STUDY REPORT

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Drainage Planes and their Applicability in New Zealand

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Summary

Drainage planes are a new class of product that can sit behind a wall cladding and form a cavity. Drainage planes offer designers more freedom in cavity wall design and potential cost savings compared with traditional timber cavity battens.

The BRANZ drainage plane study detailed in this paper was funded by the Building Research Levy. The purpose of the study was to understand how drainage planes would perform when faced with the construction styles and climate found in New Zealand. Specifically, we aimed to clarify where drainage planes belong in the risk matrix of the Acceptable Solution to Clause E2 External Moisture (E2/AS1) of the New Zealand Building Code.

The performance of drainage planes was assessed using the following techniques:

- Drainage and drying tests of 20 specimen walls under real weather conditions.
- Measurement of ventilation in the drainage space.
- A modified Verification Method (E2/VM1) for assessing water transport to the wall underlay.

The conclusions were that:

- The performance of drainage planes depends on the particular type of product.
- Drainage planes need windows to be flashed in a similar way to direct-fix claddings.
- The proprietary nature of drainage planes may be unsuitable for E2/AS1 and would then need to be treated as alternative solutions.
- If drainage planes were to form part of an Acceptable Solution (E2/AS1) then the minimum finished cavity thickness in E2/VM1 would need to be changed to 10mm.
- The cavity formed by most drainage planes is robust enough to prevent insulation bulging and blocking the drainage path.

The BRANZ drainage plane study has led to a subsequent levy-funded project evaluating using drainage planes to act as a capillary break between retrofitted insulation and the cladding in houses that have no building paper attached to the framing. This spin-off project is due to be completed in 2013.

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1. INTRODUCTION

1.1 Wall Claddings and Weathertightness

Clause E2 (External Moisture) of the New Zealand Building Code[1] requires buildings to provide adequate resistance to the entry and accumulation of external moisture.

The Acceptable Solution for External Moisture (E2/AS1)[2] comprises a set of design details that are deemed to comply with the building code. Depending on the “weathertightness risk score”, walls may require a drained cavity to be incorporated as part of the cladding system. A drained cavity allows water which occasionally penetrates the cladding system to drain to the exterior of the building and any remaining moisture to dry by evaporation.

Drainage planes are a new class of building product that can sit behind a wall cladding and form a cavity. This report details the findings of the BRANZ drainage plane study designed to understand how drainage planes would perform when faced with the construction styles and climate found in New Zealand.

This study aimed to answer questions about what happens to water when it gets behind the cladding and how does the behaviour compare with traditional drained cavity walls and direct-fix walls, such as:

- Does the water reach the line of the framing?
- How long does the wall take to dry – how is this dependent on the location of the water?

2. BACKGROUND

2.1 What is a Drainage Plane?

The BRANZ drainage plane study focuses on products that sit behind the cladding and form a cavity (see Figure 1). In New Zealand, these products have been called drainage planes and that convention is used in this document. Elsewhere in the world, drainage planes are called drainage materials, drainage mats, rainscreen products, drainage products and rainscreen drainage planes.

Strictly speaking, the term *drainage plane* refers to any surface next to an air gap that allows water to flow. In a “normal” cavity wall, the main drainage plane (for water to drain away) is the inner face of the cladding. While the emphasis of cavity wall construction in New Zealand is to prevent water reaching the wall underlay, the wall underlay must also be designed as a drainage plane. The wall underlay is generally lapped shingle fashion, *just in case* water does reach this area.

In other countries, drainage planes are often used in conjunction with traditional stucco plaster. Because this plaster is rarely used in New Zealand, it is perhaps helpful to see these products simply as a substitute for the cavity battens used in the drained cavity system in E2/AS1.

2.2 Classes of Drainage Planes

A wide variety of drainage planes exists. For example, all of the following can be classed as such (see Figure 1):

1. Textured wall underlays.
2. Tangled mats of polymer filaments.

3. Relatively solid plastic channels (similar to tanking for foundation walls).

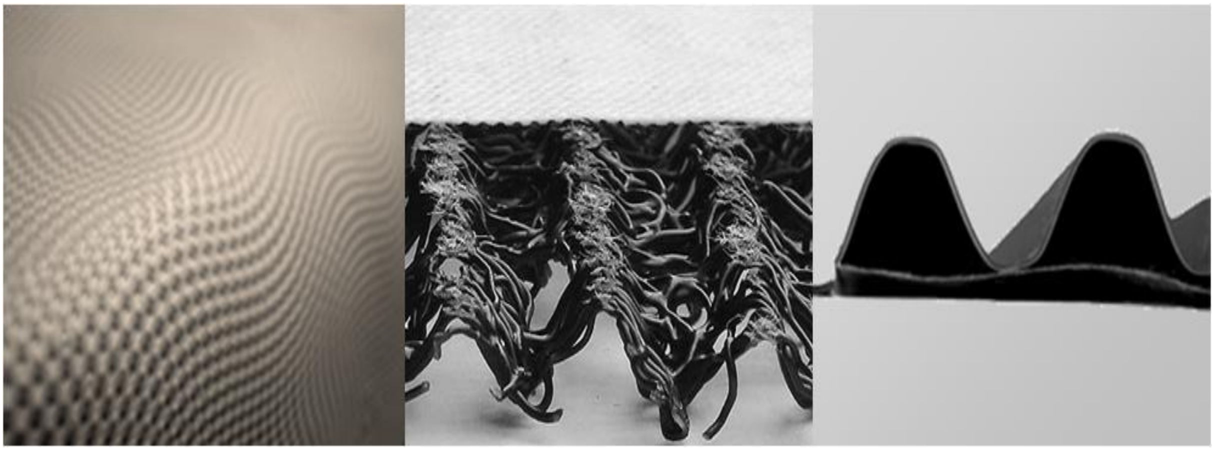

Figure 1 Classes of Drainage Plane used in this Study (Textured Underlay, Mesh Mats, Solid Channels)

Drainage plane products may also have a filter fabric, the purpose of which is to prevent stucco from blocking the drainage path. It will be shown that this filter fabric can affect how the wall manages water – even when traditional stucco is not employed.

2.3 Potential Cost Savings

A purported benefit of drainage planes is they offer potential cost savings. One manufacturer estimates the cost of material and installation is about US$1/sqft (about NZ$14/m^2). The cost of adding timber battens to a wall is approximately NZ$16/$m^2$ so the apparent cost saving would be marginal.[3] However, this will not be known for sure until the products are directly available from New Zealand and the true retail costs are known.

In New Zealand, a drainage plane will potentially have lower associated labour costs than normal cavity construction.

As an illustration of reduced labour costs, drainage planes can serve multiple purposes. Some drainage planes have an integrated synthetic wall underlay so using these products can form a drainage cavity in the time taken to wrap the framing. Using cavity battens, underlay still has to be fixed to the framing and each batten nailed to the studs. For drainage planes without an integrated underlay, the installation time is still less than the batten method – it is essentially the same as installing a second layer of wall underlay.

However, if drainage planes need extra flashings this would offset any potential savings.

2.4 Comparing Cavity Performance

Previous work at BRANZ[4] has found that a cavity speeds up drying from the cladding but not from the framing. With framing, the drying is limited by moisture transport processes in the wood. This previous work highlighted the importance of keeping the framing dry and that the main benefit of a cavity is it acts as a physical break between the cladding and the line of the framing. That work also showed that frame wetting could occur in direct-fix walls, although the source of the leak e.g. a defect in the underlay, or transport *through* the underlay was not established.

Figure 2 shows the expected construction style for drainage planes in New Zealand. Figure 2 also shows how the drainage plane material may permit water transport to the line of the framing by tracking along the filaments of a drainage mat.

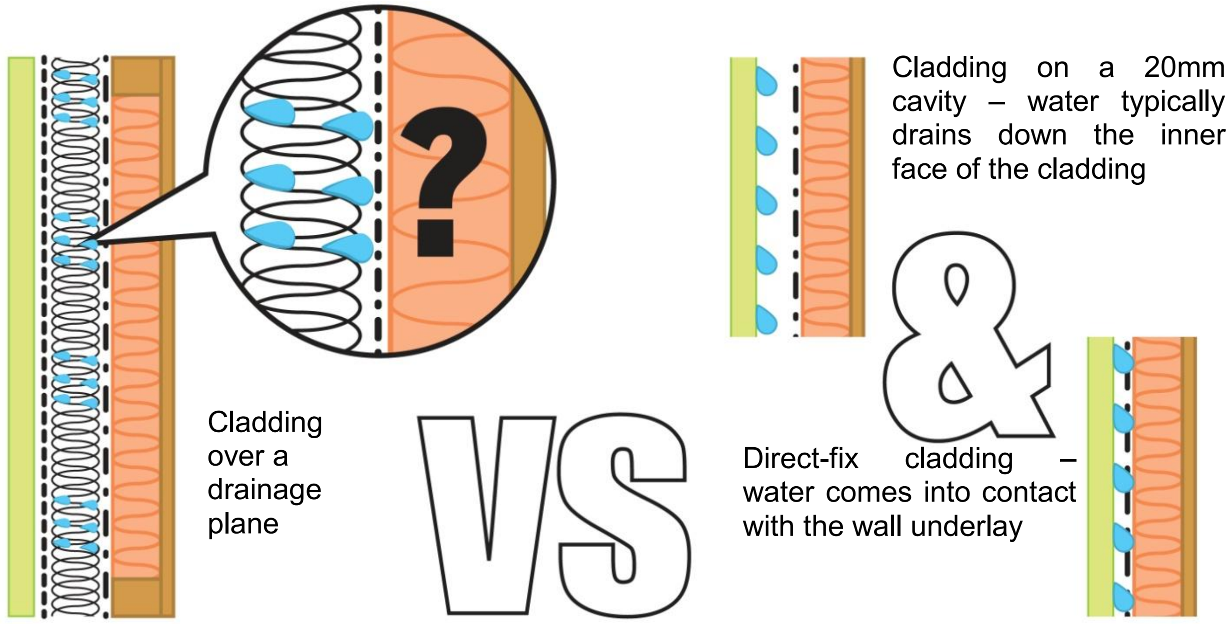

Figure 2 Drainage Planes and Traditional Options – Does Water Reach the Framing Line?

2.5 Drainage Planes in Other Building Codes

When comparing building requirements from other countries, Canada is often used as a comparison for New Zealand residential construction. The main reasons for this are a similarity of construction methods, a shared history of leaky building problems and a strong record of building science research.

For cavity walls, the New Zealand Building Code basically requires that no water will reach the wall underlay. This is emphasised in E2/VM1, the verification method for compliance of cavity walls in New Zealand. If water is present on the wall underlay, the specimen has typically failed E2/VM1.[2]

The verification method is valid for buildings that have claddings with a drained and vented cavity of at least 20mm depth with a minimum ventilation opening of 1000mm^2/m at the bottom of the wall.

By comparison, the National Building Code of Canada (NBCC)[5] assumes some water will reach the wall underlay – using the concept of first and second planes of protection. The first plane of protection is the cladding itself. The second is to be designed to intercept and dissipate any rain or snow that makes it past the first plane of protection (the cladding). This second plane of protection will usually take the form of rigid sheathing and wall underlay or two layers of wall underlay.

The NBCC also specifically mentions drainage planes (clause 9.27.2.2) and states the following:

A cladding assembly is deemed to have a capillary break between the cladding and the backing assembly, where:

- a) *There is a drained and vented airspace not less than 10mm deep behind the cladding, over the full height and width of the wall.*
- b) *An open drainage material, not less than 10mm thick and with a cross-sectional area that is not less than 80% open, is installed between the cladding and the backing, over the full height and width of the wall.*

3. PREVIOUS RESEARCH

3.1 Overseas Research

There have been relatively few studies about drainage planes overseas. Perhaps the most notable was that of Onysko.[6,7] That study measured drainage performance by weighing a wall specimen in the laboratory. It found the mass of retained water depended on the absorbency of the cladding, characteristics of the drainage media and the presence of moisture traps, e.g. starter strips and fixings. With large water loads (typically eight litres/hour distributed across 600mm of drainage cavity) the drainage materials retained a relatively small amount of moisture (0.3% to 1.4% or an average of 46ml). Half of the retained moisture dried out over the next two days.

3.2 Assessing Drainage Plane Performance

There is currently no standard to assess the performance of drainage planes. There are several types of water penetration tests or procedures which have been modified to derive drainage tests for particular classes of cladding, e.g. Exterior Insulation and Finish (EIFS) and masonry veneer, but not the drainage element itself. A number of water penetration and drainage tests were considered in the design of this study and these are outlined below.

3.2.1 ASTM E331 – 00[8]

ASTM E331 – 00 (2009) is a test for water penetration of exterior windows, skylights, doors and curtain walls. A minimum spray rate of 3.4L/m^2/min is used in conjunction with a pressure of 137Pa. If water penetrates past the vertical plane that intersects the innermost projection of the specimen, then the specimen has failed.

