oversize underlay and fold the edges.

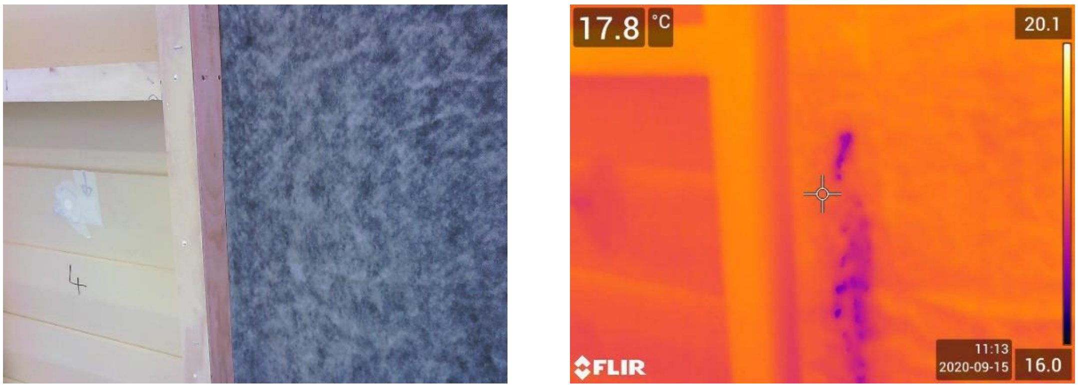
The testing started with the drainage plane mesh supplied with the attached underlay (Table 1, walls I–K). This product performed satisfactorily. Water was only transferred to the bottom corner of the diagonal bracing, stud and bottom plate (Figure 10a). Compared with the previous walls, no water was found at the bottom plate of the tall cavity (Figure 10b). Although there were no folded edges down the side of the underlay, water was not transferred onto the sides of the studs (Figure 10c).



(a) Water was transferred to framing



(b) No water was found at bottom plate of tall cavity



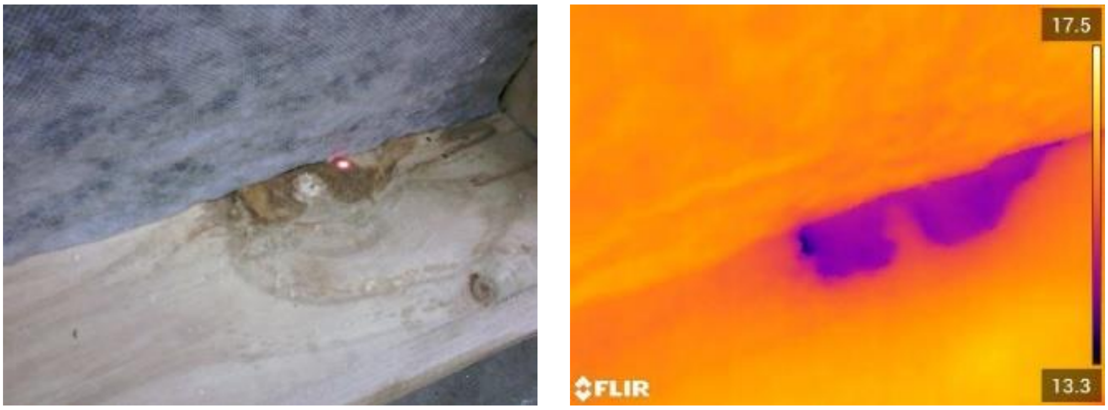
(c) No water was found at sides of stud

Figure 10. Walls insulated with drainage plane mesh and underlay.

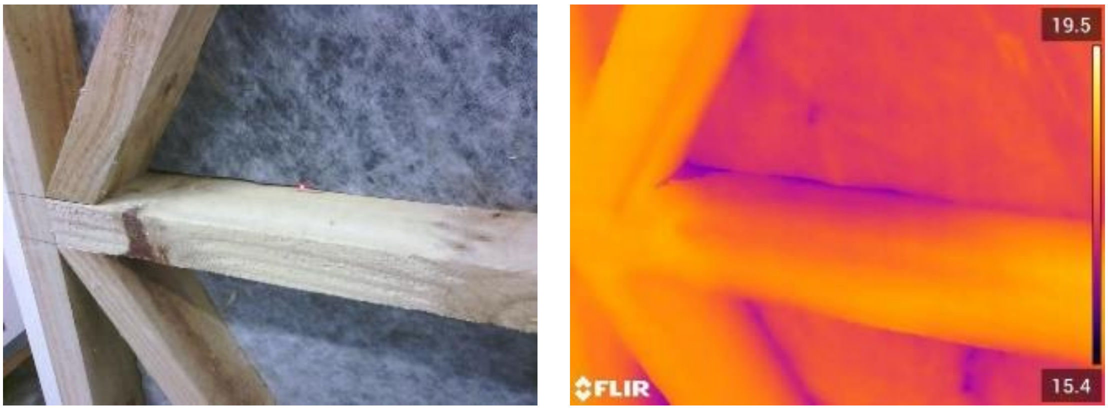
Since this test performed well, to better match the typical framing in the houses with direct-fixed cladding and without wall underlay, the wall specimen was changed to rough-sawn framing before the series of tests with the drainage plane mesh was started. Of significance was a large knot in one section of the bottom plate and dwang of this rough-sawn wall specimen.

