Study Report SR436 [2020]

Linings-on retrofit insulation in weatherboard walls: Ensuring effective water management

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Preface

This research was performed as part of the BRANZ Warmer, Drier, Healthier Homes research programme. Among the programme's aims is the generation of solutions that make existing houses warmer, drier and healthier.

This report does not represent tests of any particular product, and the performance described herein does not relate to any particular product.

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Abstract

There is a clear need to provide easier means to insulate walls in New Zealand, given the number of houses in the stock that remain uninsulated. Loose-fill insulation is one possibility for satisfying this need. However, given the nature of many New Zealand walls (direct-fixed cladding with no underlay), there is a potential risk of negatively affecting the water management of the wall by insulating it. Elsewhere in the world, there appear to be no examples of timber-framed walls without underlay being retrofitted with loose-fill insulation. There are, however, cases from overseas, where cavity wall insulation has led to water ingress. These instances have typically led to guarantee and quality control schemes being put in place by the industry and/or government in those countries. In New Zealand, there are loose-fill insulation systems that demonstrate compliance with the New Zealand Building Code via CodeMark certification. The aim of this research was to technically assess potential solutions for linings-on retrofit solutions in New Zealand and understand any associated risks. Of primary concern was that any solutions do not cause damage by water ingress. This research has shown that both bonded and loose-fill insulation can be installed behind an underlay and not lead to increased water transfer. This provides great scope for the widespread retrofit of New Zealand walls. The research has also shown that, without an underlay present, water transfer can occur, irrespective of whether the insulation material itself is hydrophobically treated. It does appear possible, however, to create installed insulation that resists moisture transfer to the inside of the wall. Overall, the research has highlighted pathways for a linings-on retrofit for weatherboard walls with or without underlay. The research has developed a laboratory-based evaluation method for assessing the performance of walls retrofitted with insulation. It is intended to be used as part of an overall assessment of an insulation system's suitability to be used in a wall without underlay without negatively affecting the water management behaviour for the wall.

Keywords

Façade testing, weathertightness, retrofitted insulation.

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Executive summary

There is a clear need to provide easier means to insulate walls in New Zealand, given the number of houses in the stock that remain uninsulated. Loose-fill insulation is one possibility for satisfying this need. However, given the nature of many New Zealand walls (direct-fixed cladding with no underlay), there is a potential risk of negatively affecting the water management of the wall by insulating it.

The aim of this research was to technically assess potential solutions for linings-on retrofit solutions in New Zealand and understand any associated risks. Of primary concern was that any solutions do not cause damage by water ingress.

This research has shown that both bonded and loose-fill insulation can be installed behind an existing underlay and not lead to increased water transfer. This provides great scope for the widespread retrofit of New Zealand walls.

The research has also shown that, without an underlay present, water transfer can occur, irrespective of whether the insulation material itself is hydrophobically treated. It does appear possible, however, to create installed insulation that resists moisture transfer to the inside of the wall. Overall, the research has highlighted pathways for a linings-on retrofit for weatherboard walls with or without an existing underlay.

The research has developed an evaluation method for assessing water transfer in walls retrofitted with insulation. It is intended to be used as part of an overall assessment of an insulation system's suitability to be used in a wall without underlay.

1. Background

The New Zealand housing stock contains a significant number of uninsulated or under-insulated properties. Analysis of the 2015 BRANZ House Condition Survey suggests that 53% (830,000) of New Zealand houses could benefit from retrofit insulation in the ceiling and/or subfloor. It is also estimated that 53% of our houses have no insulation in the wall space at all (White & Jones, 2017).

In terms of targeting insulation retrofits, the wall space is a less attractive option than the ceiling and floor. This is because installing wall insulation is generally more complicated than installing ceiling and floor insulation. For a completely uninsulated house, the biggest heat loss will be through the roof and so it is logical to insulate that area first. EECA's Warm Up New Zealand programme[1] has provided subsidies for insulation upgrades in almost 300,000 houses. That programme has now been replaced by EECA's Warmer Kiwi Homes initiative, but in all cases, wall insulation was not one of the funded measures.

Figure 1 shows approximate proportions of heat loss from typical houses that have been retrofitted with insulation to the minimum New Zealand Building Code requirements (Pollard, 2005).

Insulating the roof has much more impact than insulating the floor because the loss through the roof is proportionally higher to start with. With just the roof and floor insulated but not the walls, most of the heat loss is divided equally between the windows and walls. Clearly, insulating the walls has much more potential to reduce the total heat loss than adding further insulation to the roof since the wall heat loss is three times the insulated ceiling heat loss. Once the walls are insulated, the heat loss through the walls has dropped to being roughly the same as what is lost through each of the roof and floor and air leakage.

Retrofitting insulation to the walls is therefore an effective way of increasing the thermal performance of a house, especially when the ceiling and floor have already been targeted, but the retrofit is usually performed as part of a larger renovation when the wall linings are being replaced. In addition, retrofit of insulation to an external wall requires a building consent. If technology and systems can be employed that lower this barrier to retrofit, it is more likely that the walls of New Zealand homes can be upgraded on a larger scale.

Blowing in insulation into existing uninsulated walls is one way of increasing the thermal performance of a wall without removing the linings. Several companies have been active in this space, but best-practice guidance akin to that available for bulk insulation has not been established in New Zealand. Rockwool insulation first began to be used in New Zealand as a blown-in wall insulation in 1986 and glasswool blow-in wall insulation from around 2002.

Blown-in insulation has formed part of government-backed retrofit programmes in some countries, notably the UK (Palmer & Cooper, 2014).

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[1] https://www.mbie.govt.nz/dmsdocument/3044-eeca-programme-review-warm-up-new-zealand-pdf

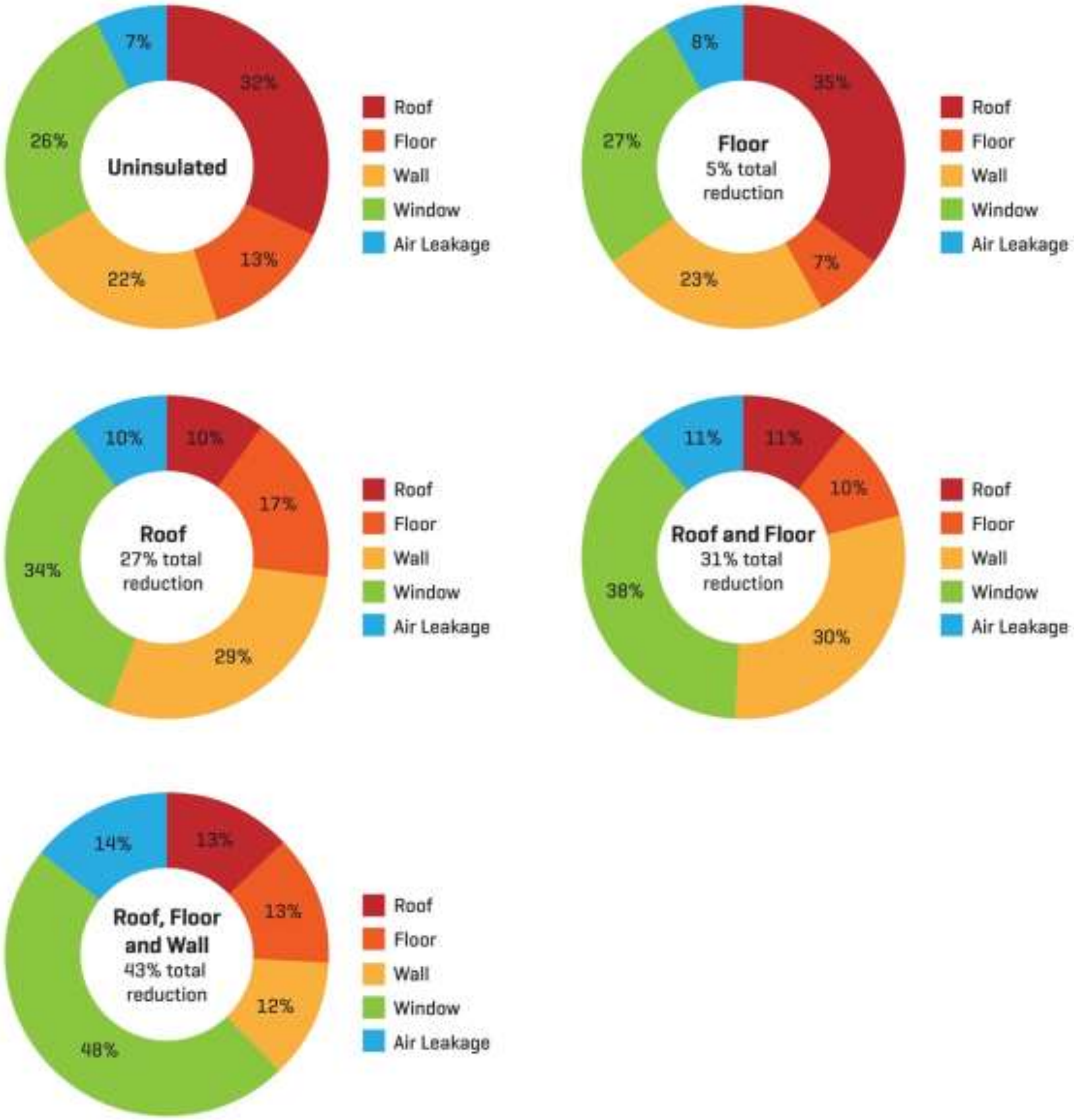

Figure 1. Approximate heat loss proportions from an average of four typical building designs and all the zone 1 and 2 regions (Auckland, Hamilton and Wellington) with insulation to minimum Building Code requirements at the time (2005).

In some instances overseas (see section 3), the addition of insulation into the wall cavity of a double-brick wall has permitted water to bridge the cavity. This has caused damage to those buildings as well as undermining the desired increase in thermal resistance. New Zealand's experience with the leaky building crisis (Howden-Chapman, Ruthe & Crichton, 2011) means any increased susceptibility to water penetration arising from insulation retrofits would be a concern.

In New Zealand, most of the houses requiring insulation to be added to the walls will be timber-framed with a direct-fixed cladding. Further, a significant number of these will have no underlay present. Bassett, Overton and McNeil (2015) looked at water management in walls with direct-fixed claddings in terms of drainage and drying. That study contained a limited number of tests on retrofit options for walls without underlay but notably did not look at loose-fill options.

The work detailed in this report comprises a review of guidance and practices from around the world in terms of loose-fill insulation, particularly with respect to timber-framed walls. A series of water management tests are then described culminating in a test that demonstrates whether insulation systems can provide resistance to water transfer to a level like that in current water penetration tests referenced in the Building Code. That test is particular to the case where there is no wall underlay present, but guidance is also provided for the case where there is an underlay. The test procedure could also be modified for use with brick veneer walls, but that is outside the scope of this work.