3.2.2 ASTM E2273 – 03[9]

ASTM E2273 – 03 concerns the drainage efficiency of Exterior Insulation and Finish Systems (EIFS) clad wall assemblies. The spray rate is in accordance with ASTM E331 and is applied to the wall for 75 minutes, with the total amount of water applied being 7950-8745ml. The water is directed through a slot in the cladding onto the weather-resistive barrier (or wall underlay) and the drained water is weighed and used to calculate drainage efficiency. No failure criteria are specified in ASTM E2273.

3.2.3 ICC-ES-EG356[10]

ICC-ES-EG356 is an evaluation guideline for moisture drainage systems used with exterior wall veneers issued by the ICC evaluation service. This document lists a number of ASTM tests that should be carried out when assessing a drainage system, including a modified version of ASTM E2273. Here the total amount of water is less (4875ml) and is introduced 975ml at a time at 15-minute intervals. A drainage efficiency of 90% is required to pass the test.

3.2.4 E2/VM1

In New Zealand, E2/VM1 is typically used to test the weathertightness of residential cladding systems that include a cavity. E2/VM1 is a series of water penetration tests based on the procedure of NZS 4284 – Testing of Building Facades.

The tests focus on the drainage characteristics of walls and how well the cladding deflects water. However, the emphasis in E2/VM1 is not on how much water drains, it is on where the water goes. Generally, if water hits the wall underlay, i.e. it has bridged the cavity, the test specimen has failed.

The amount of water the cavity has to drain depends on the cladding itself since water is applied to the cladding directly, not the drainage cavity. Water that enters the cavity will come through specifically-created holes in the cladding and faults, cracks and gaps that may be inherent in the cladding system.

E2/VM1 uses a slightly lower spray rate than ASTM E331 (3.0L/m^2/min) but a higher pressure. Further differences in E2/VM1 are the inclusion of cyclic pressures, water management testing (the inclusion of holes in the cladding) and a “‘wetwall” test (where the pressure difference is across the cladding – not the whole wall).

4. METHODOLOGY

4.1 Layout of the Study

This study has built on the earlier work of Onysko et al[6,7] by installing wall specimens in an outdoor facility so that they are subject to "real" climatic effects.

Most of the experimental work undertaken in this study comprised a series of drainage and drying tests on 20 wall specimens. Of those, 14 had drainage planes of some description and were constructed specifically for this study, with the other six being traditional wall types already installed in the hut: open rainscreen; direct-fix; and brick veneer. The wall specimens were installed in the BRANZ weathertightness test hut according to the layout and numbering as shown in Figure 3. A description of the drainage products is also given in the Figure.

Note the use of the term *open rainscreen (ORS)* to describe the "normal" drained and vented cavity of E2/AS1.

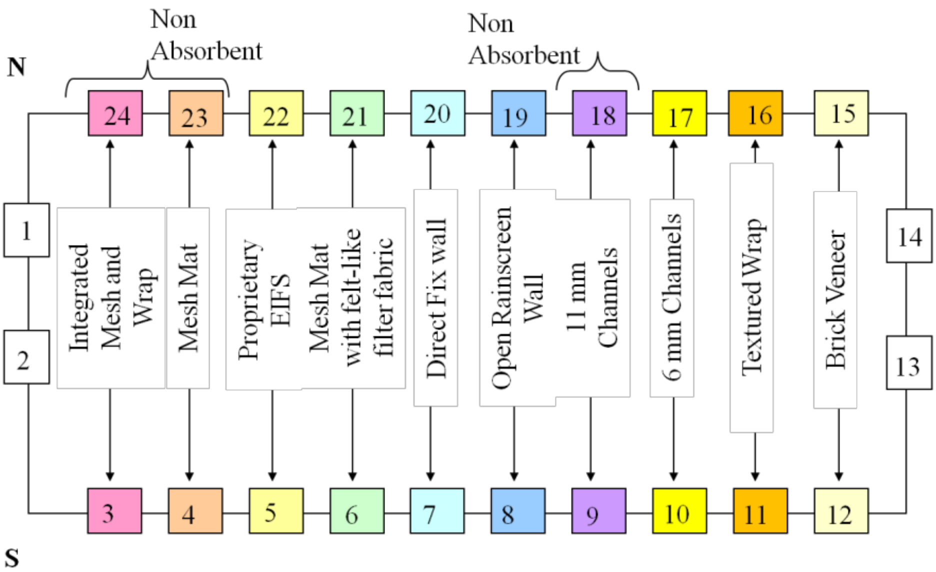

Figure 3 Specimen Layout and Drainage Plane Description

Water was introduced at a rate of one litre/hour to the back of the claddings in summer and winter through a single dosing port near the top of the walls. The water draining out of the walls was weighed and the conditions in the walls were recorded every 15 minutes.

The moisture in the cladding was "mapped" using a capacitive moisture meter. Timber moisture content sensors measured whether water reached the framing. Within the framing cavity, thermocouples measured the temperature and humidity probes measured the relative humidity. A weather station recorded the climate data for the site.

These tests allowed us to discover the following factors that were important for overall wall drying:

- Cladding absorbency.
- Wall orientation.
- Cavity type.
- Whether the framing became wet.

Further details can be found in the Appendices A and B.

4.1.1 Construction of Specimens

The general construction of the wall specimens is shown in Figure 4.

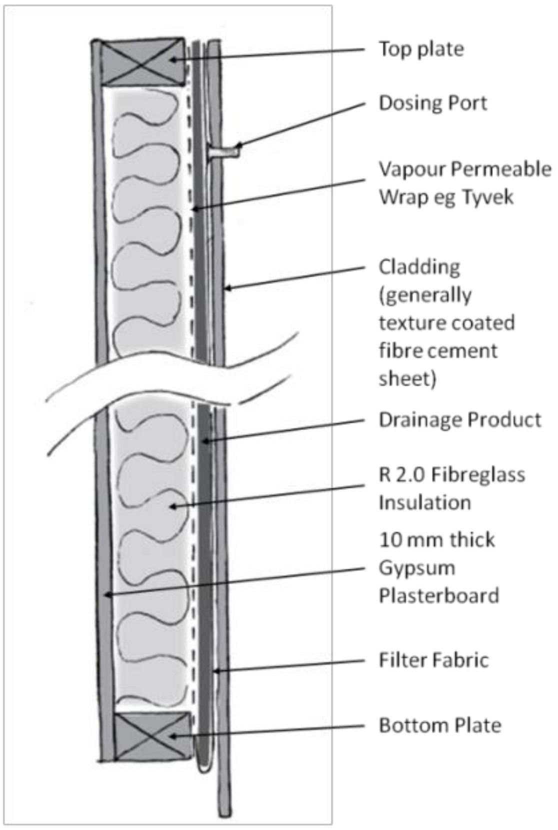

Figure 4 Cross Section of Typical Wall Specimen

The overall frame dimensions were 2400mm high × 1200mm wide. Where a drainage mat did not incorporate or comprise an underlay, a separate wall underlay was installed. Where a filter fabric was present, it was folded under the main drainage mat at the bottom of the wall to form a bug screen/cavity closer. All walls, except the EIFS and brick veneer specimens, were clad with fibre cement and finished using the same coating system. All walls, except the EIFS specimen, were insulated with fibreglass (R~2.0m^{2}C/W) in the stud space and all walls were lined with 10mm thick plasterboard. The plasterboard was painted with a primer and two water-based finish coats.

4.2 Measuring Ventilation Rates

Prior to installation in the test hut, each wall specimen was tested in the laboratory to measure the drainage cavity's resistance to airflow. This is the flow between the top and bottom of the wall, not the flow between indoors and outdoors.

The air resistance measurements were performed by attaching a manifold to the top edge of the wall and then sucking air through the cavity using an axial flow fan. Flow rates corresponding to a series of driving pressures were then measured. For the existing walls in the test hut (ORS, direct-fix and brick veneer) airflow resistances for the top and bottom of the walls were assumed using earlier work.[11]

The airflow resistances allowed the ventilation rate for each wall to be calculated, using the pressure difference between the top and bottom of the wall. The pressure difference was calculated using data from the walls and the weather station in conjunction with pressure coefficients for the test hut.[12,13]

These ventilation rates can be related to the ability of the walls to remove moisture.

4.2.1 Verifying Ventilation Rates

To verify the use of the ventilation calculations, the ventilation rate was measured in a subset of walls using carbon dioxide as a tracer gas with the *constant emission method*.[14] The interior of the cladding on these walls was painted to prevent the absorption of the tracer gas. This also allowed the effect of cladding absorbency on drainage to be assessed.

The measurements obtained supported the use of the airflow resistance calculation method.

4.3 Simulating Drying Tests (WUFI)

WUFI[15], a computer program that simulates heat and moisture transport in building materials, was used to simulate the drying tests. The WUFI analysis helped to generate some explanations for the different drying behaviour of the walls.

Further details can be found in Appendix C.

4.4 Modified E2/VM1 Tests

Following the main drainage and drying tests, a series of modified E2/VM1 tests on new wall specimens were performed to determine whether water reached the plane of the wall underlay. The specimens consisted of opaque (that is, free from penetrations) walls clad with weatherboards over a drainage plane. These tests were necessary because the drainage and drying tests had not identified any critical differences, i.e. incidents of frame wetting, between the different wall types.

Fibre cement weatherboards were chosen to allow some of the practical aspects of drainage plane installation, e.g. compression of the products, to be assessed.

Test no.	Specimen
1	Mesh with no filter fabric – weatherboard cladding (6mm)
2	Thick mesh with an underlay-like filter fabric (7mm) – weatherboard cladding
3	Solid channels with an open filter fabric – weatherboard cladding (11mm)

Table 4.1 Types of Drainage Plane Investigated Using E2/VM1

The modified E2/VM1 tests helped determine the risk classification for the different wall types and determine the need for sill flashings.

Further details can be found in the Appendices D-F.

5. RESULTS

5.1 Drainage and Drying

The results of the drainage and drying tests are outlined below.

Further details can be found in the Appendices.

5.1.1 Cladding Absorbency (Drainage)

Wall specimens with unpainted fibre cement cladding absorbed about 500ml of the one-litre dose of water. Wall specimens with painted interior faces only absorbed about 50ml of the one-litre dose, with the rest draining out of the wall. The direct-fix walls absorbed about 750ml of the one-litre dose reflecting the lack of drainage path.

Key result: cladding absorbency has the greatest effect on the amount of water stored in the wall – not the type of drainage plane.

5.1.2 Drying Time

Figures 5 and 6 show a series of moisture maps for a variety of walls with absorbent claddings. The light areas represent higher moisture content. The maps show how the claddings dry after being dosed with water in the autumn. Note that results are only shown for walls where there were exact duplicates on the north and south face of the building i.e. two walls with absorbent claddings.

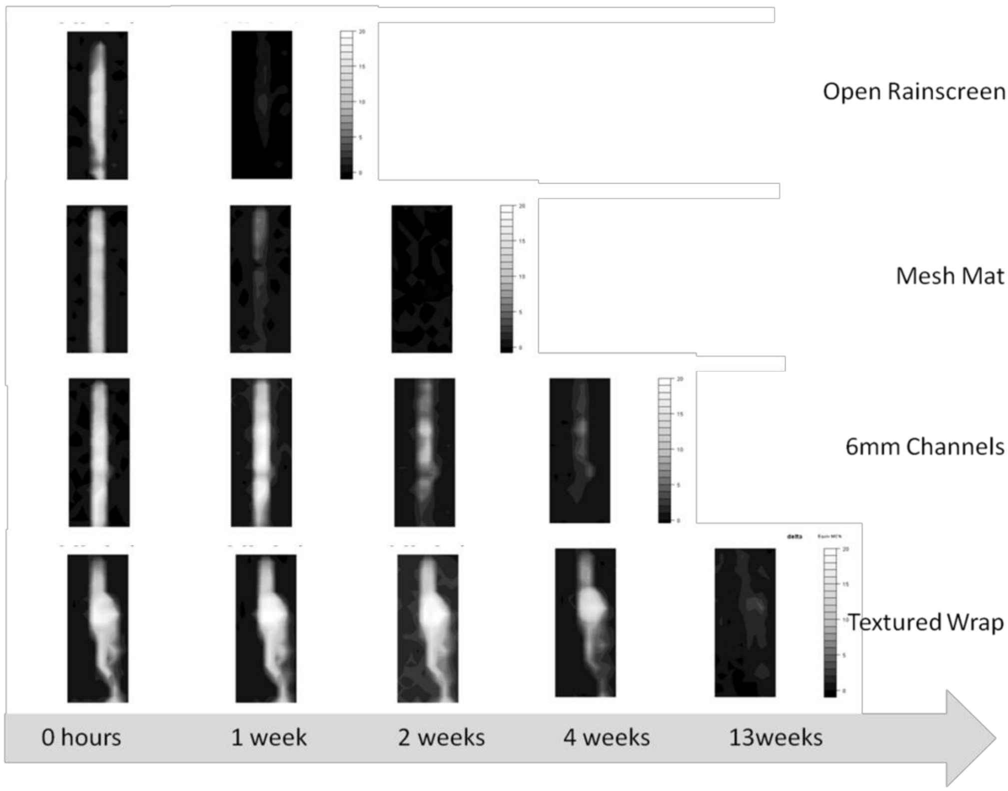

Figure 5 Drying of Walls on North Elevation (Warm)