Since the first mesh tested performed reasonably well despite it not having the folded edges, folded edges were also not used for the underlays used with the other two mesh materials. Repeated testing using this drainage plane mesh (Figures 11a–11d) and the other two drainage plane meshes in conjunction with synthetic underlay (Figures 11e and 11f) and kraft paper (Figures 11g and 11h) resulted in similar observations. These indicated that only small amounts of water were transferred onto the framing at the point where the back of the weatherboard abutted the diagonal bracing or at the points around the knot in the bottom plate or dwang. This indicates that pre-existing framing defects may have an impact on water transfer.

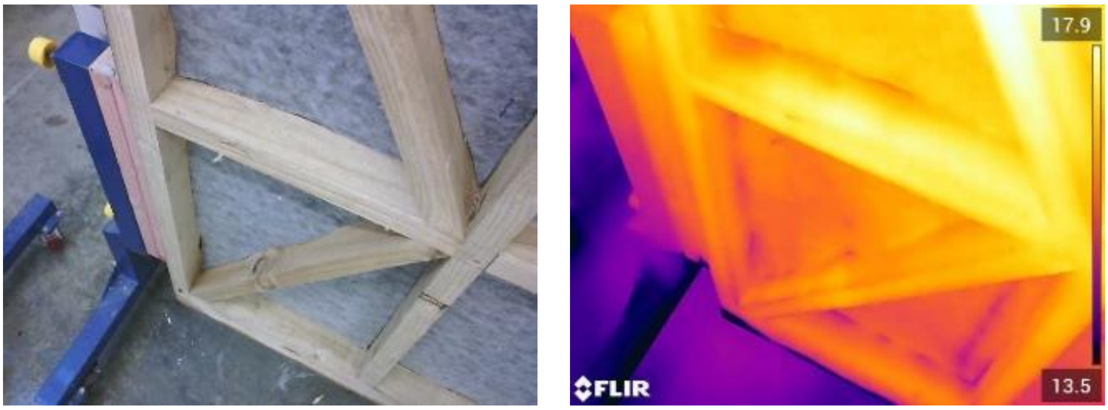
(a) Small amount of water was transferred to bottom plate with knot in it



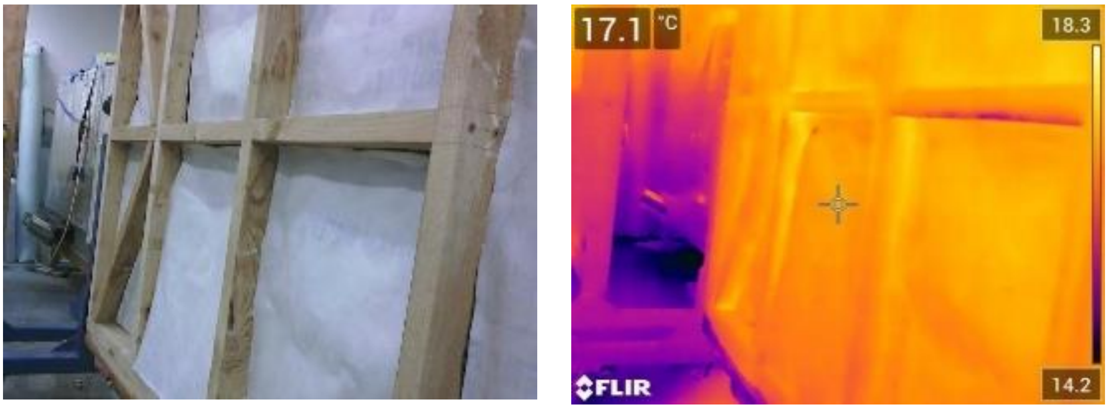
(b) Close-up view – water was transferred to bottom plate with knot in it



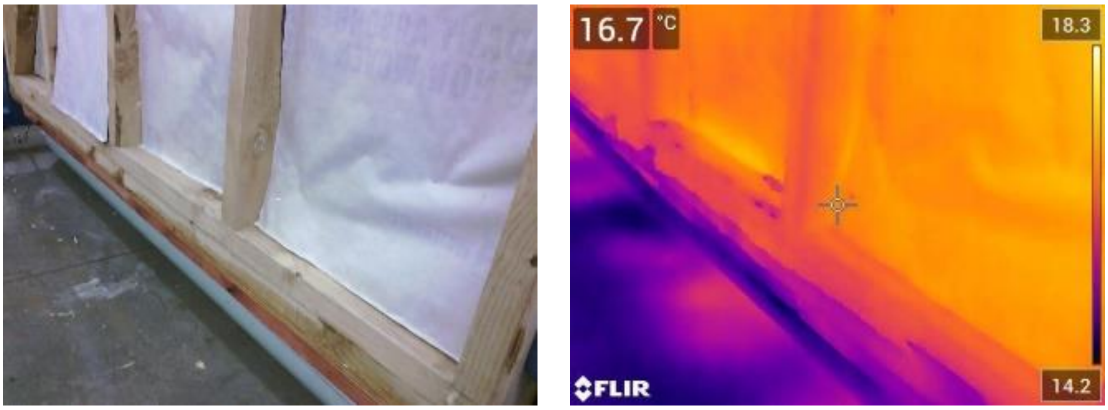
(c) Water was transferred to corner of diagonal bracing