2. Research objectives

The aim of this research was to technically assess potential solutions for linings-on retrofit solutions in New Zealand and understand any associated risks. Of primary concern was the need for any solutions to not cause any damage by water ingress.

The initial intent was to understand the various factors involved in the insulating process. For example, for a loose-fill solution, how is a successful installation dependent on installed density, source material, installation process and so on? However, because much of this information represents intellectual property of various companies, the research became focused on developing a test that could be used to prove the performance of a system from a water management perspective, irrespective of any proprietary system details.

3. Review of international experiences with retrofit wall insulation

New Zealand is not alone in recognising the potential gains from practical and affordable wall insulation retrofits. The UK has subsidised energy retrofits for two decades and has seen insulation added to the walls of more than 6 million homes. Since most UK houses have double-brick wall construction, the process control and development of methods for testing and evaluation of insulation products and installation systems has been focused on cavity wall insulation and to a lesser extent solid wall insulation. The programmes have, overall, been successful in achieving their goals of significantly reducing the number of existing houses that do not have any form of wall insulation, but they have not been without their problems. Much of the learning about the risks and the development of mitigation measures is ongoing. Similar wall insulation retrofit schemes are operating in mainland Europe, but as with the UK, the focus has been primarily double-brick and solid wall construction. Based on the UK experience, Australia has also implemented schemes for retrofitting insulation in double-brick walls, but the only countries that have had a significant amount of retrofit activity for lightweight timber-framed construction are Canada and USA. In the case of USA, there is a very active blown insulation industry retrofitting walls of existing timber-framed house. A key difference between USA construction and New Zealand construction is the presence of a rigid underlay (or sheathing) in the former.

Evaluation of insulation systems requires an understanding of the potential problems, the means for detecting them and possible means for preventing the problems in the first place. A review of the history of use of such systems internationally and the problems that occurred provides a starting point to develop evaluation and control processes specific to the New Zealand retrofit situation.

3.1 New Zealand best practice for installing insulation

NZS 4246:2016 *Energy efficiency – Installing bulk thermal insulation in residential buildings* contains detailed guidance on installing thermal insulation, including in a retrofit situation, and is a key document of the insulation installation industry.

The requirements for retrofitting wall insulation into timber-framed walls include the need to inspect the wall cavity after removing the lining to identify and eliminate water leaks. If there is an underlay present, it can be checked and repaired if necessary to ensure water cannot get into the frame cavity. However, if there is no underlay or the underlay is damaged and cannot be fully repaired, two options are presented: either retrofit an underlay or install the insulation with a separation from the back of cladding. NZS 4246:2016 points out that a retrofitted underlay could reduce the water management ability of the wall whereas using a separation is unlikely to do so.

NZS 4246:2016 contains a brief overview of the installation of loose-fill insulation. It highlights critical aspects but does not provide the same step-by-step installation process as for other materials and processes. Installation of loose-fill insulation into walls without a wall underlay is explicitly excluded from the scope of the standard. Although the practice of blowing insulation into the walls of New Zealand houses dates back to 1986, it is very difficult to find any documented analysis. Although NZS 4246:2016 does not contain installation guidance akin to that available for bulk insulation, there are loose-fill insulation systems that demonstrate compliance with the New Zealand Building Code via CodeMark certification.

3.2 UK

3.2.1 Early testing and the development of the CIGA scheme

In the early 1980s, the UK's Building Research Establishment (BRE) performed field testing of a range of insulation materials in the walls of a group of similar houses (Newman, Whiteside, Kloss & Willis, 1982a, 1982b). The gable areas were wetted at rates considered typical of those often reached in periods of driving rain. In total, nine retrofit blown-in products and three built-in insulation products were tested. For most of the cavities that were filled, it was observed that, even without the addition of insulation, water was able to cross to the inner leaf and cause dampness of the interior surface. Whilst all the built-in options and one of the blown-in materials (EPS bead) caused no increase in water transfer, the rest of the blown-in products caused it to increase and, in some cases, caused a considerable increase in the area of dampness.

Further research by BRE and others (Kingspan Insulation Solutions, 2006, n.d.) determined that one of the reasons for dampness appearing on the inner surfaces of retrofitted walls was so called incomplete fill, where large voids in the insulation were causing cold spots on the surface and consequently condensation. Over time, the fibrous blown-in products and processes were improved, and the incidence of moisture problems decreased, but they did not go away entirely.

After improving the materials, the insulation industry was still faced with considerable scepticism from the public and government, so in 1995, it instigated the industry-funded Cavity Insulation Guarantee Agency (CIGA) scheme, which guaranteed quality installations and performance of the retrofits for 25 years. The guarantee required the product and system used to be certified by the British Board of Agrément (BBA) and the installation to follow the CIGA guidelines (CIGA 2002, 2003) and BBA guidelines (BBA, 2013a, 2103b, 2015, 2016a, 2016b, 2016c, 2017, n.d.a, n.d.b, n.d.c).

After the CIGA scheme was initiated, there were still problems with retrofits. The consumer advice organisation Which? published an article on this topic ("Insulation: The price gap, the advice gap", 2011). Hidden camera recording of home assessments revealed a disparity between what was meant to happen and what was actually done when assessing suitability for cavity wall insulation. As well as considerable variability in the cost for what ought to have been a very consistent process done to standard guidelines, some of the assessors left out essential steps, provided poor advice and, in some cases, even failed to provide the homeowner with a copy of their assessment report. Included in the general advice to consumers is the warning that cavity wall insulation has the potential to cause dampness problems if it is installed in unsuitable walls, in houses that have unsuitably high wind and rain exposure or where the external walls are poorly maintained.

In response, CIGA overhauled its scheme and introduced increased levels of certification, the use of independent assessors for determining a home's suitability and independent audits of installers and the walls they had insulated. Much more emphasis is placed on documentation, including requirements to record and explain wall areas where insulation is not installed and to provide proof that the homeowner is fully aware of what is intended to be undertaken and what is achieved in practice. Publicly available specifications for retrofitting energy measures, including PAS 2035/2030:2019 *Retrofitting dwellings for improved energy efficiency. Specification and guidance. Specification for the installation of energy efficiency measures in existing dwellings and* *insulation in residential park homes*, are now a core part of the CIGA scheme. PAS 2035 includes assessing houses for retrofit whilst PAS 2030 includes the installation.

The CIGA Annual Review 2018 reveals that more stringent quality requirements to receive the guarantee has resulted in installers choosing to operate outside of the CIGA system, resulting in only 39,000 CIGA lodged installations in 2017. That was half the level of 2016 and well short of the peak of around 500,000 per annum of the 2008–2011 period. A similar halving of installations to 250,000 occurred in 2012 after the Which? article highlighted some of the issues. During the peak installation period of 2008–2011, there was a steady 800–1,000 claims per annum, but despite the rapid decline in installations from 2012, the rate of claims had risen dramatically to 4,500 in 2017.

At a similar time to the CIGA overhaul, the BBA introduced and now administers an independent audit scheme for cavity wall insulation installers called the Cavity Assessment Surveillance Scheme (CASS). The major features introduced by CASS are that all assessments must be lodged and all undergo independent desk-based audit. From those assessments, 10% are selected for an additional independent site surveillance audit of the actual house. Other aspects of CASS include systems to ensure the required inspection steps, such as visual inspection of the wall cavity, are carried out and documented.

The Chairman of CIGA introduces the CIGA Annual Review 2019 with the comment:

> Millions of householders continue to benefit from additional warmth and reduced fuel costs as a result of cavity wall insulation with over 6.2 million guarantees issued and in excess of 6 billion of savings on fuel bills along with 26.2Mt of CO_2 saved on CIGA guarantees alone. CIGA remain the largest provider of guarantees protecting 1 in 4 homeowners. (CIGA, 2019)

The review reports improvements in all the key performance indicators for the guarantee scheme and emphasises the point that, of the more than 6 million guarantees issued to date, there have been only 28,447 complaints (0.47%).

3.2.2 Testing of products for use in the CIGA scheme

As part of the certification of products, the BBA developed a laboratory test rig for cavity brick walls (BBA, n.d.b, n.d.c) based on the existing ASTM, EN and BS standards for testing the water management properties of wall claddings when exposed to pressure-driven water. The test wall is of cavity construction and consists of both an outer and inner plain brick leaf without visible defects. The test takes a week and has a water and air pressure regime that is representative of typical extended rain events. As a starting point for certification, the insulation systems are expected to pass that test in that no dampness is observed on the interior face of the inner leaf. The test is discussed further in section 4.

3.2.3 Overall impact of retrofitting cavity wall insulation

From 1970–2004, total household energy consumption rose steadily. The government's Energy Efficiency Commitments (EEC1 & EEC2) and anticipation of the dramatic increases in electricity prices that occurred from 2003 led to a substantial increase to government-subsidised energy retrofits – mostly ceiling (loft) and cavity wall insulation. Those energy efficiency retrofits continued from 2008 under the auspices of the Carbon Emission Reduction Target. From 2004 to the present, the consumption of energy has decreased steadily despite the number of homes increasing. Much of that decrease has been credited to insulation retrofits, particularly cavity wall insulation (Palmer & Cooper, 2014).

3.2.4 Timber-framed walls

The CIGA guidelines do not include blown retrofit into timber and steel-framed walls and the CIGA technician's guide to best practice for installing cavity wall insulation (CIGA, 2002) states that timber-framed walls are unsuitable for cavity wall insulation. The Scottish Government in its homeowner's guide to cavity wall insulation[2] is much blunter: "The cavities to timber frame houses for example should not be insulated due to the risk of the timber rotting."

Even for houses that have brick cavity walls, there are often areas below or above windows that have a timber frame-out and lightweight interior lining. Those areas may also have timber cladding in place of brick. The guidance from CIGA and the National Insulation Association have those areas insulated by removing the interior lining so that a drainage cavity can be maintained behind the cladding and a vapour control membrane installed.

In the BRE and BBA guidelines, timber and steel-framed walls are classified as 'difficult to treat', and there is no evidence of efforts to develop suitable materials and processes other than the alternatives to blown-in insulation such as removing linings or claddings.

The BRE report *Thermal insulation: Avoiding risks* (Stirling, 2002) is a good-practice guide on insulating all parts of buildings. For timber-framed construction, the guidance is to maintain a drained and vented cavity, and there is no mention of blown-in insulation use with timber-framed walls.

For masonry walls, reference is made to the wind-driven rain index from BS 8104-1992 *Code of practice for assessing exposure of walls to wind-driven rain*. A discussion on this index and how it might relate to New Zealand can be found in BRANZ Study Report SR300 (Overton, 2013).