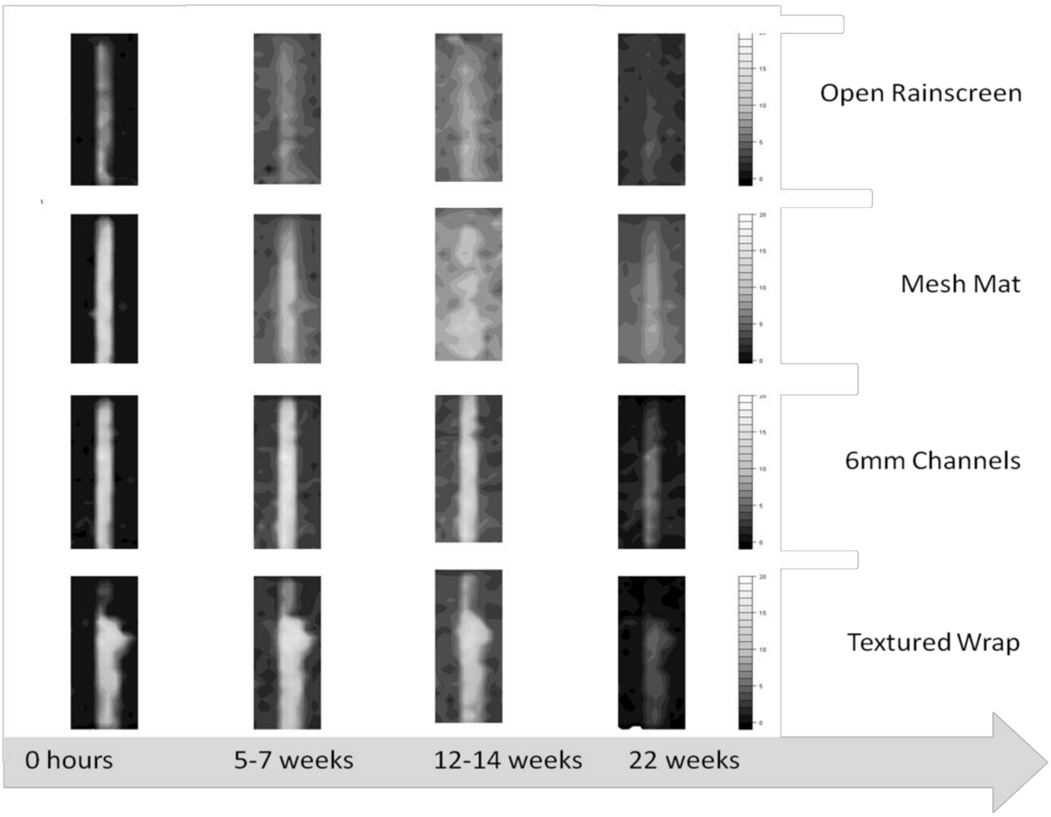

Figure 6 Drying of Walls on South Elevation (Cold)

On the north (warm) elevation, the type of cavity affected the drying time. The open rainscreen wall dried the quickest, within a week. The textured underlay walls and the direct-fix walls took the longest to dry. With these walls it was also possible to see that the water spread out. This spreading occurred because there was not a well defined drainage path.

The walls on the south (cold) elevation of the test hut took far longer to dry than any of the walls on the north face. In essence, the walls did not dry out until winter was over, irrespective of the type of cavity.

In summer, the drying times were reduced and there was little difference between the north and south elevations or between wall types.

Key result: wall orientation rather than type of drainage plane was the biggest factor in terms of allowing the walls to dry in winter.

5.1.3 Water Transport Through the Drainage Plane

None of the walls showed any evidence of water reaching the framing *through* the drainage planes. That is, the timber moisture content sensors did not record elevated levels of moisture during the dosing or drying phases (apart from the exceptions mentioned below). In a few cases, elevated moisture levels were seen at the bottom plate where water had tracked along the filter fabric (which had been folded back under the drainage plane) to the framing.

Key result: no water reached the framing line through the underlay – though attention should be paid to the detail at the bottom of the wall. Water was found to have reached the wall underlay in several specimens.

5.2 Ventilation

5.2.1 Airflow Resistance

In order to measure airflow resistance (for calculating ventilation rates), we fitted the pressure and flow data for each wall specimen to a power law relationship:

$$Q = C\Delta P^{n}$$

Where:
Q = the flow rate through the drainage cavity (l/s).
C = a fitting coefficient (l/s.Pa^n).
n = a fitting exponent (dimensionless).
ΔP = the pressure difference between the top and bottom of the wall (Pa).

The results are shown in Table 1.

Wall no.	Mean C	Mean n	Mean Q (l/s.m^2 @ 50Pa)	Mean leakage area for wall type (mm^2 at 1Pa)
3, 24	0.204	0.7856	1.56	263
4, 23	0.291	0.645	1.26	425
5, 22	0.518	0.612	1.95	669
6, 21	0.715	0.781	2.65	462
9, 18	0.561	0.839	5.04	724
10, 17	0.109	0.910	1.35	140
11, 16	0.012	0.870	0.10	16

Table 5.1 Airflow Resistance Data for the Wall Specimens

Table 5.1 also shows some common ways of expressing the airflow resistance: a flow per unit area of wall at 50Pa and an effective leakage area at 1Pa. Refer to Figure 3 for the numbering of the walls.

5.2.2 Ventilation Rates

Figure 7 provides an example of comparing the measured ventilation rate (tracer) with that predicted by the airflow resistance, in this instance for Wall 23 (mesh mat).

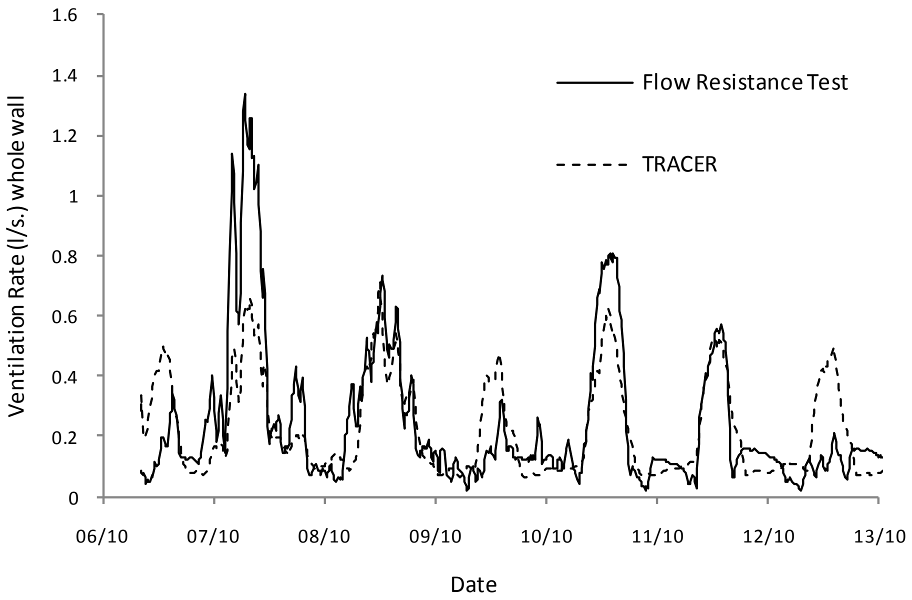

Figure 7 Measured and Predicted Ventilation Rates for Wall 23

The consistent alignment between the measured and predicted ventilation rates validates using the power law relationships (refer to 5.2.1) to calculate ventilation rates.

5.2.3 Ventilation Rates and Cavity Type

Figure 8 shows the predicted ventilation rate for a range of walls with different types of drainage plane. It can be seen that drainage plane walls generally have higher ventilation levels than an ORS with a full 20mm cavity.

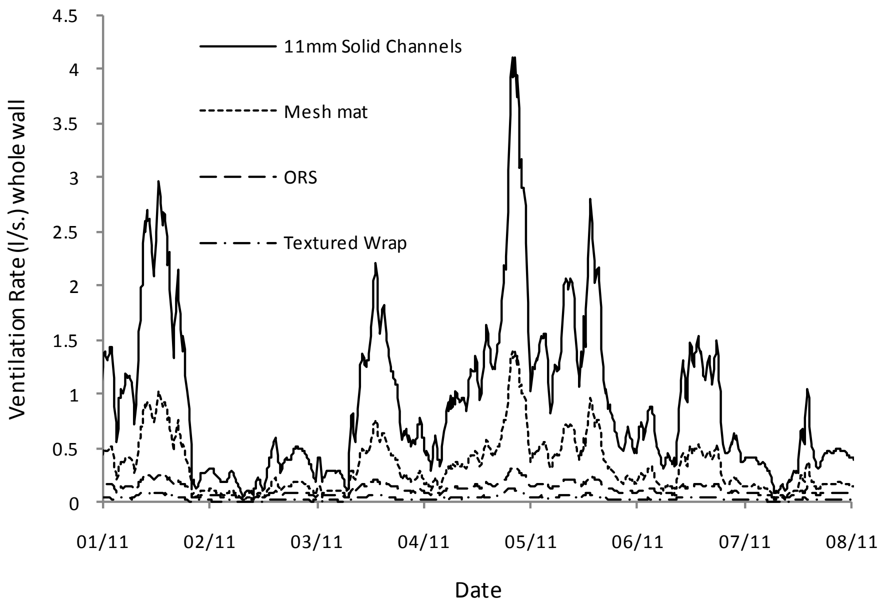

Figure 8 Predicted Ventilation Rates for Different Types of Drainage Plane

It is noted that in a New Zealand ORS wall, the top of the cavity is often closed off using a horizontal cavity batten to prevent damp air venting into the roof space. This means the flow resistance at the head of the wall is very high; air has to infiltrate very small gaps between the batten and the cladding/wrap. The cavity was not closed off in the wall specimens with drainage mats since this would have required a custom closer, i.e. one that is the same thickness as each of the products. Therefore the opening at the top has the same airflow resistance as that of the opening at the bottom. Hence, the total airflow resistance for a drainage plane wall was typically less than the ORS wall despite the smaller cavities associated with drainage planes.

To stop moist air being transported into the soffit or roof space, alternative details are required for drainage planes. Several manufacturers provide such details, none of which would affect the ventilation rate.

5.3 Simulated Drying Tests

The alignment between the simulated drying tests (using WUFI) and the physical experimental work was not very reliable. It was not possible to mimic the high moisture conditions (free water on the cladding) of the actual experiment and the drying times were shorter than those observed in reality.

However, the WUFI analysis did help generate explanations for the drying rates of drainage plane walls. For example, when simulating a cladding that was entirely at its hygroscopic limit, WUFI predicted that a drainage plane wall (with filter fabric) would dry more quickly than an ORS wall. This was different to the experimental results and suggests the extra diffusion resistance of the filter fabric was not the main reason for the longer drying time. This lead to the theory of effective ventilation rates (refer to Section 6.2).

Further details can be found in the Appendices.

5.4 E2/VM1 Testing

The modified E2/VM1 tests showed that water transport to the wrap was dependent on the type of drainage plane.

Test 1 investigated a basic mesh-type drainage plane, i.e. without a filter fabric.

The drainage product for Test 2 was a mesh-type drainage plane with a filter fabric. This drainage plane was a later generation of a product previously used for the drying tests. The main change was the filter fabric was more substantial – essentially it was now a wall underlay.

In Test 3 the drainage product consisted of relatively solid plastic channels. This type of product functions most like a normal cavity wall. Any water that penetrates finds itself in a cavity formed by the channels where it can drain and is subjected to some degree of airflow.

Test no.	Specimen	Result for E2/VM1 requirements
1	Mesh with no filter fabric – weatherboard cladding (6mm)	**Failed** On removal of linings and wall underlay, water was present on underlay
2	Thick mesh with a wrap-like filter fabric (7mm) – weatherboard cladding	**Passed**
3	Solid channels with an open filter fabric – weatherboard cladding (11mm)	**Failed** Water from upper course of drainage plane dripped down the back side of the lower course. Lapping the product would have prevented failure

Table 5.2 Results of E2/VM1 Test on Opaque Wall Specimens

The results show that a filter fabric can affect the result of the test and that attention must be paid to how certain products should be lapped.

5.4.1 Window Flashings

To install a window in a drainage plane wall the following was typically required to pass E2/VM1:

- A conventional head flashing.
- A sill tray (following E2/AS1:2005).
- The sill tray must be sealed to the jambs.