(d) Water was transferred to bottom corner of diagonal bracing and bottom plate

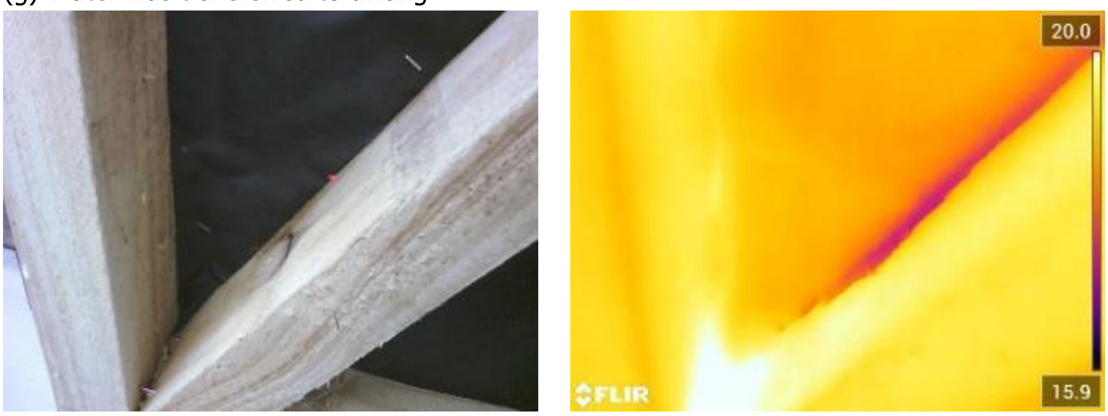


(e) Water was transferred to dwang



(f) Water was transferred to bottom plate

(g) Water was transferred to dwang



(h) Water was transferred to diagonal bracing

Figure 11. Walls with cavity via drainage plane mesh and synthetic underlay or kraft paper without folded tape around edges.

3.5 Insulation with cavity via drainage plane mesh and underlay, taping underlay to framing or tucking strip of underlay behind framing

Since the drainage plane mesh performed reasonably well, a set of five 18 mm holes was introduced in conjunction with the set of 15 holes (6 mm) for the subsequent testing with the aim to create a much higher leak rate through the cladding. This resulted in significantly more water getting to the diagonal bracing than was present for all the previous tests. Four tests were conducted under this higher leak rate (Table 1, walls L–O).

Test 1 was a cavity via drainage plane mesh and synthetic underlay with tucking a strip of synthetic underlay between the framing and back of the cladding in all rectangular cavities (Figures 12a–12d). Results showed that, despite the higher water ingress rate, the drainage plane mats were able to prevent nearly all the water from getting to the framing.

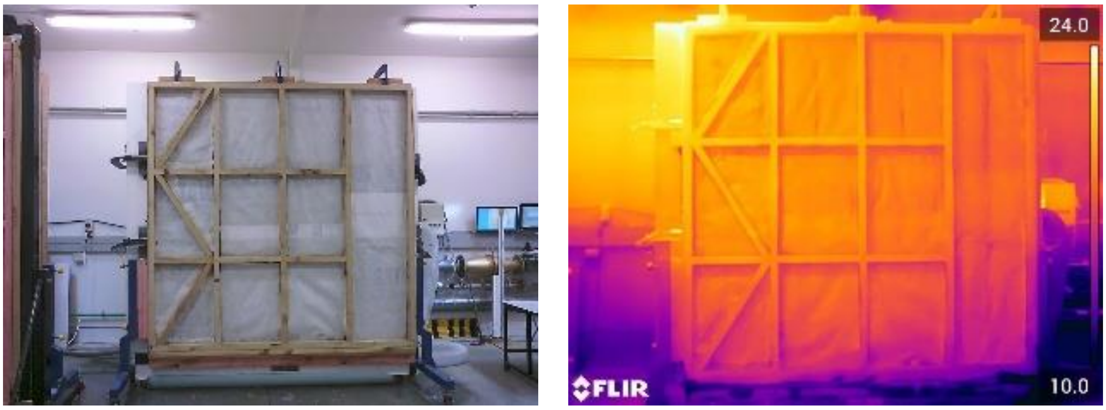
Test 2 was a cavity via drainage plane mesh and lightweight kraft paper with tucking a strip of kraft paper between the dwang or bottom plate and the back of the cladding (Figures 12e–12h). Results showed that water was being transferred onto the framing and dwangs.

Test 3 was a cavity via drainage plane mesh and synthetic underlay with taping the top and bottom edge of the underlay to the framing to secure the underlay in place, which is a practice sometimes used by installers. Three types of tape were tested. In the rectangular cavities, the edge of the underlay next to the top edge of the diagonal bracing was taped to the framing (Figures 12i–12l). Since water was not transferred onto the sides of the studs when there were no folded tabs down the side edges of the underlay, it was unnecessary to add tape to those edges or use an oversize underlay and fold edges around the side of the stud. The tape that was found to work better could be folded into a very sharp 90 degrees (or less) and hold the underlay against the lip of the bottom plate. If the taping was not done very carefully, water was able to travel via capillary action under the tapes because of the rough-sawn finish to the framing. It is reasonable to assume that the tapes would also restrict the drying of the framing.