3.3 Mainland Europe

There is a long history of insulation retrofits programmes in mainland European countries but exclusively with masonry and stone buildings and often involving either exterior on interior fixed insulation. The cavity insulation process is strictly for masonry cavity walls, and it mirrors what is now done in the UK. Timber-framed construction is treated in the same way as the UK by adding either external or internal insulation layers.[3] A typical example is Belgium (Wigger, Stölken & Schreiber, 2011).

Belgium has a quality control system[4] that was introduced in 2012 to provide confidence in the quality of retrofitted cavity wall insulation. The system is managed by the Federal Public Service Economy Department of Quality and Safety, which is

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[2] https://www2.gov.scot/resource/0039/00393653.pdf

[3] https://www.eurima.org/about-mineral-wool/design-installation-principles/lightweight-frame-construction.html; https://www.eurima.org/about-mineral-wool/design-installation-principles/two-leaf-masonry-cavity-wall-construction-full-fill-insulation.html

[4] STS 71-1:2012 *Na-isolatie van spouwmuren door in-situ vullen van de luchtspouw met een nominale breedte van ten minste 50 mm* (Retrofit-insulation of cavity walls by in-situ filling of the air gap with a nominal width of at least 50 mm).

responsible for assessment and approval of products and systems, training of installers and conformity checks on building sites.

The quality control system was investigated via a field study in 2014 and reported in 2016 by the Building Physics Group at Ghent University (Janssens, Van Goethem & Delghust, 2016). The purpose was to determine whether the system effectively met the objectives of improving the quality of the installations by analysing the relationship between the installers' declarations of conformity, the conformity checks by the certifier and the effective cavity wall performance measured in situ using heat flux sensors and including a thermal imaging survey. Twenty-six case studies were used, with a mixture of detached and semi-detached houses. All had double-brick cavity construction, and the cavity wall insulation was installed in 2012 or 2013. The insulation material was either blown-in mineral wool, blown-in expanded polystyrene beads or expanding polyurethane foam.

The study concluded that the declared wall areas were generally correct, and measured U-values were close to what was calculated based on the declared product performance. Likewise, there was no indication that unsuitable cavities with widths less than 50 mm were being filled, but the cavity width was often not reported correctly because only a single value was recorded and not the multiple locations required. The thermographic survey detected a minor lack of continuity or homogeneity of the insulation material for three of the 26 houses. There was no significant difference in quality between the three materials or between houses that had not undergone conformity checks and houses where the checks had been made.

In conjunction with the field study, the research group was also undertaking laboratory tests to investigate the watertightness of blown-in retrofit insulation (Van Goethem & Van Den Bossche, 2015; Van Den Bossche, Lacasse & Janssens, 2001). They noted that there is hardly any information on the amount of water ingress through insulated or non-insulated cavity walls. They also explained that the Belgian quality control framework was introduced as a result of some real-life water penetration issues, but there was still uncertainty about test procedures and evaluation standards. They performed a series of watertightness tests on cavity brick test specimens with cavity depths less than 50 mm to obtain some data on water ingress and to compare existing guidelines and standards.[5] In total, they tested four non-insulated and four insulated test samples using the three test standards. They used two insulation types – PUR foam and adhesive bonded EPS bead. Some of the non-insulated walls had water ingress, and whilst insulating them with the PUR foam almost eliminated the water ingress into the cavity, the EPS bead insulation increased water ingress. The conclusions were that there was significant variation in the amount of water ingress between the four test standards, and air pressure difference is not always the dominating parameter in water ingress.

3.4 North America

North America has a long history of retrofit wall insulation, including the 'drill and fill' method where holes are drilled from either the outside or inside to enable the installation of liquid foam, mineral wool (rock or glass) and cellulose. Much less

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[5] NEN 2778:2015 *Moisture control in buildings*; ASTM E514/E514M-14a *Standard test method for water penetration and leakage through masonry*; EN 12865:2001 *Hygrothermal performance of building components and building elements – Determination of the resistance of external wall systems to driving rain under pulsating air pressure*.

common but still used occasionally is EPS bead. Cellulose is often installed at a high density (referred to as 'dense pack') of around 55 kg/m^3. This is to enhance the thermal performance and aid with airtightness improvements.

Installation in timber-framed walls is common practice, and the installation processes take advantage of the walls typically having rigid underlays such as plywood and the associated absence of dwangs. There appears to be no building code legislation in respect of retrofit blown-in wall insulation. The installations are performed on both a commercial and DIY basis (Baechler et al., 2012) and are affordable,[6] even for professional installations.

Although building supply outlets selling to the DIY market sell bags of cellulose insulation and hire portable blower machines to install it, the advice to homeowners is that professional installers and equipment are needed for dense pack.[7] Home renovation websites typically advise that the hire machines are primarily designed for installing insulation into roof spaces, and although they can be used for installation into walls, the quality will not be as good as professional installations.

Technical information for the polyurethane foam products notes the need to check that the walls are strong enough to take the installation pressures, and despite the availability of DIY foam kits, again the general advice is to use professional installers.

To compete against the popularity of dense-pack cellulose, the manufacturers of glasswool blown-in products have developed materials and equipment for dense packing.[8] The density quoted for dense-packed glasswool is typically in the range 30–40 kg/m^3.

The North American Insulation Manufacturers Association has relatively detailed guidelines for the retrofitting of timber-framed walls with blown-in insulation materials (NAIMA, n.d.). The processes mostly involve installation from the outside, and all involve removing parts of the cladding such as a length of weatherboard to expose the rigid underlay and detailed procedures for making good the underlay and associated membrane. For the situation, described as rare, where cladding is directly fixed to the timber frame with the inclusion of a flexible underlay rather than a rigid one, there is a detailed procedure for repairing the underlay. There is no reference to blown-in products being installed into walls that do not have an underlay or how that might be safely accomplished.

The National Renewable Energy Laboratory has published specifications for dense packing blown insulation for walls.[9] As with the NAIMA guidance, the process involves removing areas of cladding and creating an access hole through the sheathing. Water management system will be repaired to function as originally intended (such as lapping

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[6] https://www.homewyse.com/services/cost_to_install_blown-in_wall_insulation.html; http://www.blowninInsulationcost.net/calculating-blown-in-insulation-cost/; https://www.homeadvisor.com/cost/insulation/install-blown-in-insulation/

[7] https://www.thespruce.com/blowing-in-insulation-vs-rolling-out-fiberglass-1821913; https://www.topratedlists.com/home-garden/home-exterior/insulation-review-loose-fill-blown-in.html; https://www.thisoldhouse.com/ideas/how-to-add-insulation

[8] https://www.homedepot.com/p/Intec-FORCE-2-Next-Generation-Insulation-Blowing-Machine-K20000-01/202034321; https://www.knaufinsulation.us/sites/us.knaufinsulation.com/files/BI-BWE2-SL.pdf; https://www.certainteed.com/building-insulation/products/optima-blow-insulation-system; https://www.redcalc.com/dense-pack-insulation/; https://www.buildingscience.com/documents/insights/bsi-043-dont-be-dense

[9] https://sws.nrel.gov/spec/411034

new felt paper underneath the upper and over the lower joint of the existing felt paper). Insulation will not be installed if moisture-related issues are not resolved.

3.5 Australia

Loose-fill retrofit of wall insulation has been carried out for some time, but there is relatively little documented evidence of the practices and performance. One company in the Australian state of Victoria has been installing blown-in insulation into double brick walls since before 2010. In ACT, retrofitting of wall insulation dates back to 1988. In both states, the retrofits have also included brick veneer houses with timber framing, and in the case of the ACT, a large number of the retrofits have been of local government-owned housing.

Starting in 2009, Sustainability Victoria commenced a programme of work to determine the energy efficiency of existing housing and the potential and cost benefits of energy efficiency upgrades. (Moreland Energy Foundation, 2010; Sustainability Victoria, 2014, 2015).

A key part of the Sustainability Victoria programme was a 2011 visit to the UK by one of the lead researchers to gather information about the UK retrofit cavity wall insulation industry. The report on that visit (Maksay, 2013) summarises the perceived robustness of the UK system including the guarantee scheme, product testing, training and auditing but also acknowledges the UK consumer organisation's critique and the possible need to improve pre-installation assessments. The report pre-dates the full extent of the problems in the UK (see earlier), including the major overhaul of the CIGA scheme and the introduction of CASS.

According to the report, approximately 85% of existing pre-2005 Australian homes do not have any wall insulation, and there are only four or five companies installing retrofit wall insulation. Insulation usually consists of granulated mineral fibre, expanded polystyrene beads or polyurethane foam. The report notes that Sustainability Victoria recognises that the challenges of installation standards, training, accreditation and verification of correct installation must be addressed. An insulation industry report (Energy Efficient Strategies, 2012) mentioned the need to develop an installation framework but also noted that the installation costs would be lower than those estimated in the Sustainability Victoria report.

To verify the estimates of potential energy savings along with the practicality and cost of installation of retrofitted wall insulation, 15 houses in Melbourne were monitored for energy use both before and after the retrofit of wall insulation (Sustainability Australia, 2016). Three of the houses were weatherboard clad, and the other 12 were brick veneer. The installation equipment and methods appear to have been substantially different from the BBA certificated systems used in the UK. The report refers to follow-up surveys or checks for unintended consequences such as water ingress. Among the conclusions were the need for further investigation into thermal imaging techniques for auditing installations, given that the attempts with the 15 houses were all unsuccessful at resolving installation quality.

4. Developing a water management test for New Zealand loose-fill insulation

Section 3 summarised the use of loose-fill insulation as a retrofit measure in various countries. None of the literature suggests loose-fill insulation has been commonly used in conjunction with a construction style that is the same as that typically found in older New Zealand houses. Most of these houses will have timber-framed construction without a rigid sheathing, so potentially there are additional risks that are not present in other countries where rigid underlays are the norm for timber-framed construction.

A bitumen-based flexible underlay (kraft paper) will be present in many of these New Zealand houses, but a significant number will have no separating layer between the cladding and the framing. The framing in these houses will generally be a native timber species that is naturally more durable than untreated radiata pine, which is often associated with leaky buildings. However, given the history of quality issues and moisture transfer associated with some retrofit initiatives in other countries, having more durable framing timber might not be considered adequate protection in and of itself. As such, one of the fundamental questions in this project was whether loose-fill insulation could manage water penetration in walls that did not have a kraft paper underlay between the cladding and the framing. Specifically, does adding loose-fill insulation make any leaks transfer further into the wall than they would do if the insulation was not present?

The process developed here is specific to weatherboards as it the most likely cladding to be found on older properties.