Figure 9 Window Sill Tray Details for Drainage Planes

If the sill tray is not sealed to the jamb, the specimens tend to fail E2/VM1 during the wetwall test.

6. DISCUSSION

This study aimed to answer the following questions about the cavities formed by drainage planes:

- Does water reach the line of the framing?
- How long does the wall take to dry?
- What would be a reasonable assessment of risk?

6.1 Frame Wetting

One of the key questions to be answered was whether drainage planes permit water to be transported to the framing. In this study, no evidence of water transport through the drainage planes/wrap systems to the framing was witnessed. While this is a positive result for drainage planes it does not provide a complete understanding and further investigation is warranted.

It was clear from observations during the drainage and drying experiments that water reached the plane of the underlay in some of the walls. This result is what prompted the use of a modified E2/VM1 test to look at differences between drainage products.

6.1.1 Risk Spectrum

In considering the nature of the risk of frame wetting associated with wall systems, it is useful to return to the building codes of both New Zealand and Canada.

Placing all types of wall cladding systems on a risk spectrum from cavity to direct-fix enables a comparison of the approaches. At the high risk end are direct-fix walls where any water that makes it past the cladding must come in contact with the wall underlay. At the low risk end are wall systems where no water hits the wall underlay.

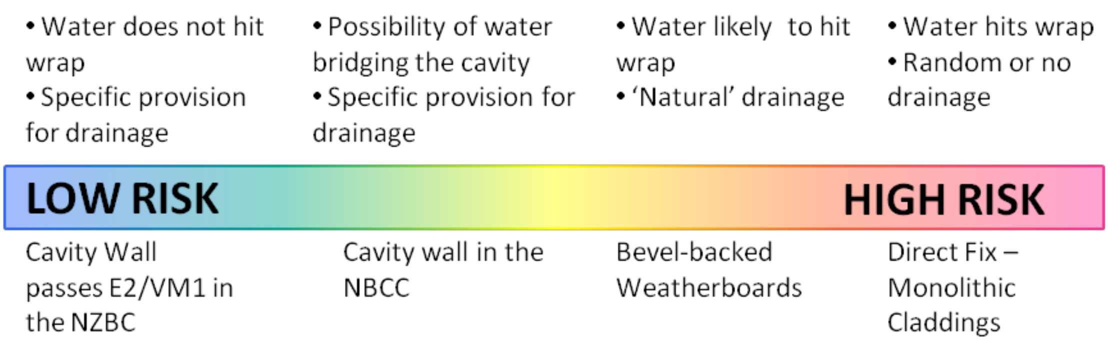

Figure 10 A Spectrum of Risk for Wall Cladding Systems

The spectrum shows that E2/VM1 represents a comparatively conservative approach. The NBCC does allow water to bridge the cavity and so represents a slightly less conservative approach (although many Canadian walls have sheathing as well).

6.1.2 "Passing" E2/VM1

As noted in section 5.4, only one of the tested drainage products passed the E2/VM1 criteria (Test 2). This product was a drainage mesh with a filter fabric that was relatively impermeable to water.

During the modified E2/VM1 test, no water penetrated the filter fabric. Therefore the "drainage" mesh performed no function other than holding the filter fabric against the cladding which is very different to how a "normal" cavity wall works. In a "normal" cavity wall, water that breaches the cladding enters a drainage space (the cavity) and can then drain under gravity or be dried by airflow in the cavity. In the case of this particular drainage plane, the drainage path is ad-hoc like a direct-fix wall (albeit removed from the framing line) and is not as exposed to the ventilation in the mesh.

Figure 11 E2/VM1 Test 2 Specimen

6.1.3 "Failing" E2/VM1

Test 1 involved a drainage product with no filter fabric. In this case the specimen failed because water reached the wrap during the water management part of the modified E2/VM1 test. Looking at the wall side-on it is easy to see the reason – the weatherboards completely compressed the product so that any water that penetrated had to touch the wrap. Incidentally, this particular product is marketed for use specifically with weatherboards, but it is debatable whether it altered the drainage gap naturally found behind most weatherboards.

Figure 12 E2/VM1 Test 1 Specimen

In Test 3 the drainage product consisted of relatively solid plastic channels. While this type of product functions most like a normal cavity wall (see Section 5.4), in this instance the product failed the modified E2/VM1 procedure during the wetwall test, but mainly because of a technicality. The upper course of the drainage product was simply butted up against the lower course (in line with manufacturer's instructions). Therefore water that ran down the upper course dripped onto the inner face of the lower course and hit the framing.

Figure 13 E2/VM1 Test 3 Specimen

Note that the system had not failed until this point; the lining, insulation and wall underlay had “pressed” the courses of material against the cladding so that water dripped from the upper to the lower course. If the product had been lapped shingle fashion, the specimen would have passed the tests in E2/VM1.

6.2 Drying Times

One of the intriguing results of the drainage and drying tests was that drainage plane walls took longer to dry than a “normal” cavity wall despite having a higher ventilation rate (see Figure 5 and Figure 8). Previous work at BRANZ[11] has confirmed a direct link between ventilation rates and drying from the cladding in cavity walls – so why do the drainage plane walls behave differently?

Although the total ventilation rate is higher than a normal cavity wall (vented at the bottom only), the *effective* ventilation rate is not necessarily so. Effective ventilation rate is the proportion of the airflow behind the cladding that can actually remove moisture from the cladding.

This is best indicated by comparing the ORS walls with the walls with the 6mm channels in Figures 5 and 6. In both pictures a well defined wetting pattern on the 6mm channels is visible whereas the ORS wall has either dried or has a less definite pattern.

Previous work[16,17] has shown that “normal” walls dry in such a way that the *effective* wetted area is larger than it is in reality and so the rate of water loss from the cladding is higher. Another way of looking at the same phenomenon is that the ventilation is more efficient at removing moisture from the wall than it should be based on the amount of airflow per metre of wall. In drainage plane walls (especially those consisting of solid channels) it appears the ventilation is less efficient than in “normal” walls (or the *effective* wetted area is closer to the *actual* wetted area).

A simpler (but experimentally-unproven) way of visualising this is that the 6mm channels reduce lateral airflow, thereby lowering the effective ventilation rate (see Figure 14).

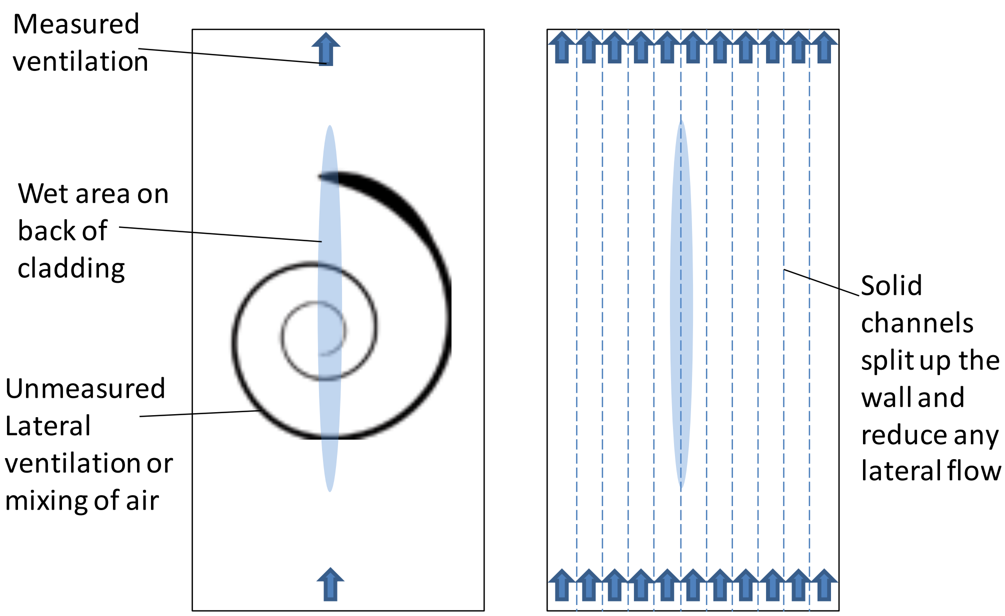

Figure 14 Lateral Ventilation (left) May Explain Faster Drying in "Normal" Cavities Despite a Lower Total Ventilation Rate

The presence of a filter fabric could also lower the effective ventilation rate. This is suggested by the results of drying in mesh mat walls compared with the ORS walls. It is possible the filter fabric creates a region of still air between it and the cladding, slowing down the rate of moisture transport to the cavity air. However, it was not possible to confirm this theory via experiment, as the gap between cladding and wrap is not suitable for tracer measurements of ventilation rate. It was also not possible to successfully model the very small air gap between cladding and filter fabric in WUFI.

The fact the cladding stays wetter for longer is not necessarily a strong reason to avoid the use of drainage planes. In winter on the cold face of a building, all of the walls including the ORS wall stayed wet for a very long time. It took 28 weeks for all signs of moisture in the walls to disappear, so essentially they were wet for the entire winter from a single dosing event. The ORS wall has an established track record of success in New Zealand, suggesting this aspect of its performance is not critical, provided the durability of the cladding itself is not compromised.

To avoid the cladding staying wet for long periods (assuming water does make it to the interior face of the cladding) the best option is to provide a non-absorbent drainage path. This can be achieved by painting or priming the inner face of the cladding or using an inherently hydrophobic cladding.

6.3 Use of Flashings

The E2/VM1 requirement that no water should reach the wall underlay also affects the need for flashings in a drainage plane wall. This is of particular importance where windows are installed. Flashings are also likely to be necessary at the bottom of the wall.

6.3.1 Window Flashings

Water that leaks from a window in a "normal" cavity wall drips in to the drainage cavity. If a drainage product is present then water will drip into the drainage product. Dependent on the type of drainage plane, this water could then be transported to the plane of the wall underlay – and thereby fail E2/VM1.

It is therefore necessary to flash the windows using a sill tray, in a way similar to a direct-fix wall, so water is directed outside. Dependent on the type of drainage plane it may be desirable to flash to the outside as well, but in theory the flashing could direct water to the back of the cladding instead (where a drainage plane is installed).

Figure 9 highlights the importance of continuity of flashing at window jambs. In this case the drainage product consisted of relatively solid plastic channels. When the sill tray was sealed to the jambs (as per Figure 9 – using flashing tape in this particular case) the specimen passed E2/VM1.

Without the sealing, water dripped onto the inner face of the drainage material and from there onto the framing/wall underlay.

6.3.2 Wall Flashings

During the drainage experiments, a few of the walls showed elevated moisture levels in the bottom plate. This was due to a lack of detailing at the bottom of the wall as opposed to water passing through the drainage product itself. The wetting mechanism is shown in Figure 15.

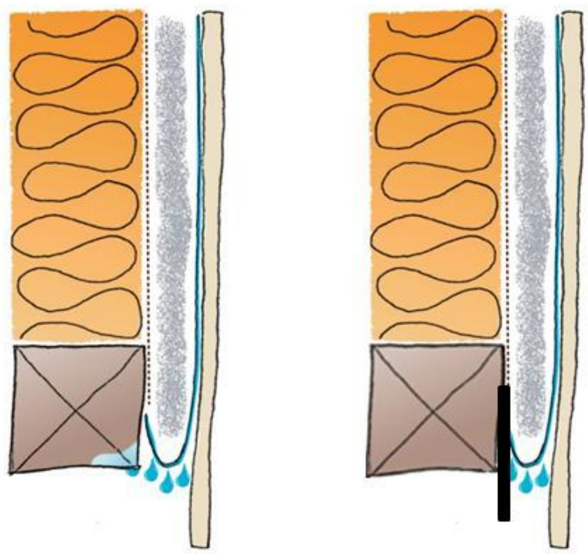

Figure 15 Wetting of the Bottom Plate was Observed in a Few Cases – an Apron Flashing Would Fix This

Water was able to reach the framing because the drainage product nominally finished flush with the bottom plate and the water could track across via the filter fabric. This could easily be remedied by adding a drip edge, which could be achieved by running the drainage product beyond the base of the bottom plate or by installing an apron flashing. The flashing option would have the benefit of being easier to inspect but with the downside of additional cost.

6.4 Drainage Planes and Monolithic Claddings

In the latest version of E2/AS1 (effective August 2011), monolithic claddings must have a cavity. If such a cladding was installed over a drainage plane (instead of a "normal" cavity) and passed E2/VM1 then the performance could be argued to be equivalent to a "normal" cavity wall.

If the drainage plane wall had failed E2/VM1, the performance could be argued to be at least as good as a weatherboard wall provided the drainage path was not blocked. In this case water might hit the wrap but there would be a defined drainage path for the water to escape.

Therefore, one potential use of drainage planes is to increase the number of sites where monolithic claddings could be used without cavity battens.

This rationale is shown in Figure 16.

