The Performance of Wall Drainage Media in New Zealand

Overton, G.
BRANZ, NZ
(email: greg.overton@branz.co.nz)
Bassett, M.
BRANZ, NZ
(email: mark.bassett@branz.co.nz)
McNeil, S.
BRANZ, NZ
(email: stephen.mcneil@branz.co.nz)

Abstract

The purpose of this research was to investigate the ability of various 'drainage-members' to manage moisture in New Zealand style walls subject to real climatic conditions. These relatively new products come in a variety of types including textured wraps, entangled polymer filaments and rigid channels.

One of the desired outcomes was to understand where these products sit within the risk matrix of New Zealand's weathertightness compliance documentation and provide for their inclusion in the NZ Building Code.

Previous work by BRANZ discovered that the drying time of wet framing can be of the order of several months on south-facing (cold) walls and highlighted the importance of keeping the actual framing dry. One of the key questions to be answered by this research was whether the cavities formed by drainage-members permit undesirable moisture transport to the framing.

Twenty 1.2 x 2.4 m walls were installed in one of BRANZ's outdoor test facilities. Each was instrumented with framing moisture content sensors, humidity probes and corresponding thermocouples. Seven types of drainage system were investigated along with a standard open rainscreen (ORS) wall, a standard direct-fixed wall and a brick veneer wall. With the exception of the brick veneer and an EIFS (external finish and insulation system) wall, all of the walls were clad identically with texture-coated fibre-cement.

A series of drainage experiments were conducted whereby 1 litre of water was introduced onto the back of the cladding at rate of 1 L/hr through a dosing point near the head of the wall. The specimen instrumentation was used to quantify the drying rate from the cladding and also to determine whether any moisture had transported through to the framing. A capacitive moisture meter was used to generate a series of moisture maps for each specimen, thus forming a time-history of where moisture was stored within the wall.

This project is a five-year study funded by the New Zealand Building Research Levy. This paper is the first in a series and concentrates on experimental design and the results from the first year of testing. These preliminary results have shown that frame wetting can occur when some drainage-members are employed. This appears to be due to an installation detail as opposed to a failure of a particular product. Subsequent work will comprise the generalisation of the results to other geographical areas and the development of testing criteria.

Keywords: Drainage, drying, rainscreen, moisture.

1. Introduction

New Zealand, like several other countries, suffered from a leaky home crisis in the late 1990s and early 2000s – the consequences of which are still being exposed (Gibson, 2009). The causes of the problem were manifold, but the move away from traditional cladding types, metal flashings and building designs with reasonable eaves certainly contributed to the problem (Groufsky, 2008). Many homes with barrier claddings and little protection from the weather were unable to manage water leaks adequately and in a few years were found to have decayed timber framing. The Department of Building and Housing developed a risk-based classification for building designs coupled with a set of acceptable construction solutions for each of the risk categories (DBH, 2005). It is desired to extend these solutions to include a relatively new class of products subsequently referred to as drainage mats. These mats can essentially replace the cavity batten and come in various forms ranging from relatively solid plastic channels, to entanglements of polymer fibres and also textured building wraps. These materials provide another way of managing rain water leaks through claddings, and this project is attempting to position the new materials against the risk categories for New Zealand buildings.

One of the principles of cavity design is that the actual cavity should not be bridged. Many of these new products violate this principle. This study aimed to clarify whether the use of these products can facilitate the transport of water from the exterior cladding to the framing.

The drainage and drying performance of claddings has been investigated by a number of authors with one notable sequence of studies (Onysko, 2008 & 2009) being particularly extensive. That study measured drainage performance by weighing a wall specimen in the laboratory. It found that 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 8 l in one hour distributed across 600 mm of drainage cavity) the drainage materials retained a relatively small 0.3% to 1.4% (an average of 46 g) of moisture, half of which dried out in the laboratory over the next two days.

This study has built on the earlier work of Onysko et al by installing wall specimens in an outdoor facility so that they are subject to ‘real’ climatic effects. Twenty walls were installed in an existing experimental building at BRANZ in New Zealand. They were subjected to a series of wetting experiments and the conditions within the wall were monitored.

The study has used tracer methods developed earlier (Bassett & McNeil, 2006) to characterise the ventilation rates associated with the systems. The results have compared well with those based on air flow resistance measurements which assume a simple power law approach to cavity ventilation.