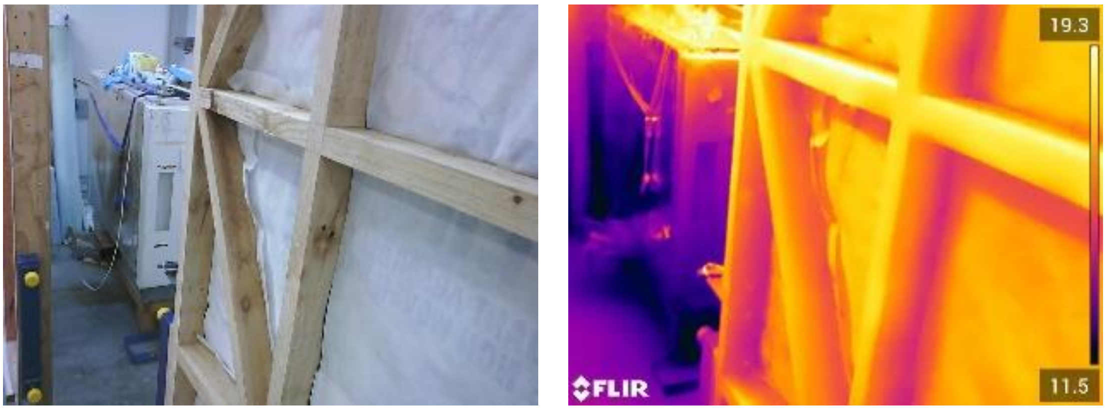
After completing Test 3, a follow-up test was conducted to investigate which solution would be more appropriate to prevent water being transferred onto the bottom plate. Four configurations were tested:

i) Underlay was cut to fit the cavity.
ii) Underlay was cut approximately 5 mm longer and tucked between the framing and the back of the cladding.
iii) Underlay was taped to framing.
iv) A strip of kraft paper was tucked between the framing and underlay.

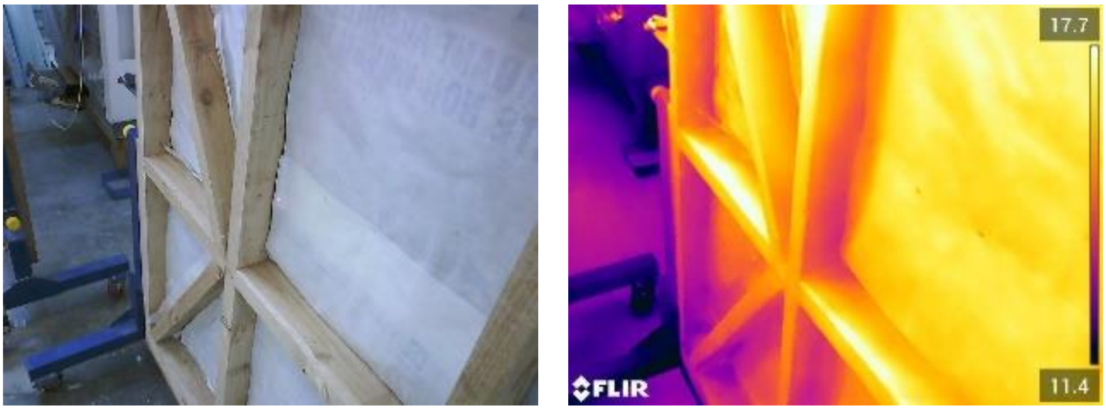
Results showed that tucking the edge of underlay into the bottom plate caused very small amounts of capillary water transfer back onto the bottom plate. The alternative method of strips of kraft paper tucked into the bottom plate was successful at preventing water being transferred onto the bottom plate and was easy to install (Figures 12m and 12n and the appendix).



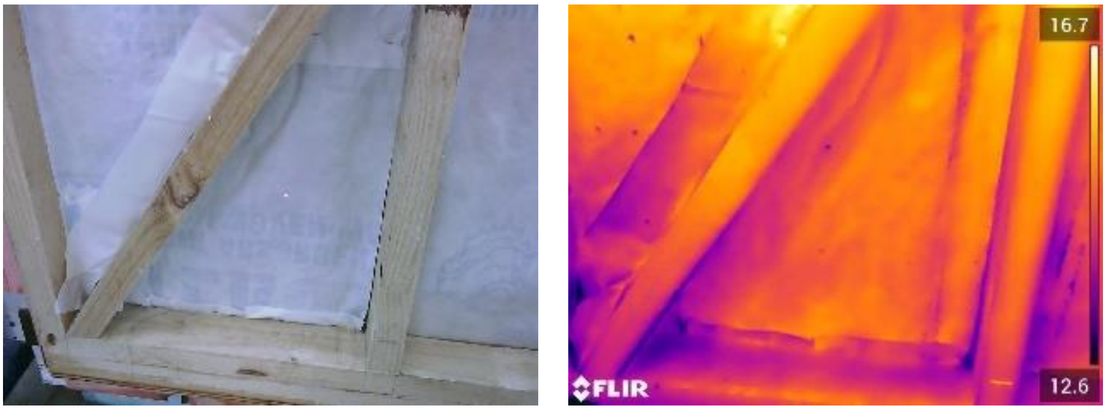
(a) Strip of synthetic underlay tucked between framing and back of cladding