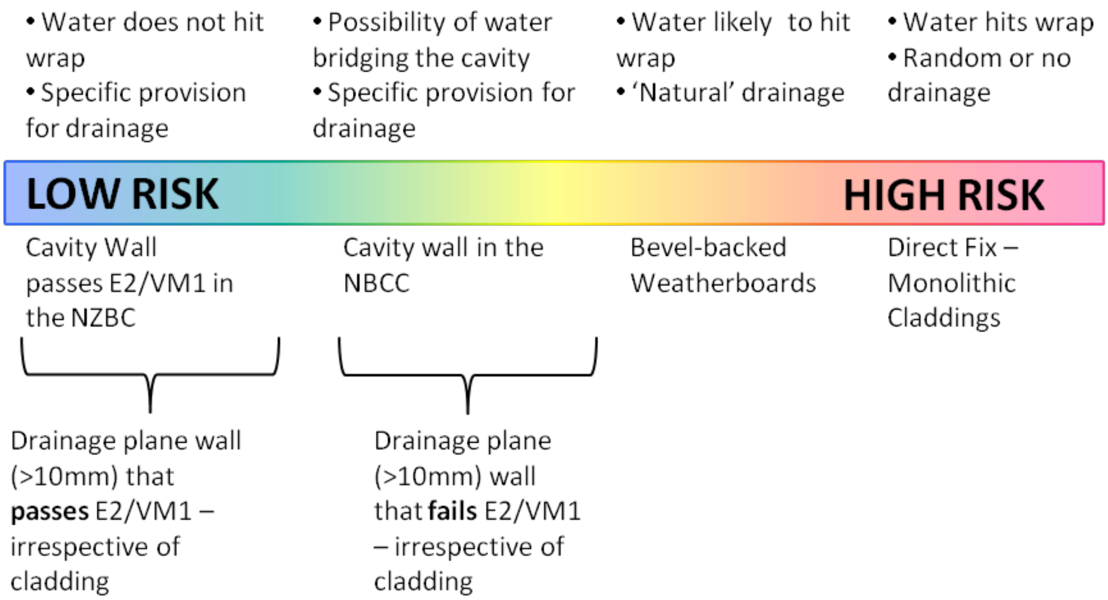

Figure 16 Drainage Planes on the Wall Cladding Spectrum of Risk

6.5 Drainage Plane Thickness

The drainage plane wall that passed E2/VM1 raised questions about the suitability of the test for drainage plane walls. That drainage plane had a filter fabric that was impervious to liquid water, much like a synthetic wall underlay, so no water made it to the drainage mesh. Therefore the wall would probably have passed E2/VM1 even if the mesh were thinner because water would still not have made it to the "real" wall underlay on the other side of the mesh.

This result would be similar to a direct-fix wall with two layers of wall underlay. The inner layer would still be dry and therefore arguably pass E2/VM1. However, it would be hard to argue that such a wall is the "same" as a drained and vented cavity from E2/AS1 even though they both pass E2/VM1. At the moment, E2/VM1 is not applicable to such a wall because a cavity of at least 20mm is required. This would have to be reduced to allow drainage plane walls to be tested – but where should the line be drawn?

In reality, any provision for drainage is better than none, but certain kinds of drainage plane offer a less robust solution. An example would be a textured wall underlay – these performed similar to a "normal" direct-fix wall in terms of drainage and drying. A cavity depth of 10mm would represent a pragmatic choice and is beyond the 0-5mm range where capillary effects are important. It would mean products similar to that tested in this research could pass E2/VM1, but would preclude systems that are essentially direct-fix but with "sacrificial" layers of wall underlay. Some systems may still hold water close to the cladding like a direct-fix wall, but at least it would be a safe distance away from the more sensitive framing elements.

6.6 Miscellaneous Issues and Appraisals Criteria

During the study, several issues were noticed while constructing the drainage plane wall specimens. In addition to more conventional appraisal criteria, these issues (detailed below) would need to be considered if particular drainage planes were to be appraised by BRANZ for use in New Zealand.

6.6.1 Cladding Blow-Out

During construction of the test specimens for the test hut, *blow-out* sometimes occurred if the cladding was simply nailed to the frame through the drainage plane. The holes in the test specimens were subsequently pre-drilled to prevent the cladding debris from altering the drainage performance of the drainage plane.

Pre-drilling would be impractical in real construction. Although the affect on drainage would be minimal (and would be assessed as part of an E2/VM1 test), blow-out potentially reduces the holding strength of the fixings. Therefore face load tests should form part of any BRANZ appraisal.

6.6.2 Compressibility

The importance of compressibility for drainage can be observed in Figure 12. If a 10mm cavity depth is chosen this should represent a “finished” cavity, not the nominal thickness of the drainage plane.

Compressibility, or lack thereof, may also be important for aesthetics of the finished wall. Waviness of the cladding may be observed due to some fixing points compressing the drainage plane more than others. This was not witnessed in any of the test specimens but those walls were of a limited size.

The following were also witnessed during the construction of the wall specimens (see Figure 17):

- Bulge in weatherboards.
- Nailthrough (over-nailing).
- Cracking of weatherboards.

Figure 17 Bulging, Nailthrough and Cracking of Claddings

These issues may be because of the particular combination of cladding and drainage plane but should be investigated as part of a thorough product appraisal.

6.6.3 Compression Effects and Rigid Sheathing

Although compression affects several aspects of installation, it is unlikely that a uniform pressure from bulging insulation would significantly impact drainage plane products. Therefore using a rigid sheathing to protect the drainage path should not be necessary, but this should be checked as part of each product appraisal.

7. CONCLUSIONS

Assessing the performance of drainage planes revealed the following results:

- No water reached the frame through the drainage planes.
- Water reached the wall underlay in several cases – this was the most important difference between drainage plane products.
- Drainage plane walls typically have a higher total ventilation rate than "normal" cavity walls due to the lack of a cavity-closer at the top of the cavity
- However, the claddings take longer to dry in drainage plane walls because the effective ventilation rate is lower. This is not considered to be a critical deficiency of drainage plane walls.
- E2/VM1 represents a conservative approach to cavity water management and to pass E2/VM1, windows in drainage plane walls are likely to need sill trays.

The study has reached the following conclusions:

- Drainage planes can help provide satisfactory weathertightness for walls in New Zealand. However, performance of drainage planes depends on the particular type of drainage plane product. Some drainage plane walls will offer the same performance as a "normal" E2/AS1 cavity, i.e. no water bridges the cavity, others are equivalent to weatherboards and some are similar to walls with direct-fix monolithic sheet claddings. The compressibility of the product and the nature of the filter fabric have a large effect on performance.
- To meet the same performance as a "normal" cavity wall, drainage planes need windows to be flashed in a way similar to direct-fix claddings. Specifically, a sill flashing is required. A flashing at the bottom of the wall may also be advisable to stop water wicking along the filter fabric to the framing.
- The proprietary nature of drainage planes may make them unsuitable for E2/AS1. If this is the case, drainage planes would need to be treated as alternative solutions, e.g. each product would need to be appraised.
- Drainage plane walls cannot currently be tested using E2/VM1 because there is a requirement for a 20mm cavity. If drainage planes were to form part of an acceptable solution then the minimum finished cavity thickness in E2/VM1 should be changed to 10mm.
    - If a drainage plane wall passes E2/VM1 its performance is equal to a "normal" drained and vented cavity wall and can be used with all corresponding risk scores.
    - If a drainage plane wall fails E2/VM1 its performance is equal to a direct-fixed weatherboard wall.
- Drainage planes less than 10mm thick should not be included in an acceptable solution.
- It is proposed that the cavity formed by a drainage plane should be robust enough to prevent any insulation in the framing cavity from blocking the drainage path. Drainage planes with a thickness greater than 10mm could be used without a rigid underlay.

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APPENDICES

APPENDIX A FURTHER CONSTRUCTION DETAILS

Twenty walls were installed in an existing experimental building at BRANZ. This building was initially constructed for use in a previous weathertightness study and has 24 openings into which wall specimens can be placed. All of the drainage products were donated by manufacturers, but they have not funded the programme in any other way. The products are described in this report but trade names have been excluded.

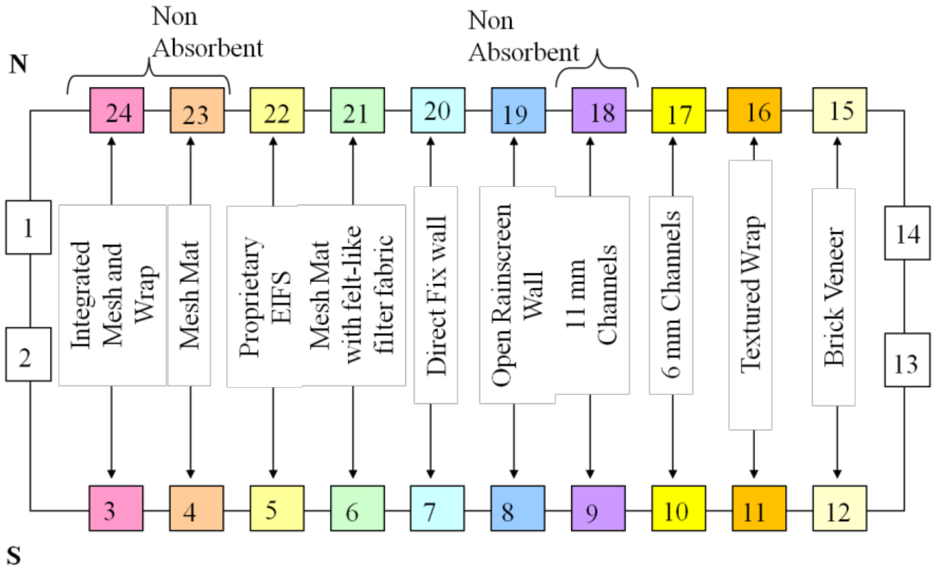

Figure A.1 Layout of Wall Specimens

Duplicate specimens were installed on the north and south elevations of the building (Figure A.1). The timber frames were constructed of untreated Pinus Radiata; this is rarely used for construction in New Zealand any more but was selected because its moisture/electrical response has been well characterised. The overall frame dimensions were 2400mm high × 1200mm wide. Studs were located 300mm from each side. Dwangs were located at 800mm centres in the central portion of the frame and at 1200mm centres in the two outer spaces.

Where a drainage mat did not incorporate or comprise a wall underlay, a separate wall underlay was installed. Where a filter fabric was present, the filter fabric was folded under the main drainage mat at the bottom of the wall to form a bug screen/cavity closer.

All walls, except the EIFS and the brick veneer specimens, were clad with fibre cement and were finished using the same coating system. All walls, except the EIFS specimen, were insulated with fibreglass (R~2.0m^{2}C/W) in the stud space and all walls were lined with 10mm-thick plasterboard, which was painted with a primer and two water-based finish coats.

A.1 Specimen Instrumentation

One of the key questions this study set out to answer was the extent to which water could track across the smaller cavities associated with drainage mats. Previous work[4] showed water could reach the framing on direct-fix walls and also that drying from the framing was orders of magnitude slower than drying from the interior face of the cladding, hence frame wetting should be avoided. The instrumentation layout was chosen to reflect this emphasis.

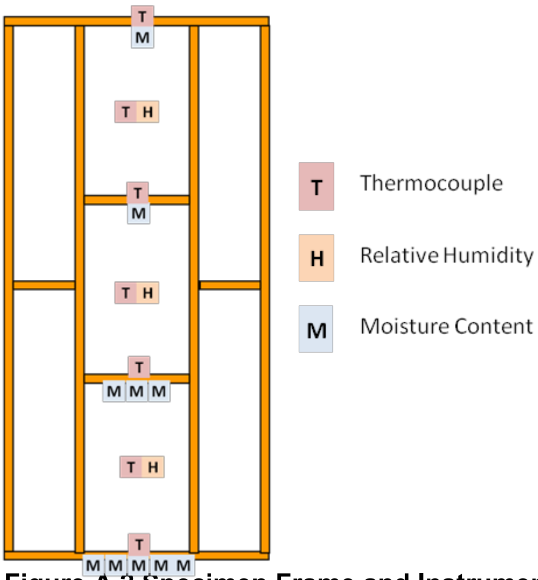

Figure A.2 Specimen Frame and Instrumentation

Each wall had ten pairs of timber moisture content pins, with the number of sensors increasing towards the bottom plate. To detect water leaks through the wrap, the moisture pins (25mm-long stainless steel nails) were installed as close to the face of the dwangs as possible. T-type thermocouples were installed in the horizontal framing members to allow temperature correction of the moisture content readings. Humidity sensors (Honeywell HIH-4000 series, calibrated at BRANZ) were placed in the stud space to help quantify the drying time of the cavity. Note that these were not placed in the cavity formed by the drainage product. It has been found that draining water can lead to durability issues and it would have meant interfering with the part of the specimen under test. This set-up resulted in 400 channels of instrumentation, which were logged every 15 minutes.