The initial investigations were based on earlier work at BRANZ, which focused only on drainage behaviour from a single leak under gravity. This allowed reasonably quick tests to be performed. As the project progressed, an approach using full-scale specimens and a combination of water, air pressure and cladding defects to create the leaks was developed. For the full-scale test, thermography became the primary means of assessing water transfer.

For practicality and indicative purposes only the initial drainage trails used previously blown material that was recovered and then hand placed rather than blown directly. The material was installed to densities of 18 kg/m^3 and 35 kg/m^3. In the later full-scale tests, commercial products were used for test development purposes.

4.1 Early drainage trials

Previous work at BRANZ (Bassett et al., 2015) looked at how some linings-off solutions performed in terms of drainage. That initial study gave an indication of how drainage plane material compared with the method of using pans of underlay to separate the cladding and the insulation (the ‘pan method’). Walls were subjected to a known leak, and the path of the water was tracked to see how much reached various parts of the wall. In the previous work, a peristaltic pump was used to inject 250 ml of water at the back of the cladding through a single dosing point over a period of 20 minutes. A further 10 minutes were allowed for drainage. The quantity is arbitrary but was intended to be between a very small leak that has little long-term consequence and a much larger leak that would initiate a speedy repair.

For the drainage trials in this project, the above method was duplicated but the focus was primarily on whether water transferred towards the interior of a weatherboard wall, not how much was stored in the different wall elements. A range of insulation products were trialled, including loose-fill insulation.

4.1.1 Results of drainage trials

Specimens with a full underlay

With an underlay in place, there was no water transfer to the inside of the wall, regardless of insulation type. This was expected to be the case because it is essentially mirroring new construction. With blown-in insulation, the installed density can often be higher than batt insulation, so there was potential to force the underlay into the cladding more, altering the drainage behaviour. The preliminary drainage experiments showed no evidence of this.

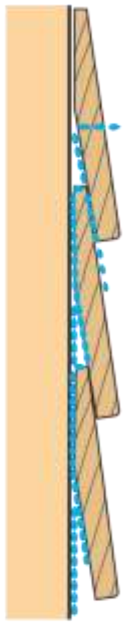


Figure 2. With an underlay in place, water drained out between weatherboard lap joints.

Specimens with a pan underlay

In these limited trials, there was no transfer with the pan method. This was a different result to the earlier work at BRANZ and was attributed to where the dwangs were positioned relative to the profile of the cladding.

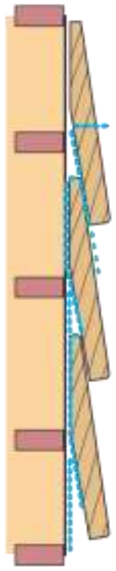
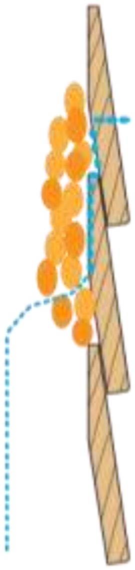


Figure 3. With an underlay pan in place, water drained out between weatherboard lap joints.

Specimens with loose-fill insulation, sealed lap joints and no underlay



With loose-fill insulation (and no underlay), the behaviour was dependent on the interaction between the insulation and the geometry of the cladding. With the material available to use, there was varying behaviour with the loose-fill insulation. If water was able to penetrate between the individual clumps of insulation (which in themselves were water repellent), water would track to the inside of the wall. This transfer tended to happen when free drainage between the weatherboards was blocked. Note again that this insulation was hand placed and therefore not necessarily representative of a commercial system.

Figure 4. With the lap joints of weatherboards sealed and no underlay, water was able to drain into the loose-fill insulation.

Figure 5. Example of water transfer to inside of loose-fill insulation. Water contains fluorescent yellow dye.

For the purposes of this report, a leak where the water begins at the outer face of the insulation is called a face leak. A leak that starts at a point between the two vertical faces of the insulation is called a body leak. It seems unlikely either bulk insulation or loose-fill insulation will cope with a body leak. A body leak could occur from a defect such as a leaking window flashing or a cladding fixing that has missed the framing that it was meant to be attached to. In practice, body leaks would be expected to be identified by the cavity inspection prior to installing insulation.

4.2 Full-scale tests

Following the preliminary drainage trails, the results were discussed with members of the insulation industry. Based on their feedback, a full-scale test method was investigated in conjunction with loose-fill insulation installed using commercial blowing equipment. As part of this work, an existing test method developed by the British Board of Agrément (the BBA test) was considered along with a modified version of

E2/VM1, a Verification Method for Building Code clause E2 *External moisture*. E2/VM1 is specifically designed for use in conjunction with claddings over a drained and vented cavity. However, there are elements of the procedure, specifically the wet-wall test, that examine the ability of a cladding in and of itself to resist water transfer further into the wall, which lends itself to the application in hand.

4.2.1 Description of BBA and E2/VM1 test methods

BBA test specification

BBA Technical Report No 3 includes a description of the standard BBA test specification. The test parameters are "generally accepted … to be extreme and are designed to ensure that cavity wall insulation systems are sufficiently robust to withstand all exposure zones in the UK, given correct specification and installation" (BBA, 2016, p. 5).

The BBA test is summarised as follows:

- Double-leaf brick walls are constructed in the test booth. Two walls are tested at once, one on each side of the test booth, such that the wetted leaf faces the inside and forms the sides of the pressure chamber.
- Each wall is calibrated. Water is delivered from a sparge pipe at the top of each wall. The flow rate from the sparge pipe is varied so leakage through the wetted leaf reaches specific rates corresponding to the booth pressure as listed in Table 1.

Table 1. Cavity from rate versus pressure.

Air pressure (Pa)	Cavity flow rate (l/min)
0	0.3 ± 0.1
250	0.8 ± 0.1
500	1.4 ± 0.1

- The walls are insulated.
- The calibration sparge flow rates are then used for three 5-day tests, one at each pressure level (0, 250 and 500 Pa). The duration of wetting per day is 8 hours.
- The inner walls are then disassembled and presence of water ascertained visually.

E2/VM1

E2/VM1 is the test method for proving the weathertightness of wall claddings on low-rise buildings within the scope of NZS 3604:2011 *Timber-framed buildings* and that incorporate a drained and vented cavity. It was derived from AS/NZS 4284:2008 *Testing of building facades*.

E2/VM1 uses a spray rate of 3 L/min.m^2, which is uniformly applied over the face of the wall, not just at the top as in the BBA test. The resultant leakage past the cladding is not measured as part of an E2/VM1 test.

Several water penetration tests at different test-booth pressures are performed in E2/VM1 (all of 15 minutes duration):

- A steady pressure of 455 Pa.
- A cyclic pressure going from 455–910 Pa.
- A steady pressure of 455 Pa with defects in the cladding.
- A cyclic pressure going from 455–910 Pa with defects in the cladding.

- A wet-wall test of 50 Pa. Here the pressure is only across the cladding (with defects), not the entire wall.

E2/VM1 primarily checks that a cladding's drainage cavity functions. Water that penetrates the cladding must not reach the plane of the underlay.

Drilling holes in the outer layer of the cladding attempts to test the effect of workmanship errors. Will the cavity (nominally 20 mm wide in E2/VM1) still drain water away even if some defect allows water in?

The wet-wall test is unique among international water penetration standards and is arguably the toughest part of the test because it stresses the cladding itself. It ensures the cladding offers a degree of protection Specific assessment for that part of the test is as follows in E2/VM1:

> Water which is able to penetrate to the back of the wetwall through introduced defects and joints must be controlled. It may contact battens and other cavity surfaces, but no water shall be transferred to the plane of the wall underlay, cavity air sealing or structural framing due to a design or systemic failure. Water that may arrive on the underlay due to an 'isolated blemish' may be disregarded. No water may drip through an airspace within the cavity where it is possible for water to impact on a surface in the cavity and splash onto the wall underlay. However, any spattering of water into the cavity through the introduced defects shall be ignored.

4.2.2 Comparison of the two methods

An obvious difference between the BBA test and E2/VM1 is that the former is associated with masonry walls and the latter is associated with timber-framed walls. However, neither is directly applicable to the case in hand, which is water leakage through weatherboards that are directly fixed to the timber framing.

The spray rates are different in the two tests in respect to both the location of wetting and the amount. The BBA test has a sparge pipe at the top of the wall, and the water flow rate is then adjusted to deliver the target leakage rate across the entire inner face of the brick. In E2/VM1, the water delivery is uniform across the outer face. In the case of weatherboards, the only leakage will be through any natural or introduced defects.

In the non-wet-wall parts of an E2/VM1 test on a cavity system, it is likely the drainage cavity will be pressure equalised and therefore the leakage though the defects will be dependent mainly on the run-off rate down the cladding and the size of the defect. In the wet-wall test, the leakage should be higher, because there is a 50 Pa pressure difference acting to force water through the defect as well.

If the E2/VM1 procedure was used on a direct-fixed cladding, the relative airtightness of the different layers (cladding, underlay, interior lining) would determine the pressure drop across each component. Therefore, in the non-wet-wall parts of the test, varying leakage rates could result for different test specimens, which would be an undesirable inconsistency. However, in the wet-wall test, the cladding would have to manage a consistent leak, i.e. that through a 6 mm hole under a pressure difference of 50 Pa.

4.2.3 Selection of the E2/VM1 test as a basis for full-scale tests

Given that E2/VM1 is intended for use with timber-framed walls, contains aspects of water management through non-brick claddings and is recognised in the Building

Code, it represents a logical choice as a basis for a test method for loose-fill insulation in New Zealand. The wet-wall test asks claddings to manage a known leak without systematically transferring water to the framing, and this requirement, if met, would demonstrate that a loose-fill insulation system could manage water in and of itself. The other advantages over the BBA test method for this particular application are that it is a quicker test to perform, meaning that development work could be performed more quickly.

4.2.4 Thermography and sample images

To modify the E2/VM1 wet-wall test for the purposes of evaluating loose-fill insulation in direct-fixed weatherboard walls, a means of assessing water transfer is required. Thermal imagery has been chosen as the primary means to do this because it allows visualisation of wetting both when the internal linings are still in place and during disassembly. It also allows for a time-lapse video to be created of the whole test and an easy comparison with the baseline uninsulated case after insulation has been removed. The following sections discuss a number of features that the thermal imagery allows assessment of.

Example of an uninsulated wall

Figure 6 shows the leakage pattern of an uninsulated wall after the linings have been removed. This is the baseline comparison case. It shows the tendency for water to drain back out of the weatherboards between the lap joints (short dark-blue vertical lines).