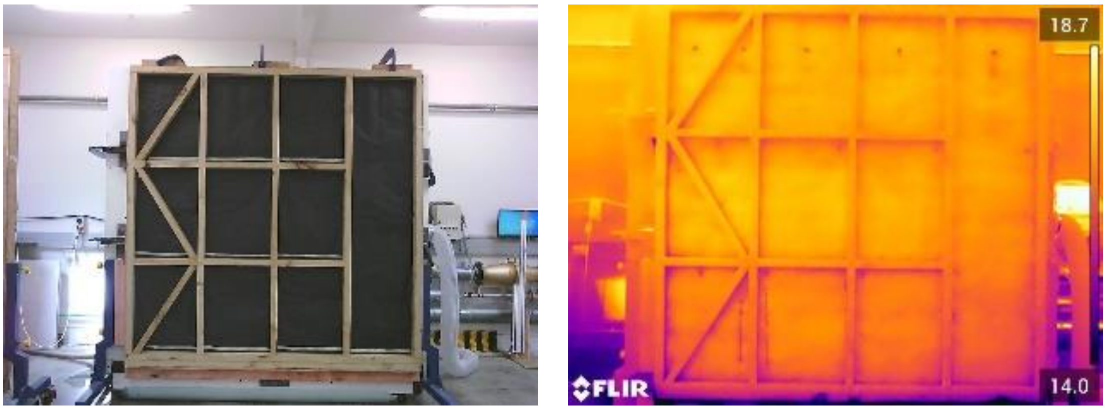
(b) Water was not transferred onto framing



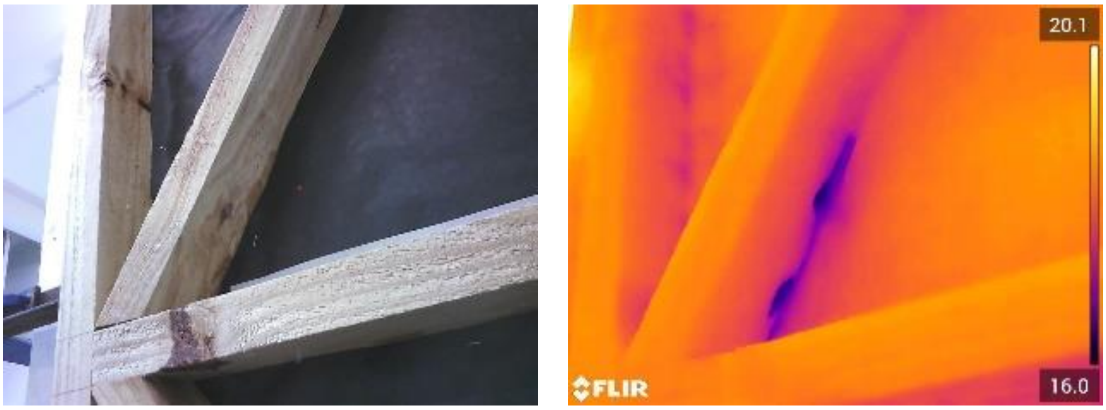
(c) Water was not transferred onto framing



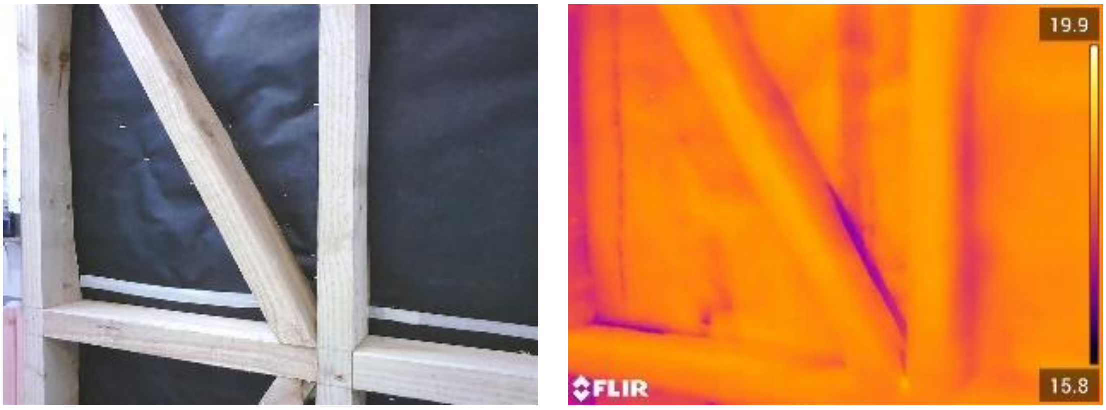
(d) Small amount of water was transferred onto corner of diagonal bracing and bottom plate