This project is a five-year study funded by the New Zealand Building Research Levy and is due to finish in 2013. This paper covers the experimental design, airtightness and ventilation testing, and the first set of drainage and drying tests which began in March 2009.

2. Experimental method

Twenty walls were installed in an existing experimental building at BRANZ (Bassett & McNeil, 2006). 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 program in any other way. The products are described in this report but trade names have been excluded.

Duplicate specimens were installed on the north and south elevations of the building (Figure 1). The timber frames were constructed of untreated Pinus Radiata; this is rarely used for construction in New Zealand anymore but was selected because its moisture/electrical response has been well characterised. The overall frame dimensions were 2,400 mm high × 1,200 mm wide. Studs were located 300 mm from each side. Dwangs were located at 800 mm centres in the central portion of the frame and at 1,200 mm centres in the two outer spaces.

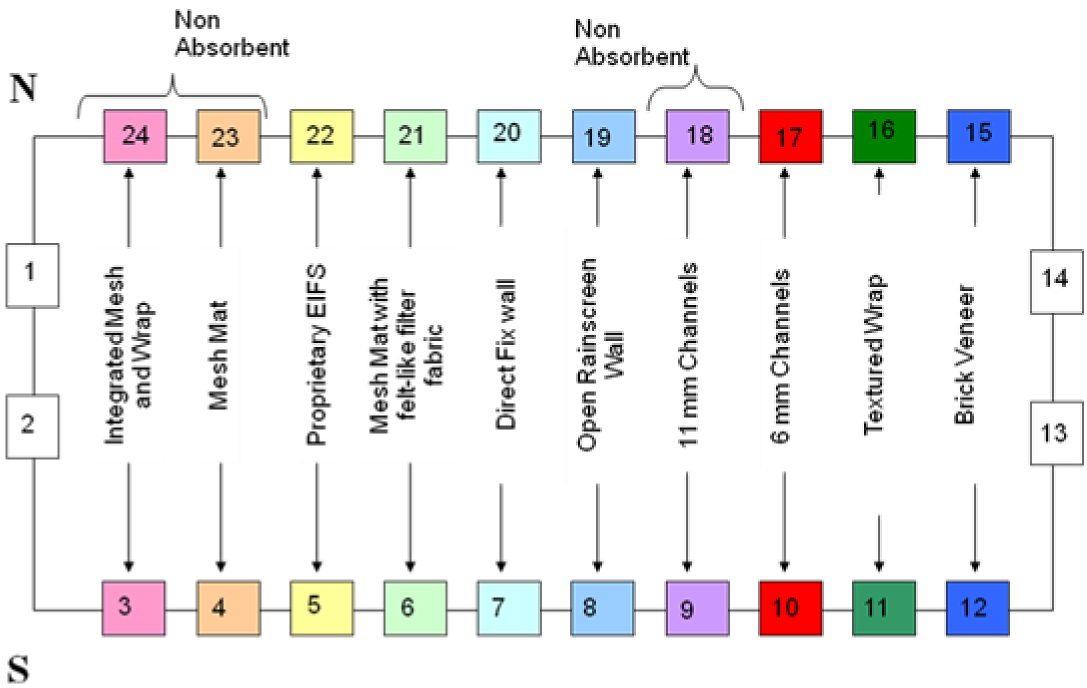

Figure 1. Layout of wall specimens

Where a drainage mat did not incorporate or comprise a building wrap, DuPont™ Tyvek® was used as the building wrap. 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 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~2.0 m^2C/W) in the stud space, and all walls were lined with 10 mm thick plasterboard, which was painted with a primer and two water-based finish coats.

2.1 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 (Bassett & McNeil, 2007) showed water could reach the framing on direct-fix walls, and also showed 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.