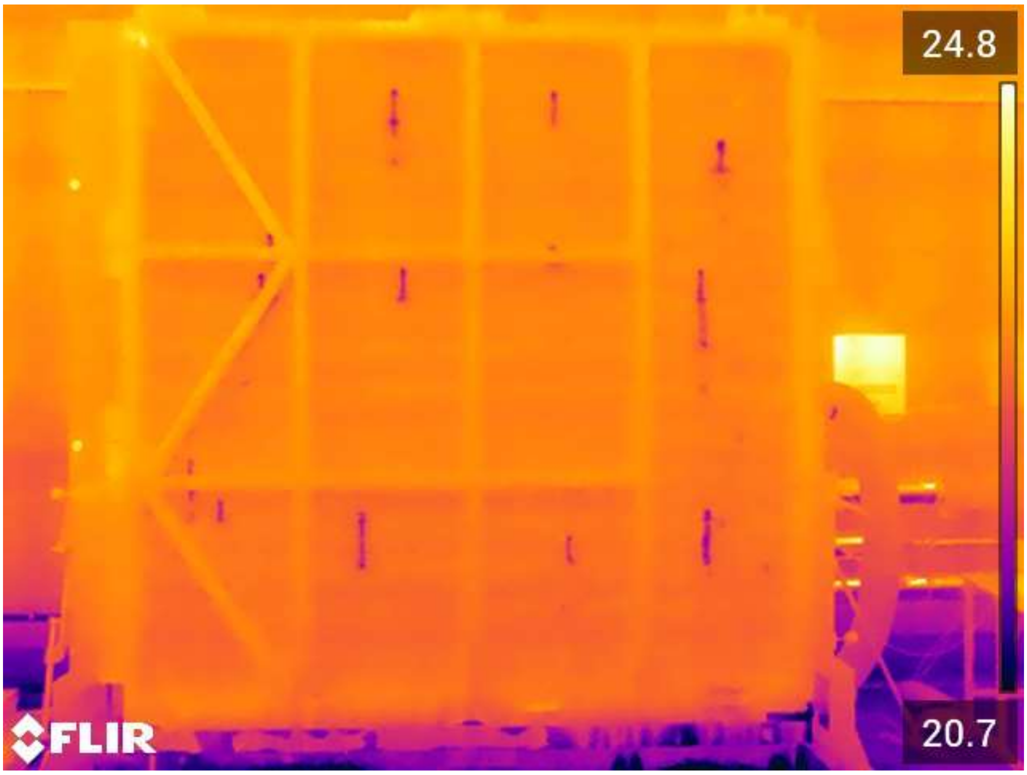


Figure 6. An uninsulated wall without lining.

This also highlights the difficulty of introducing a known water entry rate since the actual rate is a moot point if it leaves the wall at the next lap joint. For example, whether you are introducing 10 ml a minute or 100 ml a minute, the effective wetted area in the inside of the claddings is likely to be very similar.

Example of an uninsulated wall with underlay

Figure 7 shows the effect of having an underlay (building paper) against the back of the weatherboards. None of the water was able to transfer through the underlay or onto the framing. Adding 50 Pa pressure across the weatherboards and underlay appears to have had minimal impact on the amount of water transferred through the weatherboards. The test panel is not the same one as shown in Figure 6.

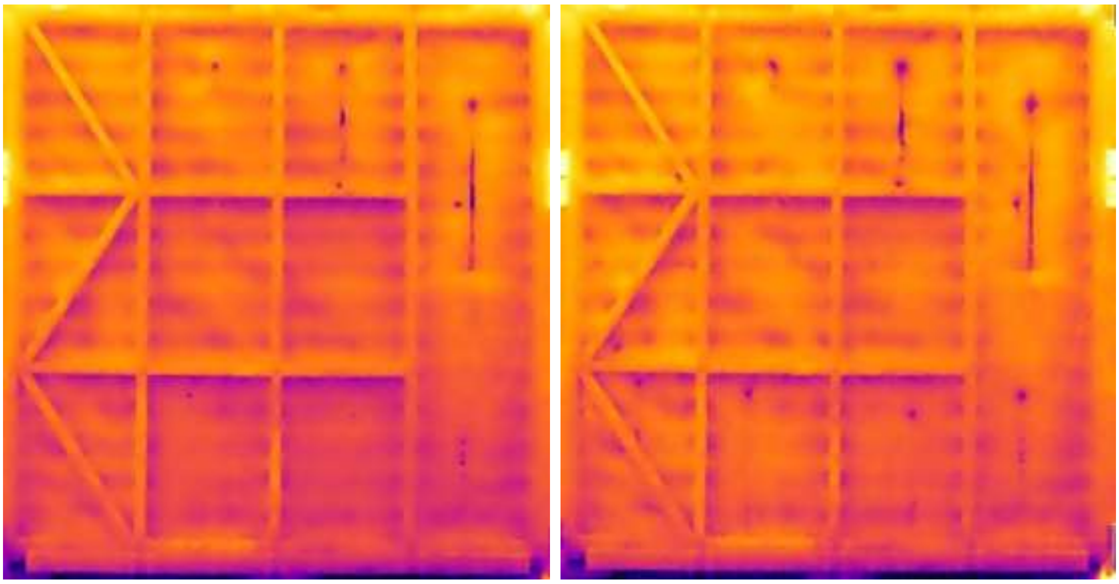


Figure 7. An uninsulated wall with underlay and without lining. Left images is without air pressure difference and right image is with 50 Pa across weatherboards and underlay.

Example of a full-scale test of an insulated wall with underlay where water has not been transferred

Figure 8 shows the start and end of a full-scale test of the wall from Figure 7 but after the inclusion of a lining and the installation of blown insulation. There is no evidence of water transfer past the underlay. This was further confirmed after removing the linings and insulation.

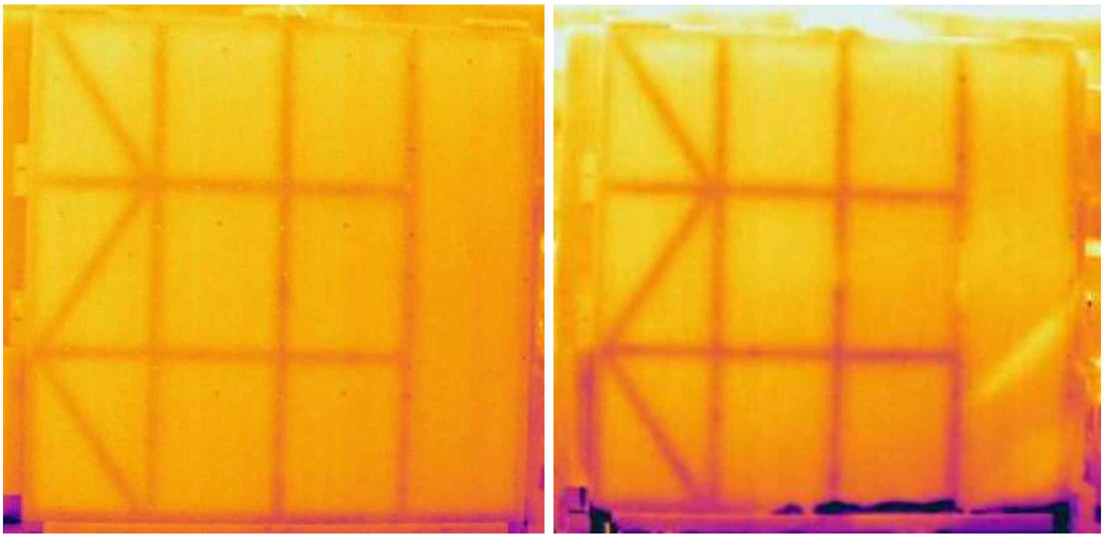


Figure 8. The wall with underlay from Figure 7 after adding lining and installing blown insulation. Left image is at the start of the test and right image is at the end.

This test had the same outcome when repeated using glasswool insulation segments and when repeated using dense polyester insulation segments.

Example of a full-scale test of a wall without an underlay where water has been transferred

Figure 9 shows the surface of the interior lining after the test on an insulated wall. The cold spot at the bottom right is not associated with moisture but more likely is the result of airflow through the installation hole. Water transfer through the insulation to the back face of the interior image is visible near the centre of the image.

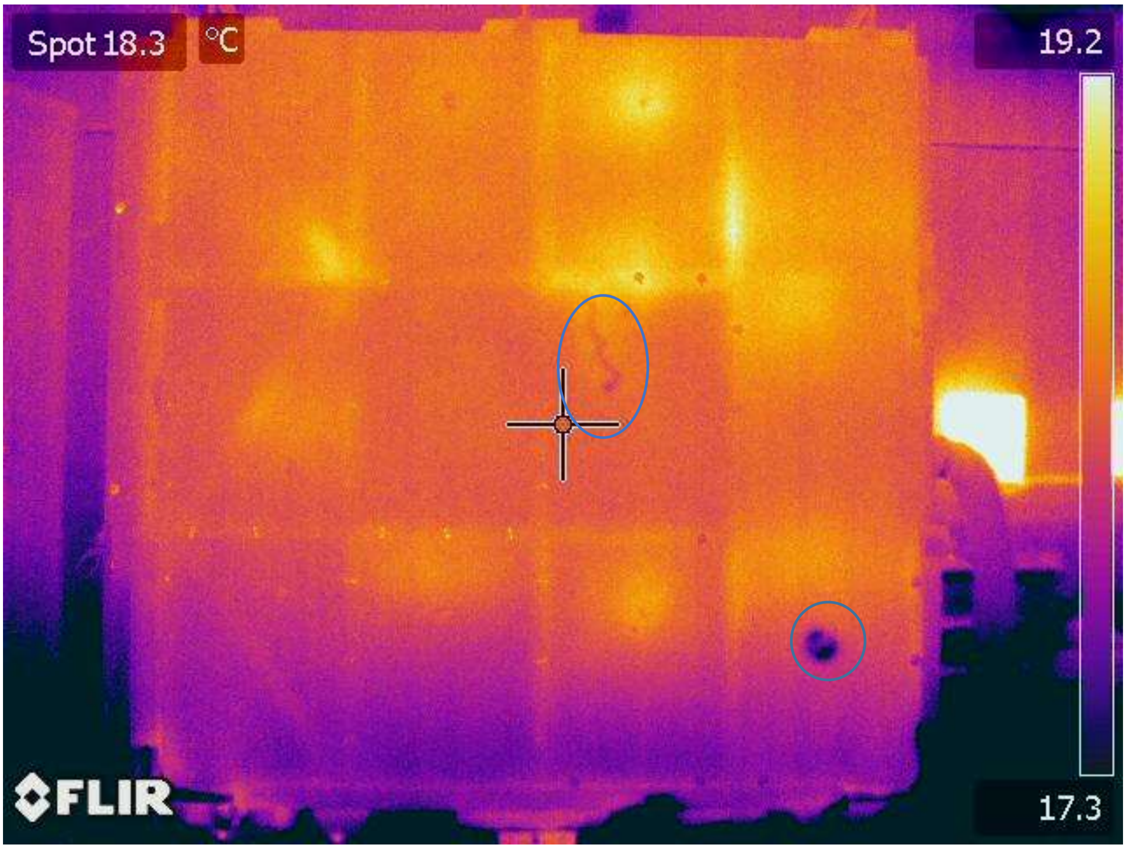


Figure 9. A wall where water has been transferred (marked in the centre of the picture). The cold area marked in the bottom right is believed to be from airflow and not water.