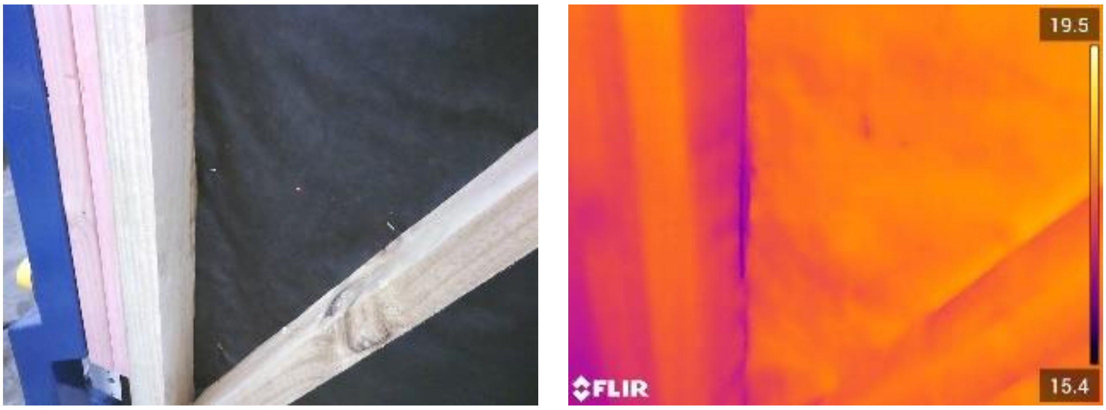
(e) Strip of kraft paper tucked between framing and back of cladding



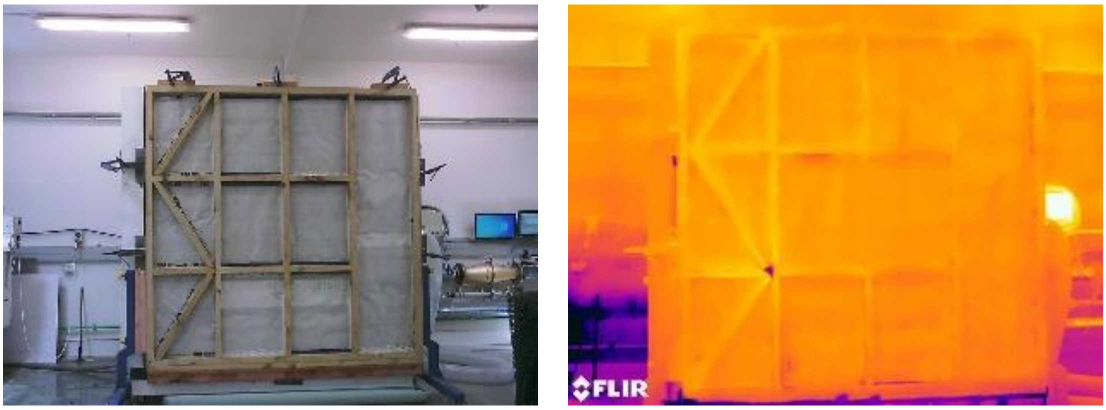
(f) Water was transferred onto diagonal bracing