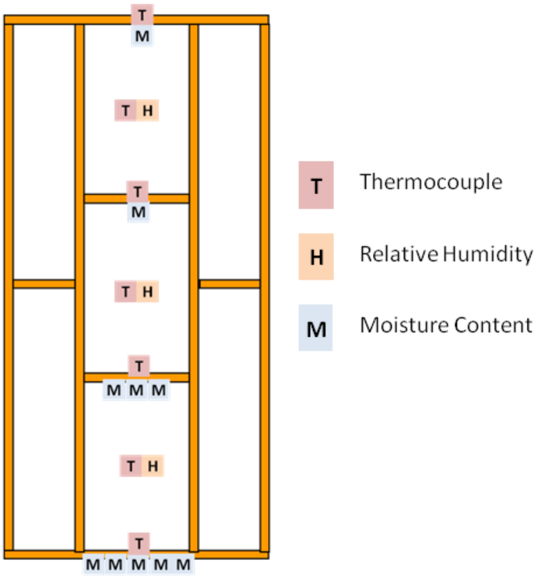

Figure 2. Specimen frame and instrumentation

Each wall had 10 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 (25 mm long stainless steel nails) were installed as close to the face of the dwangs as possible. Thermocouples were installed in the horizontal framing members to allow temperature correction of the moisture content readings. Humidity sensors 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 25 mm. 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.

2.2 Moisture dosing

This study involved introducing water into the wall specimens and observing what happened. Numerous experimental programs (Davidovic, 2005; Smegal, 2006; Straube, 1998) have quantified the drying ability of walls and there are standard tests for testing the drainage efficiency of walls (ASTM, 2003). However, to date there is no consensus on what level of water entry wall assemblies should be designed to cope with.

For this study, 1 L of water was introduced through a single dosing point near the head of the wall over the course of one hour. This amount is not insignificant and the single dosing point provides a well-defined wetting pattern. If the wall was wetted over a wider area it was felt that some aspects of the behaviour of the wall assemblies could be masked e.g. any spread of moisture. Any water that drained out of the bottom was collected in a trough and weighed to determine the quantity of retained water.

2.3 Flow resistance measurements

Knowledge of the resistance to air flow for each wall specimen permits the calculation of ventilation levels within the wall specimen when subjected to various wind speeds and temperatures.

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. This arrangement measured the resistance of the whole cavity. This meant that any pressure difference calculated (wind and stack) could simply be applied to the flow resistance equations to give the ventilation rate. To calculate the pressure difference across the height of the walls, the pressure coefficients from Bowen (1976) and re-presented by Liddament (1986) were used.

2.4 Ventilation measurements

Ventilation rates were measured using tracer methods (Bassett & McNeil, 2006) in Walls 21, 23 and 24 to allow comparison with the results using the flow resistance data. To avoid tracer absorption by the fibre-cement the inside face of the cladding on these walls was painted. The paint on the interior face essentially made the cladding non-absorbent, which subsequently affected the drainage efficiency of these wall systems.

3. Results and analysis

3.1 Flow resistance measurements

Table 1 shows the flow resistance data for the specimens fitted to a power law relationship, $Q=C\Delta P^n$, where Q is the ventilation rate, ΔP is the pressure difference, and C and n are the power law coefficient and exponent respectively.

Several wall specimens not documented in Table 1 were already installed in the building. These were conventional walls which were retained from the previous study for reference. Typical values for the flow resistance were assumed for these specimens (Bassett & McNeil, 2006).

Table 1. Summary of air flow resistance results

Specimen	*Coefficient*	*Exponent*	*L/s.m2 @50Pa*	*Effective leakage area (mm2 at 1Pa)*	*Average for wall type (north and south walls) (mm2 at 1Pa)*
Wall 3	*0.201*	*0.786*	*1.51*	*260*	*263*
Wall 4	*0.297*	*0.605*	*1.10*	*383*	*425*
Wall 5	*0.467*	*0.612*	*1.76*	*603*	*669*
Wall 6	*0.388*	*0.771*	*2.75*	*501*	*462*
Wall 9	*0.552*	*0.839*	*5.10*	*712*	*724*
Wall 10	*0.119*	*0.890*	*1.35*	*154*	*140*
Wall 11	*0.004*	*0.970*	*0.06*	*5*	*16*
Wall 16	*0.020*	*0.760*	*0.14*	*26*	
Wall 17	*0.098*	*0.938*	*1.34*	*127*	
Wall 18	*0.569*	*0.824*	*4.97*	*735*	
Wall 21	*0.327*	*0.795*	*2.55*	*422*	
Wall 22	*0.569*	*0.609*	*2.14*	*735*	
Wall 23	*0.284*	*0.681*	*1.42*	*366*	
Wall 24	*0.207*	*0.795*	*1.61*	*267*	

3.2 Ventilation rate

Figure 4 compares the measured ventilation rate with that calculated using the air flow resistance of Wall 23. Figure 5 shows the calculated ventilation rate for a range of walls for the period 01/11/08 to 08/11/08.