Figure 10 was taken during disassembly of the same wall specimen. The interior lining is being held up to display its inner face, which had been against the surface of the insulation. The water on the surface of the insulation in that cavity is clearly visible, and the two water patterns match. The insulation has already been removed from the five cavities in the bottom left corner of the wall. In the bottom row and right-most of those five cavities, water tracks are visible on the back of the weatherboards.

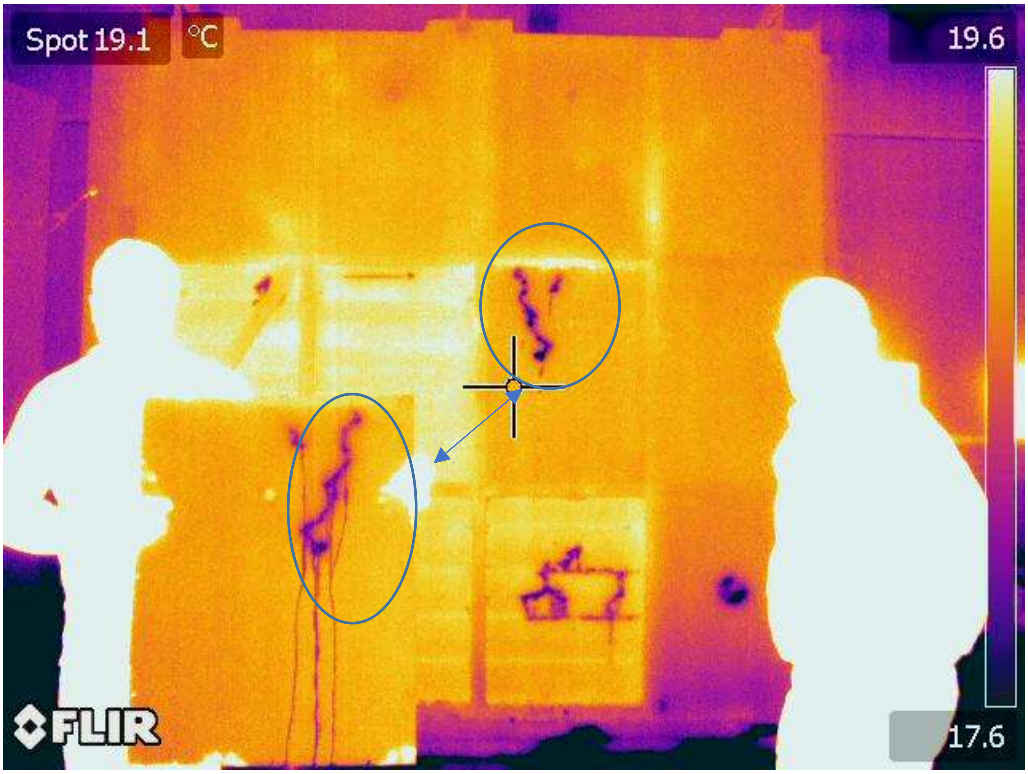


Figure 10. Disassembly of a wall where water transfer has occurred. The pattern on the back of the lining matches the pattern on the surface of the insulation.

Example of test where no water transferred

Figure 11 is from a different test to that shown in the above section.

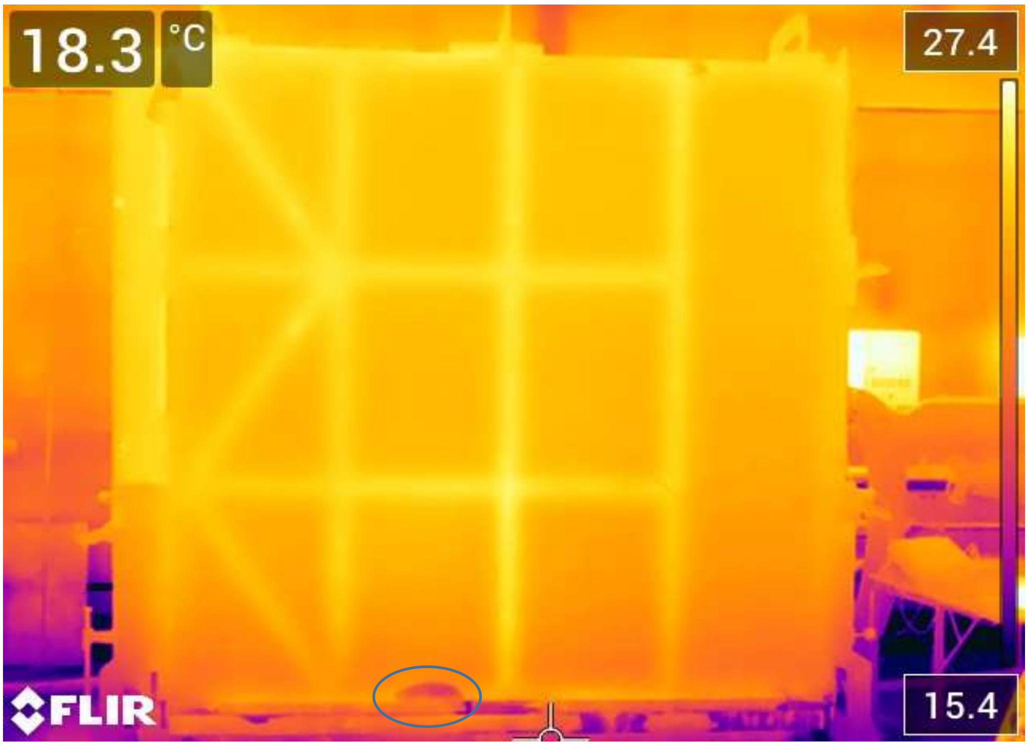


Figure 11. A wall where water transfer has not been detected. The area marked above the bottom plate is believed to be from a flaw in the connection to the test apparatus.

In this instance, no water transferred to the interior was detected. The cold spots at the bottom of the wall are due to a water leak that arose from how the test specimen was sealed to the booth. The image shows the wall before the lining was removed. In this instance, the areas of the wall thermal bridged by framing appear warmer and not colder because the inside of the test box (the other side of the wall) is warmer than the laboratory. The water being sprayed against the wall is recycled so will have been heated by the air, making it more difficult to detect any moisture transfer that may have occurred.

Figure 12 shows the wall specimen from Figure 11 during disassembly. The wetting around the defects can be seen to be different to that in Figure 6, but the presence of the insulation does not seem to have caused the water to track further into the wall or across to the studs. However, as noted for Figure 11, the framing in this instance is warmer than the ambient environment in the laboratory so any water tacking may have been masked by the additional heat coming from the elevated air temperature on the other face of the test wall.

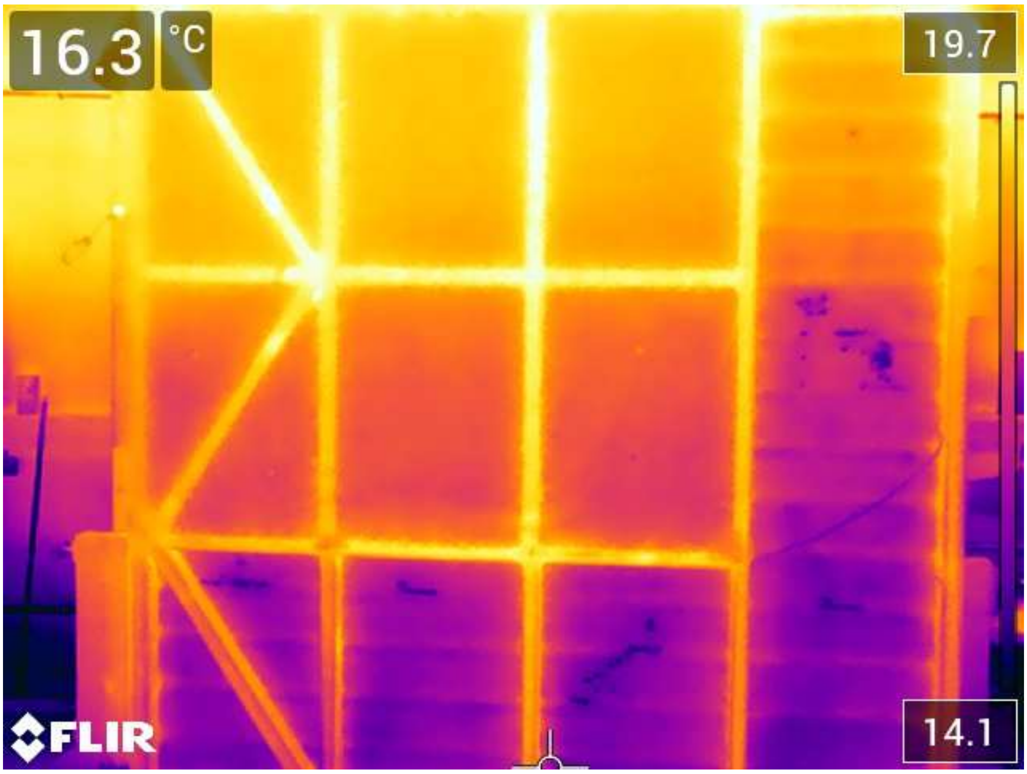


Figure 12. Disassembly of a wall where water transfer hasn't occurred.

5. Discussion

There is a clear need to provide easier means to insulate walls in New Zealand, given the number of houses in the stock that remain uninsulated. Loose-fill insulation is one possibility for satisfying this need. However, given the nature of many New Zealand walls, i.e. direct-fixed cladding with no underlay, there is a potential risk of negatively affecting the water management of the wall by insulating it.

Figure 13 shows a decision tree for retrofitting wall insulation based on current BRANZ recommendations. Prior to this research, BRANZ's recommendation during a linings-off retrofit and discovering there is no underlay present would be to maintain a physical separation between the cladding and the insulation, thereby not interfering with the drainage process.