In addition, a capacitive mositure meter was used to generate maps of moisture levels within the wall. A guide for meter placement was painted on the exterior face of the cladding to facilitate repeatable measurements. A Wagner L612 moisture meter was chosen, primarily for its ability to store many readings. A capacitive moisture meter expresses its measurement as equivalent moisture content of some species of timber. The measurement is based on what the meter “sees” in a volume represented by the area of the sensor and a depth of 25mm. When applied to the outside face of one of the wall specimens, the meter would “see” a coat of paint, some plaster with reinforcement, a fibre cement sheet, the drainage product (and any moisture present there), the wall wrap and possibly some of the framing timber. Therefore the absolute values of moisture content are relatively meaningless. However, the readings relative to an initial dry state provide real information as to whether moisture is present in the wall and where that moisture is.

APPENDIX B FURTHER DRYING RESULTS

Table A.1 summarises all of the drainage and drying tests performed in the test hut.

Specimen	Product	Orientation	Retained water (ml)	Non-absorbent cladding	Frame wetting	Approx time for cladding to dry (winter)	Approx time for cladding to dry (summer)
Wall 3	Underlay and mesh	South facing	479	N	N	30 weeks	5 weeks
Wall 4	Mesh mat	South facing	510	N	N	30 weeks	5 weeks
Wall 5	Proprietary EIFS	South facing	24	Y	N	0 days	0 days
Wall 6	Mesh mat	South facing	528	N	N	30 weeks	5 weeks
Wall 7	Direct-fix	South facing	699	N	N	30 weeks	6 weeks
Wall 8	Open rainscreen	South facing	256	N	N	30 weeks	4 weeks
Wall 9	11mm channels	South facing	452	N	N	30 weeks	5 weeks
Wall 10	6mm channels	South facing	600	N	N	30 weeks	8 weeks
Wall 11	Textured underlay	South facing	579	N	N	30 weeks	9 weeks
Wall 12	Brick veneer	South facing	–	N	N	N/A	N/A
Wall 13	Brick veneer	North facing	–	N	N	N/A	N/A
Wall 16	Textured underlay	North facing	608	N	Y	13 weeks	11 weeks
Wall 17	6mm channels	North facing	625	N	N	10 weeks	7 weeks
Wall 18	11mm channels	North facing	58	Y	N	0 days	0 days
Wall 19	Open rainscreen	North facing	409	N	N	1 week	4 weeks
Wall 20	Direct-fix	North facing	758	N	N	4 weeks	7 weeks
Wall 21	Mesh mat	North facing	552	N	Y	2 weeks	6 weeks
Wall 22	Proprietary EIFS	North facing	40	Y	N	0 days	0 days
Wall 23	Mesh mat	North facing	78	Y	Y	0 days	0 days
Wall 24	Underlay and mesh	North facing	32	Y	N	0 days	0 days

Table A.1 Drainage and Drying Results for Winter and Summer

Note that some of the walls on the north face dried quicker in winter than in summer. This counterintuitive result is explained by the weather conditions at the time of dosing. Wind speeds and stack pressures were actually higher for these walls in the winter, meaning more ventilation drying. The larger stack pressure can be explained by two factors. First, the ambient temperature was lower in winter and second, the cavity temperatures were actually higher due to the more direct incidence of solar radiation on the wall. These factors combine to provided a larger temperature difference across the cladding and hence a larger stack pressure. The higher cavity temperatures may have also resulted in moisture transport within the cladding towards the (cooler) top of the wall.

APPENDIX C USING WUFI TO MODEL THE RATE OF DRYING FROM THE CLADDING

C.1 Introduction

Drainage planes are a relatively new class of product that are used to form a small cavity behind the cladding. The aim of BRANZ's drainage plane programme is to understand how the products perform in New Zealand construction styles and climate. In particular we want to know how they compare to the larger 20mm cavity that is defined in E2/AS1.

C.1.1 Surprising Drying Results

Earlier in the study, measurements of ventilation rates in the cavity and drying rates from the back of the cladding had been performed.

The ventilation rate in drainage plane walls was thought to be higher than the E2/AS1 cavity wall despite the smaller cavity. This was because the cavity wall has a horizontal batten at its top to close off the cavity – this batten acts as a bottleneck that limits the airflow through the wall.

Ventilation plays an important part in drying moisture from the cladding. Because of this we expected the drying rates to be higher in walls with drainage planes. However, we found that walls with drainage planes actually dried slower than the E2/AS1 style cavity.

C.1.2 Using WUFI to Explain the Results

It was proposed that the longer drying time associated with drainage plane walls was due to the presence of filter fabric and in this particular study WUFI was used to investigate this theory.

A custom version of WUFI 2D was used. It differs to the standard version in two ways:

- The materials database contains New Zealand-specific materials.
- A ventilation rate can be included for air spaces.

The aim was to simulate the wetting experiments which led to the results shown in Figure 2, which entailed:

- A conditioning run to get the models into the pre-wet state.
- Simulating the wetting experiment by introducing water on to the back of the cladding.

The analysis was conducted for two models:

- A drainage plane wall with a filter fabric.
- A "normal" E2/AS1 wall with a 20mm cavity.

It was subsequently found that WUFI was not suited to modelling the localised free water present on the cladding in the experiment. Instead, a situation where the whole sheet of fibre cement was taken up to its hygroscopic limit and allowed to dry.

C.2 WUFI Models

The process of creating a WUFI model consists of three stages:

- Creating the geometry.
- Applying the boundary conditions.
- Applying the loads, i.e. climate, ventilation and moisture.

C.2.1 Geometry – Normal Cavity

The model used in the simulation of the E2/AS1 cavity wall is shown in Figure A.3. Note this is not to scale, the purpose is to show which materials were used. The number to the right of the material name is the density in kg/m^3.
The thickness of each layer, in mm, is shown in Figure A.3 as well.

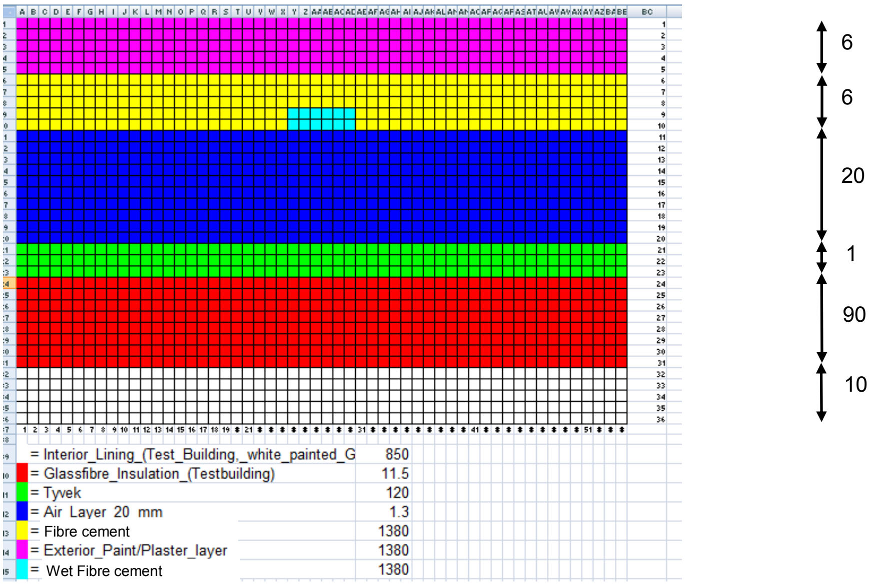

Figure A.3

C.2.2 Geometry – Drainage Plane

The model used in the simulation of the drainage plane wall is shown in Figure A.4. Note this is not to scale, the purpose is to show which materials were used.
The thickness of each layer, in mm, is shown in Figure A.4 as well.

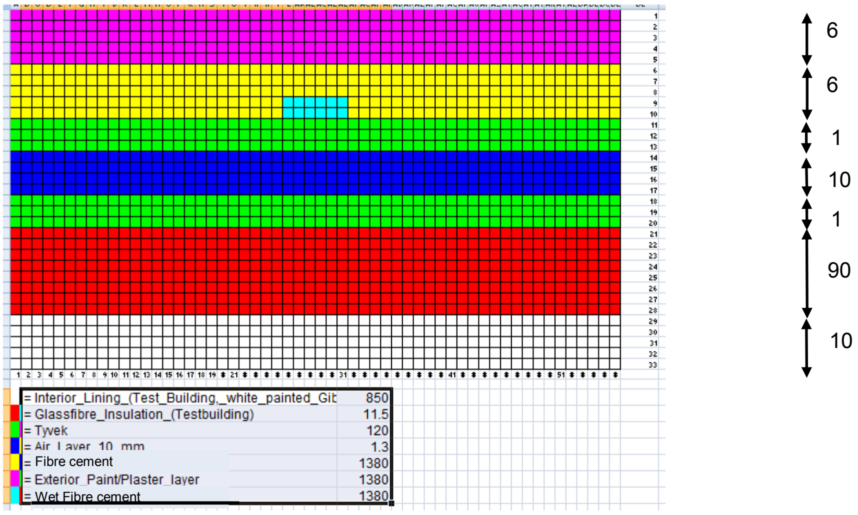

Figure A.4

C.2.3 Boundary Conditions

All materials started at 20˚C and 80% relative humidity.

Boundary facing	Heat transfer co-efficient (W/(m²K))	Vapour diffusion thickness (m)	Short wave absorptivity (-)	Long wave absorptivity (-)
West (bottom)	0	$1x10^6$	0	0
East (top)	0	$1x10^6$	0	0
North (outside)	17	0	0.4	0.9
South (inside)	8	0	0	0

Table A.2 Boundary Conditions used in WUFI Models

C.2.4 Loads

The climate file for the WUFI models was created using data from the weather station and test hut at BRANZ.

The interior temperature and humidity in the test hut were used for the south, west and east face of the WUFI model. The data from the weather station was used for the north face.

The climate file covered the period:

- 1/9/2008 to 31/3/2009 – the preconditioning period.
- 1/4/2009 to 18/12/2009 – dosing and drying period.

C.3 Ventilation

The airflow through the cavity in the walls is dependent on the pressure difference between the top and the bottom of the wall. This pressure difference is due to any wind incident in the wall and the temperature difference between the cavity and the outdoors.

The actual wall specimens were not instrumented in such a way that the cavity temperature was directly available. Instead, the mean temperature in the insulated cavity was used.

C.3.1 Normal Cavity Wall

A number of different options for calculating the ventilation rate in the cavity were tried. The following option, based on the equation for flow through an orifice and assuming a constant ratio between the flow resistance at the top and bottom vent, has the advantage of being solvable without iteration.

$$Q = KA\sqrt{(2\Delta P)/\rho)}$$

Where:
Q = volume flow rate (m^3/s).
K = Discharge coefficient.
A= Orifice Area (m^2).
ΔP = pressure difference between across orifice (Pa).
ρ = density of fluid (kg/m^3).

$$Q(l/s) = 1000 \times 0.61 \times 0.0012 \times \sqrt{(2 \times P/101)/1.2)}$$

Where P is now the pressure difference between top and bottom of the wall.

This assumes the pressure drop across the infiltration path is 100-times greater than the drop across the bottom vent. This assumption begins to become invalid for larger pressure differences. For instance, using the data in Table 1, if the total pressure difference is 0.5Pa then 1.16% of the pressure drop occurs across the bottom vent (in line with the above equation) at 20Pa this becomes 4.83%. Therefore this equation will under-predict ventilation levels for larger pressure differences compared to the power law data of Table 1.

Another option for calculating the ventilation rate was to use published data for the airflow resistance of infiltration paths and vents[11].

	Required	**Measured**	**Modelled**	
Location of vent	**Vent area** mm^2/m	**Vent area** mm^2/m@1Pa	**Coefficient (C)** $m^3/m.s.Pa^n$	**Exponent (n)**
Vents in brick veneer D&V walls	1000	1016-2625	0.0008	0.5
Vents at base of open rainscreens	1000	836-4170	0.0008	0.5
Infiltration through solid battens	None	22-228	0.00008	0.7
Vents in ventilated battens	None	177-11000	0.0016	0.5
Infiltration at the top of cavities	None	88-270	0.0001	0.7

Table A.3 Vent Areas Associated with Various Construction Details

This data was used in CONTAM[18] in two forms:

- Using the C and n parameters.

- Using approximate orifice area data – $0.001m^2$ for the vent and $0.0001m^2$ for the infiltration at the top of the wall.

A comparison between the different models is shown in Figure A.5. All of the models gave similar results. The C and n model was a bit more "peaky" than the other two which gave almost identical results.

The simple equation was used because it meant the ventilation rate could be calculated directly from the pressure difference. Its approximate nature was considered good enough for this purpose, especially since the actual resistance of the airflow paths in the ORS wall had not been measured in this study. Another reason for choosing the equation was the fact the ventilation rate was slightly lower than the C and n model. This lower ventilation rate meant the difference between the cavity wall and the drainage plane models ventilation rate would be greater – meaning any differences in moisture level would be easier to spot in the WUFI results.