Figure 5 shows that drainage media can result in higher ventilation levels than an ORS with a full 20 mm cavity. In a New Zealand ORS wall, the top of the cavity is closed off using a cavity batten. This means that 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. This would require 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 air flow resistance as that of the opening at the bottom. Cavities are normally closed off at the head to prevent damp air venting into the roof space via the eaves. Tactics for preventing moist air entering the roof cavity will be investigated later in the project. This illustrates that the specimens with a drainage mat and solid channels both resulted in higher ventilation rates than the ORS wall.

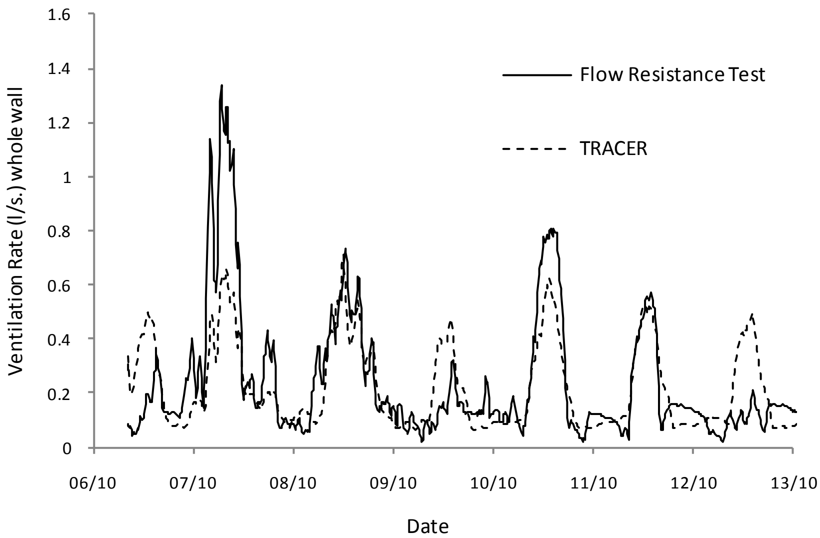

Figure 4. Comparison of measured and predicted ventilation rates for Wall 23

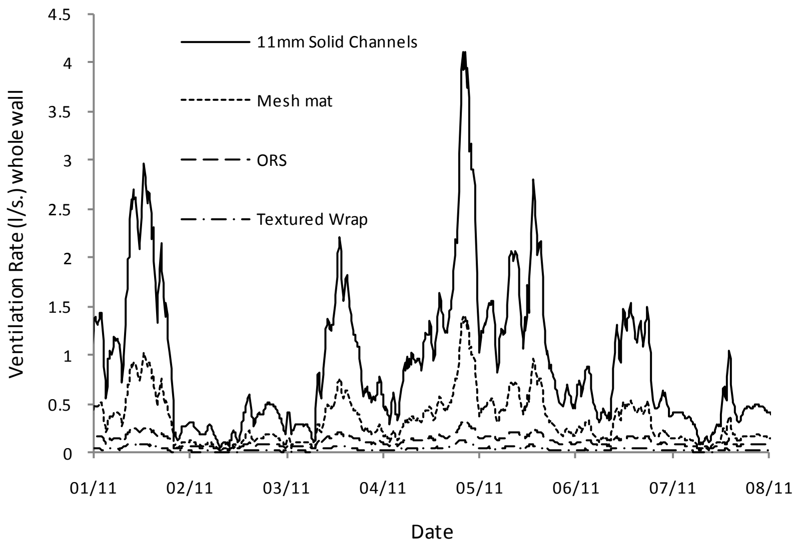

Figure 5. Comparison of ventilation rates for different wall types

3.3 Moisture dosing results

Table 2 displays a summary of the tests for all the walls.