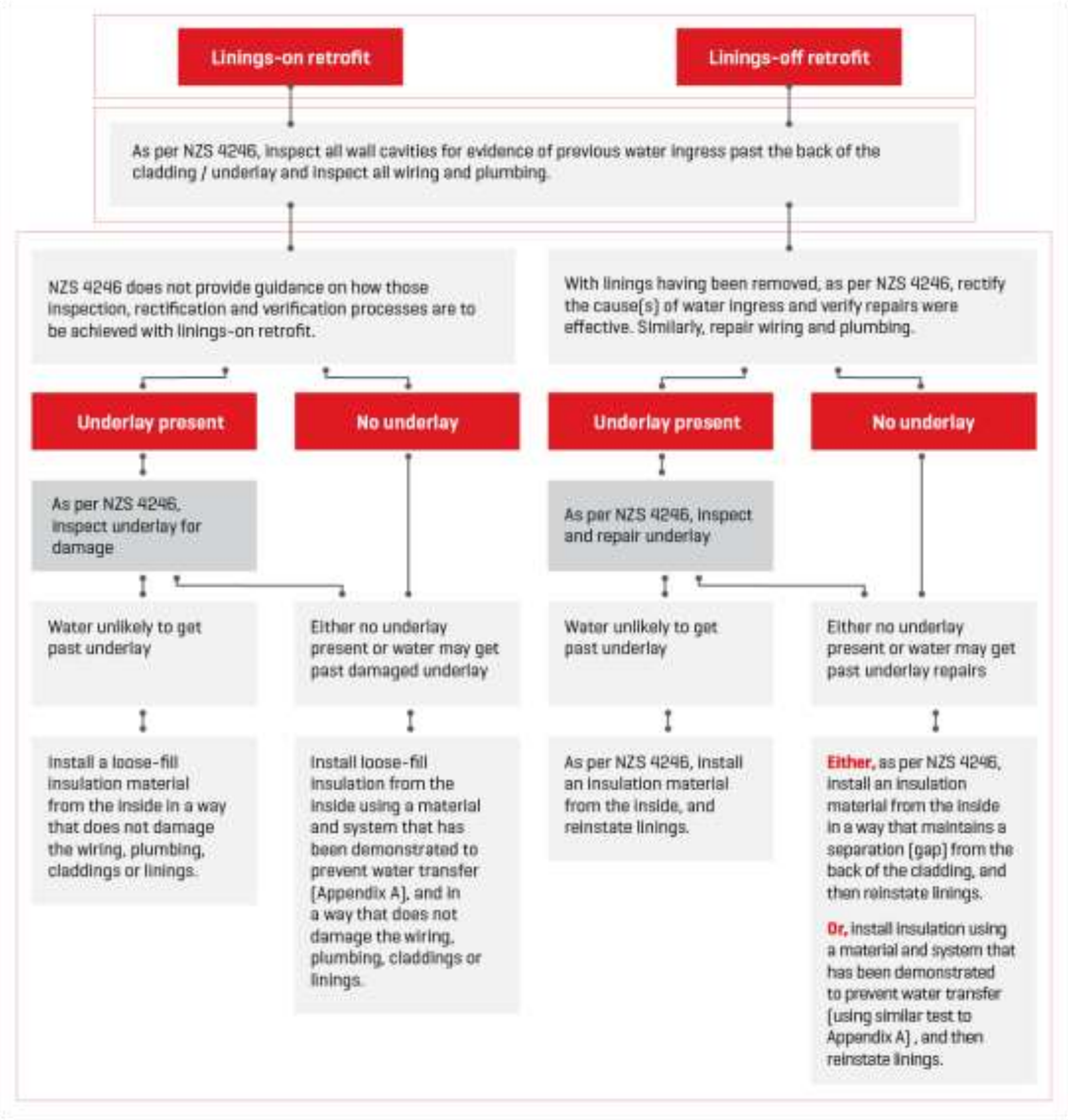


Figure 13. Decision tree for retrofitting a wall.

As a result of this research, there is a possibility of providing several more options for retrofit. If an underlay is present, loose-fill insulation can be installed without negatively affecting the water management of the wall. If an underlay is not present, loose-fill insulation could be recommended as an option if it can be proven to manage moisture to a similar level to what is required in the Building Code.

Elsewhere in the world, there appear to be no examples of timber-framed walls without underlay being retrofitted with loose-fill insulation. There are, however, cases where cavity wall insulation has led to moisture ingress. These instances have typically led to guarantee and quality control schemes being put in place by the industry and/or government in those countries.

In this research, we have developed a test method based on the existing E2/VM1 test method for claddings. The test method is outlined in the next section and described in detail in Appendix A. The test method is intended to be used as part of an assessment of an insulation system's suitability to be used in a wall without underlay and without the system leading to an increased risk of damage by water transfer. E2/VM1 requires claddings to be able to manage water through defects when there is a pressure of 50 Pa across the cladding. The method essentially asks the same of claddings when there is loose-fill insulation installed.

This research has shown that both bonded and loose-fill insulation can be installed behind an underlay and not lead to increased moisture transfer. This provides great scope for the widespread retrofit of New Zealand walls.

The research has also shown that, without an underlay present, water transfer can occur irrespective of whether the insulation material itself is hydrophobically treated. It does appear it may be possible, however, as indicated in Figures 11 and 12, to install hydrophobic insulation in a way that resists moisture transfer to the inside of the wall.

There is of course the wider question: What is a damaging leak? Would a wall dry out again before water could accumulate and cause damage? We are proposing that a conservative approach be taken in that no water should reach a potentially damaging location in the wall. The other way of reducing the risk of damage is to have less water transfer through the cladding in the first place. Taken to the extreme, i.e. no water penetration through the cladding, this approach would mean you could use any insulation product or system and no transfer would occur. In reality, we know some water tends to get past the cladding for a variety of reasons, and therefore we need to know that incidental leaks can be managed effectively.

There is another wider question at play here as well: What level of failure, at a stock level, is acceptable? If a proportion of walls without underlay fail after being insulated and the failure can be cost-effectively detected and fixed by repair or removal, is that outweighed by those that don't fail and now contribute to the occupants living in a more thermally effective house? This could potentially be explored in conjunction with field trials of real installations.

Overall, this research provides an avenue for many existing walls to be safely insulated more easily than before by providing a method for assessing the water management performance of walls in those cases where an underlay isn't present. It may, however, still be prudent to have a scheme such as the UK's CASS system to reduce the chance of insulating unsuitable walls.

6. Overview of the evaluation method

Appendix A contains an evaluation method assessing the water management behaviour of blown-in wall insulation based on the findings from the current research. The test consists of subjecting a wall to a consistent leak arising from a water spray of 0.05 $l/m^2.s$ over the face of the cladding, a 50 Pa air pressure difference across the cladding and a series of 6 mm diameter holes (to simulate defects) through the cladding. Thermal imagery is used as the primary means of assessing whether water has transferred to the inner parts of the wall.

This test is only aimed at assessment of face leaks at the interface between the back of the cladding and the adjacent face of the insulation (face leak). Systems that pass this test may not necessarily cope with the more challenging aspect of leaks into the bulk of the insulation (body leak) such as what can occur when a window or door flashing leaks or a flaw such as where water is able to travel along a cladding fixing nail that has missed a stud.

The tests in the evaluation method shall be undertaken in a test facility with IANZ or equivalent accreditation to ISO/IEC 17025:2017 *General requirements for the competence of testing and calibration laboratories*. This test in the first instance is restricted to the case of a plain, timber-framed test wall with direct-fixed weatherboard cladding. The general principles could however be used for tests of other scenarios such as a test wall that incorporates a feature such as a window.

The use of thermal imaging cameras requires considerable care, especially in uses such as this where unsuitable conditions, equipment, experience and/or interpretation of the images are more likely to result in the thermal effects of water transfer being masked or missed in the analysis. Confidence in the process of test and analysis requires at least some incidences where relatively small amounts of water are transferred. An artificially created progressively increasing leak into the body of the insulation would be one way that aspect could be checked.

The minimum required quality of thermal imaging camera is unknown other than the fact that the two cameras used by BRANZ staff to develop this test method were generally found to be good enough, but on occasion were stretched to the limits of their resolution and sensitivity. A key factor was temperature uniformity and stability of the environment, including the test wall, air temperatures on both sides, and water temperature.

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ISO/IEC 17025:2017 *General requirements for the competence of testing and calibration laboratories*

Appendix A: Evaluation method for assessing the water management behaviour of blown-in wall insulation

Abstract

This evaluation method represents a test method to determine whether water can transfer off the back surface of direct-fixed weatherboard cladding without an underlay when loose-fill insulation is retrofitted by being machine blown into timber-framed walls. If, after repeated testing of an installation system (material, density and process), there is no evidence of water being transferred, there can be more confidence that such installations will not compromise the water management ability of the retrofitted walls.

Parameters

- Series of 15 x 6 mm diameter holes through weatherboard cladding to provide small streams of water onto the back of the cladding.
- Water spray rate onto the face of cladding consistent with E2/VM1 of at least 0.05 l/m^2.s.
- Constant air pressure of 50 Pa.
- Test time of 2 hour.
- Thermal imaging of the surface of the lining during the test, surface of the insulation after removing the lining at the end of the test and empty wall cavity after removing the insulation. Thermal imaging and visual observation after removing the insulation are the means for detecting the transfer of water.

Contents

1. General

This evaluation method represents a method of testing for water transfer when blown-in insulation is retrofitted into a timber-framed test wall that has weatherboard cladding that is directly fixed without an underlay. The aim is to provide a test procedure including infrared thermal imaging that can be reliably repeated to assess the impact, if any, that the insulation process might have on the ability of a wall system to manage inadvertent leaks in the cladding. The tests in the evaluation method shall be undertaken in a test facility with IANZ or equivalent accreditation to ISO/IEC 17025:2017 *General requirements for the competence of testing and calibration laboratories*.

The parameters have been developed from research funded by the Building Research Levy and a partnership engagement with an industry stakeholder. This test method is loosely based on the New Zealand Building Code clause E2 *External moisture* Verification Method E2/VM1, in particular the wet-wall component of that. E2/VM1 applies to wall systems that including a cavity behind the cladding, so this method is necessarily significantly different. The principal similarities are use of a minimum spray rate of 0.05 $l/m^2.s$, the use of 6 mm diameter holes as water entry points and the use of static pressures.

2. Scope

It is intended that this test method is used as the initial assessment of suitability of retrofit blown-in systems for use with houses that either don’t have a wall underlay or have an underlay where it is not possible to be confident it is fully functional without removing the lining.

The scope is restricted to laboratory test specimens and set-ups where:

- the walls fit within the field of view of the thermal imaging camera whilst still maintaining a resolution that can detect features such as a narrow stream of water
- construction is identical to the wall specimen described here
- the test specimen is not disturbed or altered after installation of the insulation.

Comment

Removing and reattaching the lining appeared to alter the water transfer behaviour of one of the test walls (it appeared to reduce the water transfer). Rough handling or moving of the testing specimen could cause the same effect. It is recommended that either the plasterboard is replaced with new board for each new test, or a fixing method used that doesn’t weaken with successive reattachment.