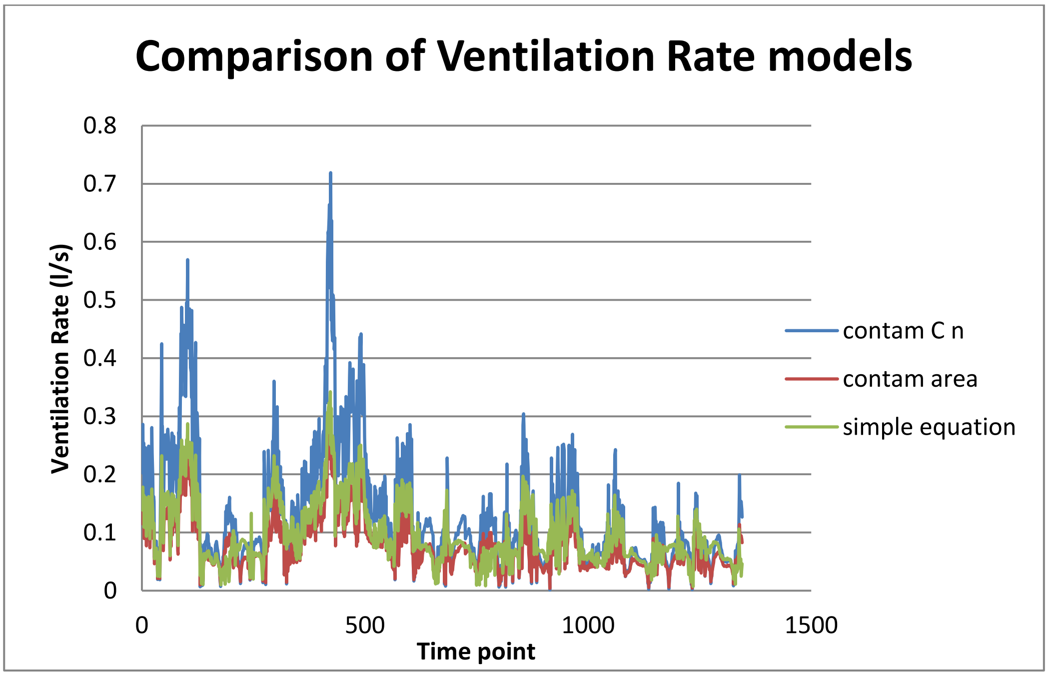

Figure A.5 Comparison of Different Ventilation Options for Use with WUFI

C.3.2 Drainage Plane Wall

The relationship between cavity ventilation and pressure for the drainage plane wall had previously been derived in the laboratory (see Section 5.2.1). Other drainage plane specimens had similar relationships verified using tracer methods.

$$Q\ (l/s) = 0.795*P(Pa)^{0.327}$$

The ventilation rate was calculated using the above equation in conjunction with wind and temperature data from the climate file. The ventilation rate is used as an input to the WUFI model in the form of a separate file. This contains an air change rate (air changes per hour) for each time step in the climate file.

C.4 Dosing with Water

In the real drying experiments, the wetting pattern occurred around the middle of the wall because that was where the dosing port was located. In the models, the presence of the "wet fibre cement' material in the middle of the "normal" fibre cement allowed this localised wetting to be simulated.

The amount of water in the material was specified in a dedicated input file. The units are kg(water)/m^3(material)

In the real drying experiments the water stored in the wall was approximately 500ml. In the models, the wet fibre cement corresponded to a rough volume of (60mm x 2mm x 2400mm) of 2.88×10^{-4}m and a water content of 1736kg/m^3. A lower water content of 1200kg/m^3 was chosen for the input file for the initial simulations.

As mentioned in the introduction, this technique did not work especially well. The water content in the wet fibre cement dropped almost immediately to normal levels. This was because the material data in WUFI (transport coefficients and sorption data) was not designed to go above a water level of 470kg/m^3.

Because WUFI could not model the high water content of the actual experiment, we decided to change how the model was run. At the start of the dosing phase the water content of the cladding was set to 470kg/m^3 across the whole of the material, i.e. all of the material was at its maximum moisture content (equivalent to fibre saturation).

C.5 Results

C.5.1 Drying Time for the Cladding

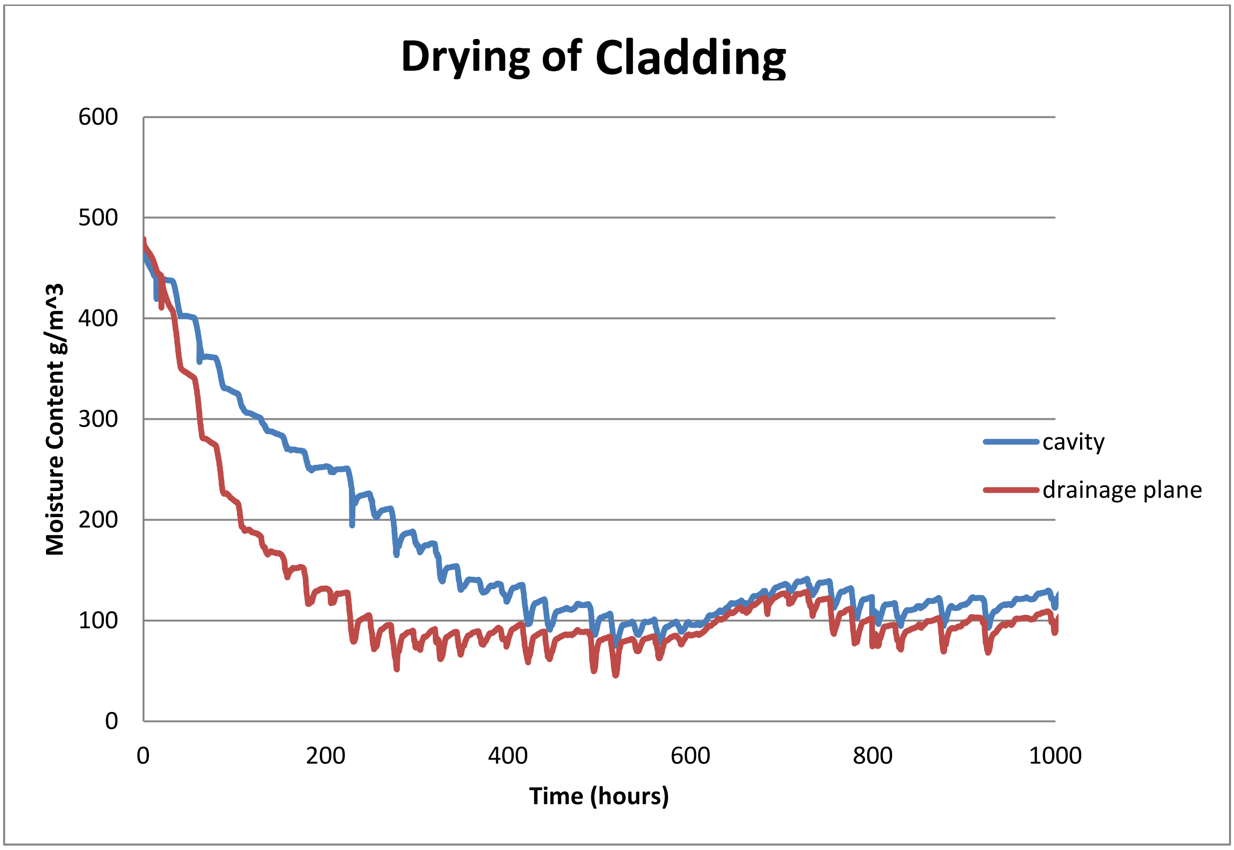

Figure A.6 Comparison of Drying Times

Figure A.6 shows that WUFI calculates the drying time for the cavity wall to be longer than that of the drainage plane wall.

The drainage plane wall is estimated to be back to normal after approximately 250 hours and the cavity wall after approximately 500 hours.

This is the OPPOSITE of what was observed during the actual wetting experiment.

C.6 Discussion

WUFI predicted the drainage plane wall would dry quicker that the "normal" cavity wall. This is the opposite of what happened in reality.

There are two possible reasons for this:

- The real ventilation rate in the cavity wall is higher than assumed.
- The EFFECTIVE ventilation rate in the drainage plane wall is lower than measured.

C.6.1 Cavity Wall Ventilation May be Higher Than Calculated

The calculation method assumed values for the resistance to airflow of the bottom vent and the infiltration path at the top of the wall. It is proposed that the infiltration resistance may be lower in reality and this would have increased the flow (and hence the drying potential).

Some exploratory WUFI runs were performed where the walls had the same ventilation rate as each other and in that case the cavity wall did dry quicker than the drainage plane wall.

This provides some weight to the theory that the cavity ventilation rate is higher than in reality. This also somewhat confirmed the original theory that the extra vapour resistance of the filter fabric is responsible for the longer drying time observed in the drainage plane walls.

C.6.2 Effective Ventilation May be Different in Drainage Plane Walls

The other possibility is that the EFFECTIVE ventilation rate in the drainage plane walls is lower than the measurements suggest. We measured the total flow in the cavity – it may be that the effective flow is just the portion between filter fabric and the cladding. This space may actually be still air, so future WUFI runs may add a 1mm air gap next to the cladding.

The concept of effective ventilation may also explain some of the other drying results from the test hut. The specimens with solid channels had the highest total ventilation rate, but they ended up having very well defined and long-lasting wetting patterns. The effective ventilation rate here may just be the airflow in one of the channels – so if there were 50 channels across the wall, the effective ventilation would be 50-times lower than the measured total ventilation.

C.7 Conclusion

On the whole, the agreement between WUFI and the experiment was not very good. It was not possible to mimic the high moisture conditions (and possibly the effective ventilation) of the actual experiment and the drying times were shorter than those observed in reality.

It was decided not to continue the analysis for this reason.

Another reason for not continuing was the output would be a drying time for a cladding. This is less important than the drying time of wet framing. The drying of wet framing has previously been shown to be independent of cavity type and so re-running the analysis with a drainage plane in the model would likely be of limited value – even if the ventilation process was realistically modelled.

APPENDIX D WEATHERTIGHTNESS TEST TO E2/VM1 OF 6MM-THICK DRAINAGE PRODUCT

D.1 Introduction

The purpose of this series of tests was to compare the performance of the cavity formed by drainage products with that provided by the “standard” 20mm cavity formed by timber cavity battens.

A modified version of weathertightness test Class 2 E2/VM1 was used since in standard form, the test is only applicable to walls with a 20mm cavity or larger.

In this particular test, the specimen was essentially a plain wall (no windows, meter boxes etc) and was clad with fibre cement weatherboards. A 6mmthick mesh drainage plane was installed behind the weatherboards.

D.2 Limitation

The results reported here relate only to the item(s) tested.

D.3 Sample Description

The sample tested consisted of a timber frame covered with wall underlay and clad with fibre cement weatherboards over a 6mm drainage plane.

The jointers for the weatherboards were in line with the studs. This was not in accordance with the technical manual but was done because the weatherboards had already been cut to length.

The butt joint between weatherboards was not sealed – again this was not in line with standard practice.

A rectangular opening was made in the wall underlay and was covered with perspex, to allow viewing of the specimen during the test.

Plywood sheets acted as the interior lining of the wall.

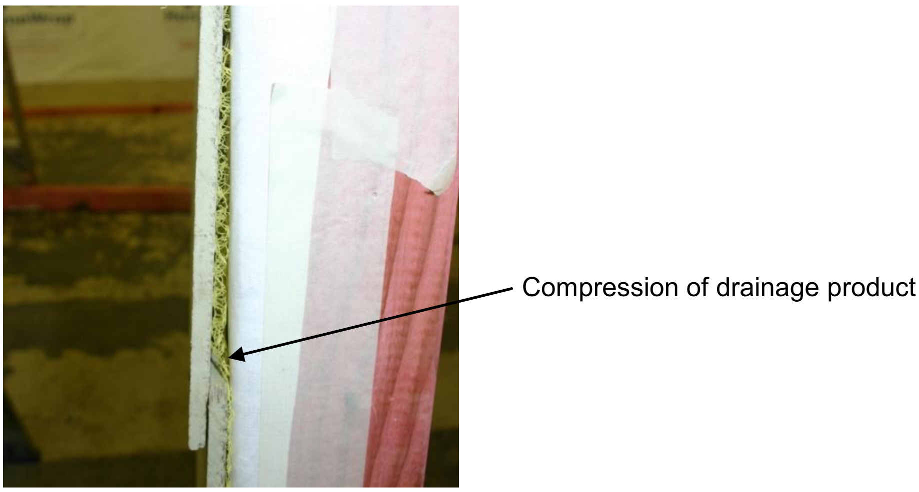

Figure A.7 Detail Showing Drainage Product in Relation to Gap Behind Weatherboards

Figure A.8 Face Nailing of Weatherboards

Figure A.9 Perspex Panels in Line with Underlay and Plywood Interior Linings

D.4 Test

The test conducted was a weathertightness one using relevant components of the method of E2/VM1 drawn from AS/NZS 4284.