(g) Water was transferred onto framing



(h) Water was transferred to side of stud

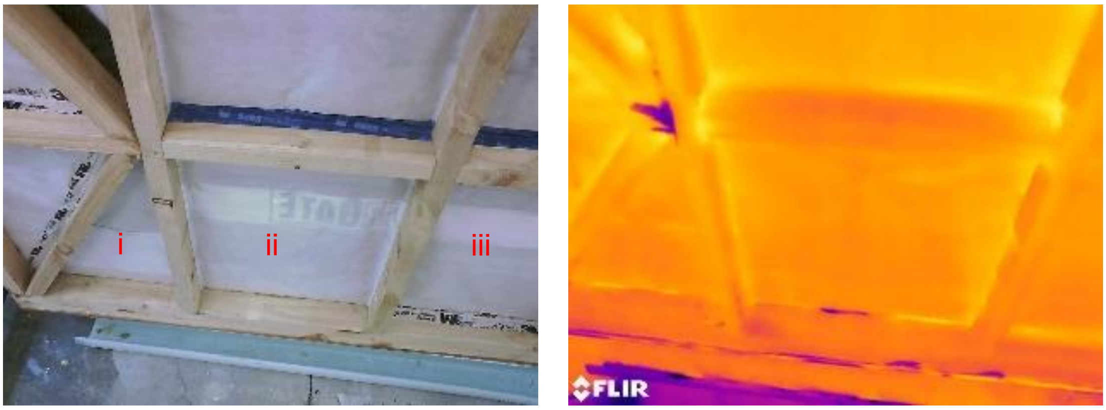


(i) Underlay taped to framing

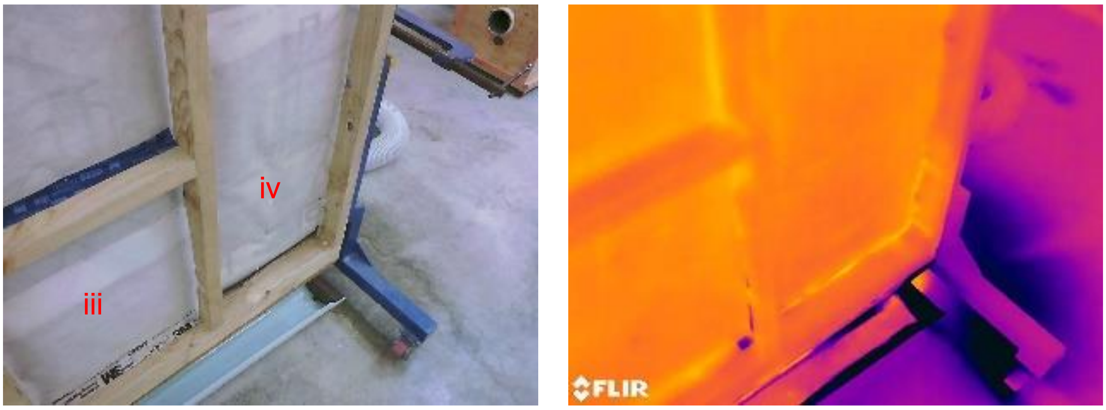
(j) Water was transferred to framing

(k) Water was transferred to framing

(l) Water was transferred to framing



(m) (i) Underlay cut to fit the cavity, (ii) underlay tucked between bottom plate and back of cladding, (iii) underlay taped to framing



(n) (iii) Underlay taped to framing, (iv) strip of kraft paper tucked between framing and underlay

Figure 12. Walls with cavity via drainage plane mesh and synthetic underlay or kraft paper with strip of underlay tucked behind framing or taped to framing.

3.6 Discussion

This study found that water was transferred to the framing and/or the insulation regardless of the insulation material used when there was no separation or underlay between the back of the cladding and the insulation. The mitigation measures using the kraft paper or synthetic underlay pans were unable to prevent water transferring onto the framing and, in some cases, the insulation. Using the pan methods changed the way water was distributed but still resulted in water transfer onto the framing.

Creating a separation between the back of the cladding and insulation was not able to prevent some small amounts of water being transferred onto the framing and onto the insulation materials. Compared with the pan method installed underlay, using the separation did not result in water being trapped along the top edges of the weatherboards. The downside to the method is the limitation on the insulation thickness.

Repeated testing using the drainage plane meshes in conjunction with the underlay resulted in water only being transferred onto the framing at the point where the back of the weatherboard abutted the bracing or dwang or the framing with a knot in it or areas around the diagonal bracing. It was a relatively small amount and much less than what was transferred when using the pan method despite the higher water ingress rate. Using a folded strip of kraft paper was reasonably effective at reducing but not eliminating water transfer onto the framing. It is reasonable to assume that more water would have been transferred onto the framing under the higher water ingress rate when using the pan method without a separation between the cladding and the underlay.

Since the drying ability for any wall after the installation of insulation is unknown, the conservative approach is to avoid altogether any water transfer into the insulation or onto the framing. While the actual quantitative leak rate imposed on the test walls may appear somewhat arbitrary or even possibly excessive, it is important to keep in mind that the weatherboards for these test walls are straight and true and in good condition with open overlaps so that water is relatively free to drain back out. In practice, many walls will have large paint build-up across the overlaps, restricting the ability for water to drain back out and putting more importance on the ability of water to drain the full height of the walls and then to drain at the overlap between the bottom plate and the bottom weatherboard. The backs of the weatherboards were factory primed whereas, in practice, the weatherboard may be unprimed on the back and therefore able to accumulate water and expand and contract, opening and closing the overlaps.

In practice, water will always be getting to at least the outer face of wall studs in walls without an underlay, even after mitigation measures. The only exception would be where the cladding is removed and an underlay installed. However, this is generally not a problem provided the back of the cladding is able to drain and the water does not get further into the frame cavity beyond the back of the cladding.

4. Conclusion and recommendation

Requirements for wall insulation were introduced to the New Zealand Building Code in 1978, which means the walls that do not already have insulation are generally at least 45 years old. Removing the linings to retrofit insulation into the frame cavity provides the opportunity to thoroughly inspect the condition of the framing and to repair any defects that are causing water ingress into the frame cavity instead of draining down the back of the weatherboards. Presuming that process is done with appropriate care and attention, the mitigating measures tested in this study are expected to only need to cope with the relatively small amounts of water that can get through the undetected leak points or what might infiltrate through the weatherboard overlaps during severe weather events.

If the mitigation measures ensure that any water that gets through the cladding can drain out again without migrating into the insulation or onto the framing, the reduced drying potential resulting from the addition of insulation should not be an issue for the wall.

The reliable mitigation measure was found to be drainage plane mesh combined with a synthetic underlay between the mesh and retrofitted insulation. Since the most effective way to install it was a neat fit without edge folds and likewise for the underlay, the combination was found to be easier and quicker to install than the alternative mitigation measures. More importantly, repeat testing showed it to be a reliable method that was able to cope with an even higher water ingress rate than was used for testing those alternatives. The 7–8 mm thick drainage mesh compared with using the 20 mm separation method means that thicker, higher R-value insulation can be installed.

Though most testing was conducted using 100 mm framing, some existing framing is only 95 mm (and in a few cases 90 mm depth). This method (combination of drainage plane mesh and underlay) requires the insulation products to fit with the drainage material and still allow the linings to be attached correctly. Therefore, the specific insulation product needs to be chosen to match the framing depth and the installation process. For example, with the 90 mm frame depth, a suitable product would need to have a thickness of 83 mm or less or be soft enough to be compressed and allow the lining to be attached correctly.