3. Specimen details

The minimum size of the wall specimen to be tested shall be 2.4 m high by 2.4 m wide. The wall framing shall be as shown in Figure 1, and cladding shall be 185 mm high bevel-backed pre-primed weatherboards. The 9.5 mm thickness plasterboard lining shall be cut into 12 pieces approximately 600 mm wide by 800 mm high.[10] For the tall cavity, the three sections of lining will need to be taped during the installation of the insulation and testing of the sample. New plasterboard lining should be used for each test. No other joints in the plasterboard should be taped – the intent is that most of the pressure difference is across the cladding, not the lining.

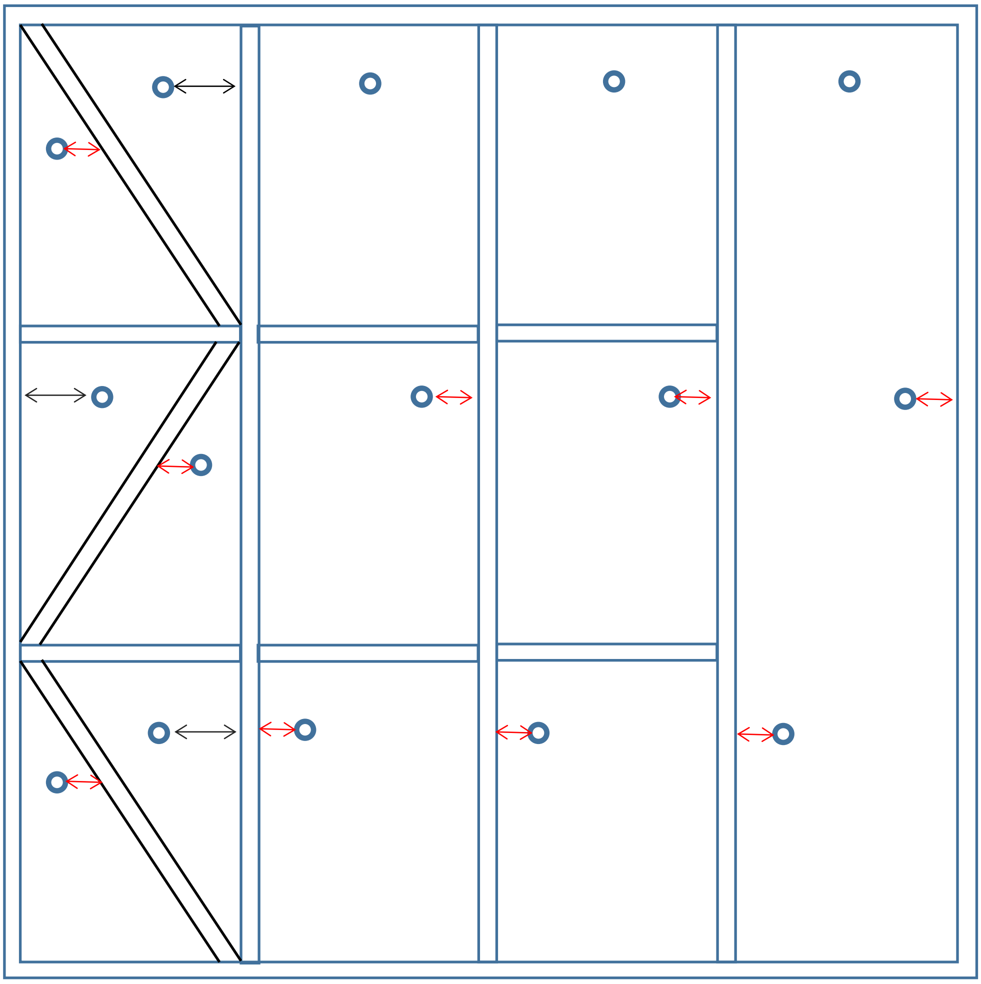

Figure 1. Wall framing layout for test specimen.

3.1 Leak points

One leak point shall be installed near the top of each of the 12 smaller frame cavities, and a further three leak points shall be installed in the large frame cavity at the locations shown in Figure 1. The leak points are 6 mm diameter holes drilled through

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[10] Plasterboard segments are used so that they can be individually removed for inspection and to facilitate weighing of the insulation at the end of the test. Development testing at BRANZ has shown that this has a negligible effect on the nature of the leak through the defects or the propensity for water transfer to occur when compared with the use of full-size sheets of plasterboard.

the thick (non-bevelled) part of the weatherboard. The holes are to be drilled perpendicular to the face of the cladding. All holes are to be drilled through the area of the weatherboard with parallel faces, away from overlaps. Holes should be spaced 50 mm from framing where indicated in red, and 240 mm where indicated in black. Plugs need to be placed in the leak point holes during the installation of the insulation.

3.2 Pressure measurement

As well as measuring the booth pressure, a pressure tap shall be available in the large frame cavity compartment to enable the pressure difference across the cladding to be measured. The pressure trap should be close to the back of the cladding.

3.3 Water management without insulation

Before testing the wall with insulation installed, the wall shall be tested without insulation or wall lining using the test procedures described as a reference point for the water management ability.

4. Test procedure

This method comprises the following test steps:

- Initial pressure checking without water.
- Pre-wetting without pressure.
- Pre-conditioning with pressure and water but no leak points open.
- Testing at 50 Pa with at least 0.05 l/m^2.s water spray and 15 leak points open.
- Removal of lining and thermal imaging of insulation surface.
- Removal and weighing of insulation from each frame cavity. Thermal imaging of empty frame cavity.
- Visual inspection of empty frame cavity for water transfer onto framing.

4.1 Initial pressure check

Apply a pre-conditioning pressure load of 50 Pa across the cladding of the test sample for a period of 1 minute with the leak point plugs removed. There should be no significant pressure in the frame cavity, but if there is, the pressure applied to face of the cladding needs to be increased to still provide the necessary 50 Pa across the cladding. Check with the thermal camera that the test sample is at a suitable temperature and that the temperature is uniform across the surface of the lining. Ideally, the framing should not be visible because everything is at the same temperature. Check that the water is cold enough to provide a significant temperature difference from the framing and insulation temperature. Start the time-lapse recording of both the thermal and visual images at the maximum rate of one a minute.

4.2 Pre-wetting

With the leak point plugs installed and the pressure off, apply water spray for 5 minutes at the rate of 0.05 l/m^{2}s. Ensure that any water leaks from the spray box are not going to interfere with detection of water transfer onto the framing around the perimeter of the test sample.

4.3 Pre-conditioning

With the leak point plugs installed, apply both 50 Pa pressure and 0.05 l/m^{2}s water spray for a period of 30 minutes. It is important to wait until the pressure has stabilised before adding the water spray to avoid a spike in the pressure causing water to get forced through the weatherboard overlaps. This pre-conditioning cools the cladding to a uniform temperature close to the temperature of the water so that the water leaks are not heated as they flow through the holes in the cladding.

It is important that there is no inadvertent water bypass around the sides and along the bottom of the test panel. This has potential to mask water transfer caused by the presence of the insulation and needs to be eliminated so that those areas of the test sample still form a valid part of the test. For instance, it is important to test the ability of the water coming down the back of the cladding to drain out at the point where the bottom of the cladding overlaps the bottom plate. The outer edge studs of the sample represent a situation that occurs in practice, and the characteristic of the insulation installation and the way the water drains may well be different than what occurs away from the edges at the other studs.

4.4 Testing

Turn the pressure and water spray off and remove the leak point plugs. Turn the 50 Pa pressure on first and wait for it to stabilise before turning on the 0.05 l/m^2s water spray. Run the test for a period of at least 120 minutes.

4.5 Removal of lining

Each of the 12 sections of lining are to be removed in turn, starting at the top and working down. The water load is less at the top of the wall, so the impact of a leak is likely to be shorter lived and less noticeable, hence the need to inspect and thermal image that area first. The lining to the tall cavity needs to be removed top to bottom because of the high risk of insulation falling out. Remove all 12 sections of lining and thermal image the full insulation surface area before starting removal of the insulation.

4.6 Removal of insulation

As with the lining, remove the insulation in sections from top to bottom. Thermal imaging of the insulation immediately after removal may provide some qualitative assessment of water transfer into the insulation but needs to be considered in conjunction with the expected water that will be on the insulation where it has touched the back of the cladding. As the primary means for evaluating water transfer is the thermal imaging and the visual inspection of the framing for dampness, there is not necessarily a need to weigh the sections of insulation other than if confirmation is needed that the target density is being achieved or that the density is uniform.

4.7 Inspection of empty frame cavity

Inspect the empty wall cavity to determine visually if water has been transferred to the surface of the framing.

4.8 Evaluation criteria

The individual test pass criteria are that there is no evidence of water being transferred either into the insulation or onto the framing other than on the face of framing that is against the back of the cladding. Water should not reach the sides of the studs, the top and bottom surfaces of the dwangs or the top of the bottom plate. Poor thermal conditions may mean there is insufficient resolution to be certain of detecting water transfer into the insulation even though, after removing the insulation, there is no evidence of water transfer onto the framing. Running the test for the extra hour will provide some confidence, but obviously the decision to extend the test needs to be made without the benefit of knowing whether water was transferred to the framing during the first hour. Without knowledge of the drying behaviour of water that gets transferred, the ideal scenario is to have no water transfer at all. If water continues to drain out without getting past the back of the cladding as it does without the addition of the insulation, there is some confidence that the addition of the insulation is not altering the water management ability, regardless of the presence of leaks.

The full pass criteria are that there is a pass for two nominally identical wall samples and there is a pass for repeats of both samples.

5. Reporting

The test report shall contain the following:

- Test date and report number.
- Confirmation that this is an EM_ test without modification.
- Testing agency contact details and IANZ accreditation number (for ISO/IEC 17025).
- Identification of IANZ-accredited test officer and other persons attending the test.
- Name of client and specifier.
- Any deviations from the official test method.
- Detailed specimen description, including drawings. All materials must be uniquely identified and not described generically.
- The results of each test and relevant observations on the behaviour or performance of the test samples with a summary of each test result as acceptable or unacceptable. This shall include the pressure in the frame cavity during the test.
- Photographs of the system under test.
- A summary statement of overall conformance or non-conformance.
- Time-lapse thermal images of the empty frame cavity under test without lining attached.
- Continuous series of time-lapse thermal images of the sample under test from the initial pressure check at the start through to the removal of the insulation and inspection of the empty cavity.
- Photographs of the empty frame cavity including any evidence of water on the framing.

6. Referenced documents

AS/NZS 4284:2008 *Testing of building façades.*

ISO/IEC 17025:2017 *General requirements for the competence of testing and calibration laboratories*

New Zealand Building Code Verification Method E2/VM1 *External moisture*, 3rd edition, Amendment 7 (2017).