The sample was installed in the BRANZ weathertightness testing booth on Thursday 21 October 2010 (the wetwall test was performed the following day).

Series 1: Static Water Penetration Test pressure 500Pa Duration 15 mins	No leaks
Series 1: Cyclic Water Penetration Test pressure 150-300Pa	No leaks

Duration 5 mins Test pressure 300-600Pa Duration 5 mins	
Series 2: Water Management Tests **Static water penetration** Test pressure 500Pa Duration 15 mins	No leaks
Series 2: Water Management Tests Test pressure 150-300Pa Duration 5 mins Test Pressure 300-600Pa Duration 5 mins	No leaks
Removal of linings and wall underlay	Water present on back of underlay. Drops of water present at several locations on drainage product.
Series 3: Wetwall Test Static Water Penetration Test pressure 50Pa Duration 15 mins	No leaks. Water was observed to occasionally "bubble" between the lap joints in the vicinity of the butt jointers.

After completion of the wetwall test the pressure was ramped up to 150Pa. Water percolated through the larger gaps in the vicinity of the jointers. This gap was formed by the jointer itself. This path would have been present even if the butt joint between boards was sealed. It is likely this path was the source of the water on the wrap.

No water was seen through the perspex panel. This could be explained by the fact there was no jointer directly above the panel.

D.5 Results

The specimen failed because water was present on the back of the wrap after Series 2.

D.6 Discussion

Fibre cement weatherboards were chosen as the cladding because they were perceived to represent a "worst-case scenario" in terms of compression of the drainage plane and "blow-out". When fixing a cladding it is usual for there to be a timber member supporting it, e.g. battens in an open rainscreen wall or studs in a direct-fix wall. With drainage materials this is not necessarily the case. The action of driving a nail through the cladding into an airspace could cause the interior face of the cladding to detach (or blow-out) in the vicinity of the hole. This is likely to be most common with cementitious products.

A relatively unusual feature of the tested boards was the requirement for face-nailing. This was due to the boards being relatively tall and it leads to a tighter gap where they overlap. The exception to this was in the vicinity of the jointers. The jointer causes the gap between weatherboards to be slightly larger (approximately 1mm in size).

The 6mm drainage mesh compressed in the vicinity of the nails can be seen in Figure A.7. This makes the wall similar to a direct-fix case and significant blow-out (i.e. to the point where the fixing strength is compromised) was not thought to have occurred. This could be confirmed with fixing pull-out tests if necessary.

In reference to Figure A.7, it is debatable whether the drainage product makes any difference to the overall installation of weatherboards. The fixing points are effectively direct-fixed (compression of drainage product) and the natural gap formed due to the overlapping nature of the weatherboards is relatively unaltered by the presence of the drainage product.

Water was thought to penetrate though the larger gaps near the jointer. The top of each board was effectively in contact with the wall underlay and so it was unsurprising that some water remained on the wrap at the time of post-test examination (an E2/VM1 failure).

APPENDIX E WEATHERTIGHTNESS TESTS TO E2/VM1 OF 7MM-THICK DRAINAGE PRODUCT WITH FILTER FABRIC

E.1 Introduction

The purpose of this series of tests was to compare the performance of the cavity formed by drainage products with that provided by the “standard” 20mm cavity formed by timber cavity battens.

A modified version of weathertightness test Class 2 E2/VM1 was used since in standard form, the test is only applicable to walls with a 20mm cavity or larger.

In this particular test, the specimen was essentially a plain wall (no windows, meter boxes etc) and was clad with fibre cement weatherboards. A 7mm-thick drainage product with a filter fabric was located behind the weatherboards.

E.2 Limitation

The results reported here relate only to the item(s) tested.

E.3 Sample Description

The sample tested consisted of a timber frame covered with wall underlay and clad with fibre cement weatherboards over a 7mm-thick drainage product with a filter fabric. The filter fabric of the drainage product was adjacent to the cladding.

The butt joint between weatherboards was not sealed – this was not in line with the manufacturer’s guidelines (see discussion).

A rectangular opening was made in the wall underlay and was covered with perspex. This was to allow viewing of the specimen during the test.

Plywood sheets acted as the interior lining of the wall.

Figure A.10 Detail Showing Lapping of Drainage Product Filter Fabric

Figure A.11 Compression of Drainage Product after Cladding is Applied

Figure A.12 Perspex Panels in Line with Underlay and Plywood Interior Linings

E.4 Test

The test conducted was a weathertightness one using relevant components of the method of E2/VM1 drawn from AS/NZS 4284.

The sample was installed in the BRANZ weathertightness testing booth on Monday Tuesday 16 November 2010.

Series 1: Static Water Penetration Test pressure 500Pa	No leaks

Duration 15 mins	
Series 1: Cyclic Water Penetration Test Pressure 150-300Pa Duration 5 mins Test pressure 300-600Pa Duration 5 mins	No leaks
Series 2: Water Management Tests **Static water penetration** Test pressure 500Pa Duration 15 mins	No leaks
Series 2: Water Management Tests Test pressure 150-300Pa Duration 5 mins Test pressure 300-600Pa Duration 5 mins	No leaks
Removal of linings and wall underlay	No water present on back of wrap
Series 3: Wetwall Test Static Water Penetration Test pressure 50Pa Duration 15 mins	No leaks
Additional water penetration requirements	

After completion of the wetwall test the pressure was ramped up to 150Pa. Water percolated through the larger gaps in the vicinity of the jointers. This gap was formed by the jointer itself and would have been present even if the butt joint between boards was sealed. Water that did penetrate at the butt joints was deflected by the jointer and drained back out (see Figure A.13).

Figure A.13 Water Penetration Through Boards

E.5 Results

The specimen passed.

E.6 Discussion

Fibre cement weatherboards were chosen as the cladding because they were perceived to represent a “worst-case scenario” in terms of compression of the drainage plane and “blow-out”. When fixing a cladding it is usual for there to be a timber member supporting it, e.g. battens in an open rainscreen wall or studs in a direct-fix wall. With drainage materials this is not necessarily the case. The action of driving a nail through the cladding into an airspace could cause the interior face of the cladding to detach (or blow-out) in the vicinity of the hole. This is likely to be most common with cementitious products.

A relatively unusual feature of the tested boards was the requirement for face-nailing. This is due to the boards being relatively tall and it leads to a tighter gap where they overlap. The exception to this was in the vicinity of the jointers. The jointer causes the gap between weatherboards to be slightly larger (approximately 1mm in size).

The drainage product compressed in the vicinity of the nails (see Figure 2). However, it did not compress by the same amount as the specimen in Appendix D. The technician felt that cladding was not as secure as in the previous case.

In reference to Figure 1, the main difference between this specimen and that of Appendix D was the presence of a filter fabric. The main purpose of this fabric is for the application of stucco, but it also acts as another barrier for water to pass through prior to reaching the synthetic wall underlay adjacent to the framing.

The amount of water passing through the cladding would have been almost identical to that in Appendix D, but the presence of the filter fabric prevented any water reaching either the drainage mesh or the wall underlay.

This leads on to the question whether a direct-fix wall built with two layers of wall underlay would pass the E2/VM1 test. Strictly-speaking, this is not possible because E2/VM1 can only be used where the cavity is greater than 20mm in depth, but with the potential introduction of drainage products, this criteria could be altered. In all likelihood the presence of something as trivial as a second layer of building paper would indeed stop water being present on the wall underlay adjacent to the framing. This in essence could be perceived as “cheating” the test and it may be desirable to impose some limit to the depth of the cavity to prevent this occurring. A depth of 5mm represents the limit of capillary effects and a safety margin may be desirable on top of this. A 10mm cavity depth would bring us in line with the Canadian building code.

The result also raised questions about the sensibility of holding water near the cladding for extended periods of time. The filter fabric essentially stopped any water reaching the mesh and so the drainage space is really that between the filter fabric and the cladding – which is small compared to the overall cavity depth. The airflow in this small space will also be small compared to the whole cavity. Therefore the ability to drain has been reduced and the ability to dry the cladding has been reduced. These things are not assessed by E2/VM1 and they did not cause a E2/VM1 failure but perhaps they raise an issue for further consideration. This issue came up in the drying studies of the various drainage products but none of those had a filter fabric like the specimen tested. It could be proposed that the cladding would dry at a similar rate to a normal direct-fix wall but with a lower risk of the framing becoming wet.

APPENDIX F WEATHERTIGHTNESS TEST TO E2/VM1 OF 11MM-THICK SOLID CHANNEL DRAINAGE PRODUCT

F.1 Introduction

The purpose of this series of tests was to compare the performance of the cavity formed by drainage products with that provided by the “standard” 20mm cavity formed by timber cavity battens.

A modified version of weathertightness test Class 2 E2/VM1 was used since in standard form, the test is only applicable to walls with a 20mm cavity or larger.

In this particular test, the specimen was essentially a plain wall (no windows, meter boxes etc) and was clad with fibre cement weatherboards. An 11mm-thick drainage product comprising plastic channels and a filter fabric was located behind the weatherboards.

F.2 Limitation

The results reported here relate only to the item(s) tested.

F.3 Sample Description

The sample tested consisted of a timber frame covered with wall underlay and clad with fibre cement weatherboards over an 11mm-thick drainage product comprising plastic channels and a filter fabric. The filter fabric of the drainage product was adjacent to the cladding. The drainage product consisted of two courses of material, with the upper and lower courses butted together, i.e. not lapped shingle fashion.

The butt joint between weatherboards was not sealed – this was not in line with the manufacturer’s guidelines (see discussion).

A rectangular opening was made in the wall underlay and was covered with perspex, to allow viewing of the specimen during the test.

Plywood sheets acted as the interior lining of the wall.

F.4 Test

The test conducted was a weathertightness one using relevant components of the method of E2/VM1 drawn from AS/NZS 4284.

The sample was installed in the BRANZ Ltd weathertightness testing booth on Thursday 18 October 2010.

Series 1: Static Water Penetration Test pressure 500Pa Duration 15 mins	No leaks
Series 1: Cyclic Water Penetration Test pressure 150-300Pa Duration 5 mins Test pressure 300-600Pa Duration 5 mins	No leaks
Series 2: Water Management Tests **Static water penetration**	No leaks

Test pressure 500Pa Duration 15 mins	
Series 2: Water Management Tests Test pressure 150-300Pa Duration 5 mins Test pressure 300-600Pa Duration 5 mins	No leaks
Removal of linings and wall underlay	No leaks
Series 3: Wetwall Test Static Water Penetration Test pressure 50Pa Duration 15 mins	A small amount of water dripped from upper course of the drainage product on to the framing.

As in the other tests, upon completion of the wetwall test the pressure was ramped up to 150Pa. No further leakage paths were identified.

F.5 Results

Because water reached the plane of the framing during the wetwall test the specimen failed.

F.6 Discussion

Fibre cement weatherboards were chosen as the cladding because they were perceived to represent a “worst-case scenario” in terms of compression of the drainage plane and “blow-out”. When fixing a cladding it is usual for there to be a timber member supporting it, e.g. battens in an open rainscreen wall or studs in a direct-fix wall. With drainage materials this is not necessarily the case. The action of driving a nail through the cladding into an airspace could cause the interior face of the cladding to detach (or blow-out) in the vicinity of the hole. This is likely to be most common with cementitious products.

A relatively unusual feature of the tested boards was the requirement for face-nailing. This was due to the boards being relatively tall and it leads to a tighter gap where they overlap. The exception to this was in the vicinity of the jointers. The jointer causes the gap between weatherboards to be slightly larger (approximately 1mm in size).

The drainage product did not compress as much as the other drainage products (Appendix D and Appendix E). This is a desirable aspect because the drainage space is maintained. However, the technician felt that the cladding was not as secure because the nails had not “grabbed” as much timber as in the other cases. Several boards cracked near the fixings. One nail was “over nailed’ and in one location a larger gap was formed between the weatherboards (see Figures 1, 2 and 3).

Figure A.14 Bulge in Weatherboards

Figure A.15 Cracking of Weatherboards

Figure A.16 Nailthrough Required a Second Nail to be Used Here

Water was thought to penetrate though the larger gaps near the jointer. The amount of water coming through the cladding would have been highest in the wetwall test. During the other parts of E2/VM1 a higher degree of pressure equalisation across the cladding should have occurred due to the relatively large vent areas (at the bottom of the wall and between the boards) and low leakage (a single piece of underlay with no lap joints). This equalisation would lead to less of a pressure drop across the cladding and hence less water penetration than during the wetwall test. When this water was incident on the upper course of the drainage product, it drained down the surface. When water reached the bottom of the upper course, it dripped down and since the lower course was not lapped under the upper course and the channels were not perfectly aligned, water was able to drip on to the framing (see Figure A.17).

Figure A.17 Frame Wetting During the Wetwall Test Due to Product Not Lapping