In some situations, while taping the underlay where it meets dwangs or the bottom plate may in principle provide additional protection from water getting to the insulation, it did not appear to be necessary. It is reasonable to assume that, if not done with care, taping may end up directing water onto the framing via capillary action between the tape and the rough-sawn surface and in the process also presumably restrict the ability of the timber surface to dry. A more effective way to direct water and protect the bottom plate and dwangs from water transfer was with the use of a strip of kraft paper tucked into the gap between the framing and the back of the cladding (Figure 3c and the appendix).

Care is needed in the areas where diagonal bracing is hard against the back of the weatherboards, but this is the case regardless of the mitigation method used. Again, a folded strip of kraft paper was reasonably effective at directing most of the water to the back of the cladding. As is the case with the paper/synthetic pan method, stainless steel staples are recommended. The results found in this study are based on lab testing, so use in practice is needed to confirm the practicality of implementing the mitigation measures. In practice, installation constraints such as obstruction from plumbing or wiring also need to be considered. The installation quality may affect the results as well. However, the workmanship is out of the scope of this study and field trials with industry are planned.

Based on the results found in this study and BRANZ's previous retrofitting insulation experience, our recommendation is that these findings are considered as part of any update to NZS 4246:2016.

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Appendix: Additional images

Figure A1. Four types of configurations were tested: i) the underlay was cut to fit the cavity; ii) the underlay was cut approximately 5 mm longer and tucked between the framing and the back of the cladding; iii) the underlay was taped to the framing; iv) strip of kraft paper was tucked between the framing and underlay. This image was taken before the test.

Figure A2. Close-up view of (i) the underlay cut to fit the cavity. This image was taken after the test.

Figure A3. Close-up view of (ii) the underlay cut approximately 5 mm longer and tucked between the framing and the back of the cladding. This image was taken after the test.

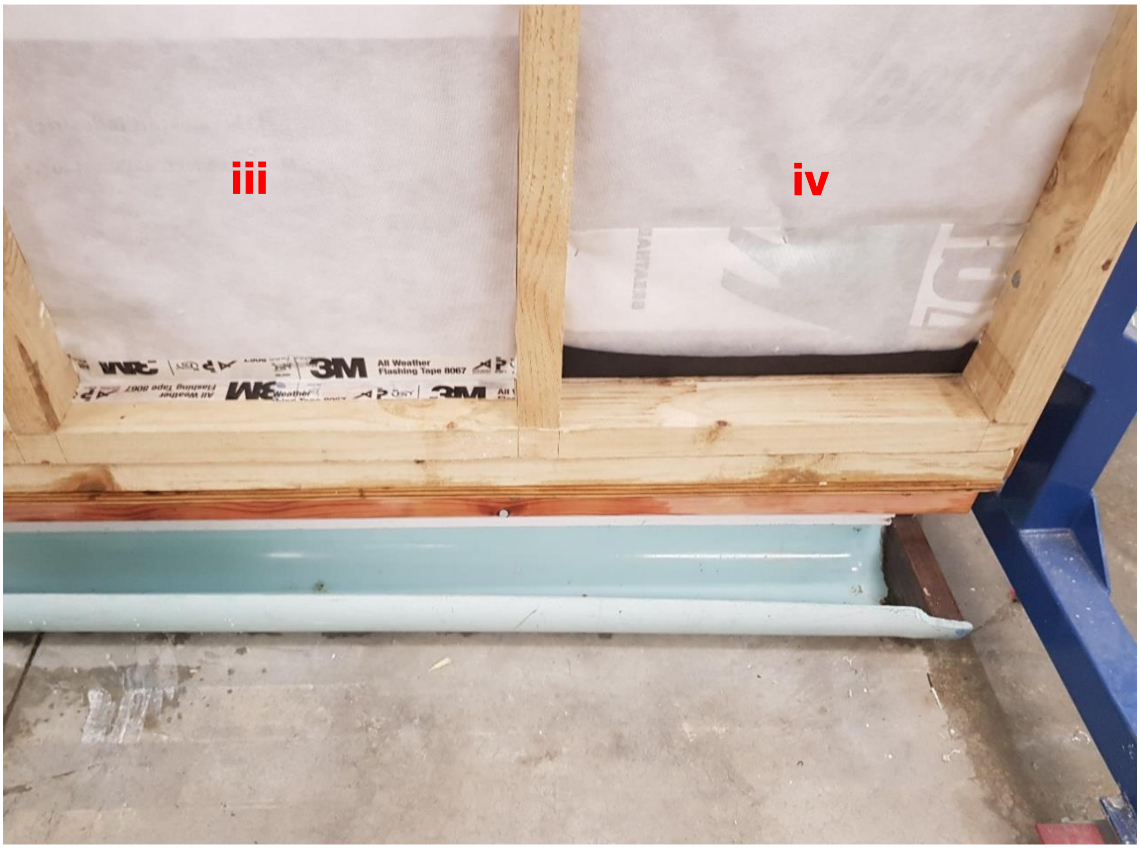

Figure A4. Close-up view of (iii) the underlay taped to the framing (iv) a strip of kraft paper tucked between the framing and underlay. This image was taken after the test.

Figure A5. Close-up view of the pulled-out strip of kraft paper tucked between the framing and the underlay. This image was taken after the test.