Table 2. Summary of results

Specimen	*Product*	*Orientation*	*Retained water (ml)*	*Non-absorbent cladding*	*Frame wetting*	*Approximate time for cladding to dry*
Wall 3	*Wrap & mesh*	*South facing*	*479*	*N*	*N*	*30 weeks*
Wall 4	*Mesh mat*	*South facing*	*510*	*N*	*N*	*30 weeks*
Wall 5	*Proprietary EIFS*	*South facing*	*24*	*Y*	*N*	*0 days*
Wall 6	*Mesh mat*	*South facing*	*528*	*N*	*N*	*30 weeks*
Wall 7	*Direct-fix*	*South facing*	*699*	*N*	*N*	*30 weeks*
Wall 8	*Open rainscreen*	*South facing*	*256*	*N*	*N*	*30 weeks*
Wall 9	*11 mm channels*	*South facing*	*452*	*N*	*N*	*30 weeks*
Wall 10	*6 mm channels*	*South facing*	*600*	*N*	*N*	*30 weeks*
Wall 11	*Textured wrap*	*South facing*	*579*	*N*	*N*	*30 weeks*
Wall 12	*Brick veneer*	*South facing*	*–*	*N*	*N*	*N/A*
Wall 13	*Brick veneer*	*North facing*	*–*	*N*	*N*	*N/A*
Wall 16	*Textured wrap*	*North facing*	*608*	*N*	*Y*	*13 weeks*
Wall 17	*6 mm channels*	*North facing*	*625*	*N*	*N*	*10 weeks*
Wall 18	*11 mm channels*	*North facing*	*58*	*Y*	*N*	*0 days*

Wall 19	*Open rainscreen*	*North facing*	*409*	*N*	*N*	*1 week*
Wall 20	*Direct-fix*	*North facing*	*758*	*N*	*N*	*4 weeks*
Wall 21	*Mesh mat*	*North facing*	*552*	*N*	*Y*	*2 weeks*
Wall 22	*Proprietary EIFS*	*North facing*	*40*	*Y*	*N*	*0 days*
Wall 23	*Mesh mat*	*North facing*	*78*	*Y*	*Y*	*1 day*
Wall 24	*Wrap & mesh*	*North facing*	*32*	*Y*	*N*	*1 day*

For the EIFS walls the moisture meter could not detect any moisture due to the thickness of the polystyrene insulating material. However, given the small amount of moisture retained in the wall it is unlikely that there would have been a significant wetting pattern. The absorbency of the brick veneer made the application of the moisture meter meaningless for Walls 12 and 13. It was also impossible to capture any drained moisture since the weep holes were at ground level.

3.3.1 Frame wetting

Frame wetting was observed in several walls. However, no moisture was seen to pass through the building wrap(s) and wet the framing. Instead, water was seen to track along to the bottom plate and up into the framing as illustrated in Figure 6. These frames drained out relatively quickly. However, subsequent tests will utilise a flashing in an attempt to prevent the initial wetting. Indeed at least one manufacturer now supplies such a flashing. Alternatively the product could be terminated below the level of the bottom plate to form a drip-edge.

Figure 6. Frame wetting – water tracked along from bug screen

3.3.2 Absorbent vs non-absorbent cladding

Figure 7 shows the relative moisture content from two near-identical walls. They were housed next to each other on the north (warm) face of the experimental building and both contained a drainage media consisting of relatively solid plastic channels; one was of 6 mm depth and the other was 11 mm deep. The main difference was that Wall 18 had paint on the interior face of the cladding.

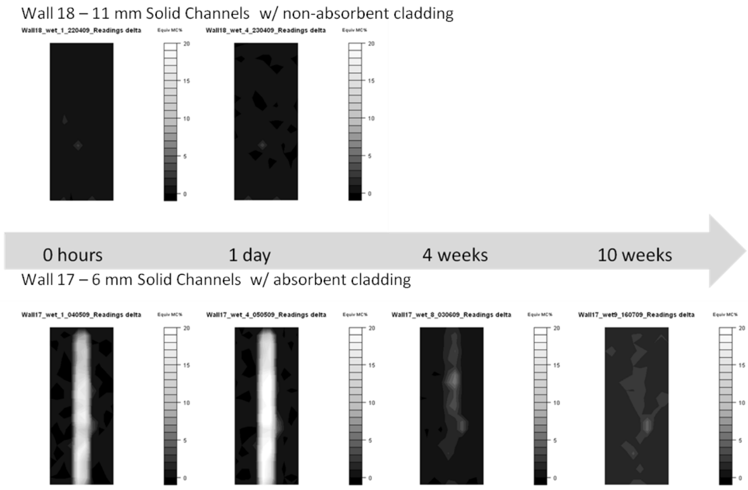

Figure 7. Comparison of non-absorbent and absorbent claddings

With a sealed non-absorbent interior face the vast majority of the water (942 ml) simply drained straight out of the wall assembly. This was shown by the lack of a distinctive wetting pattern in the subsequent moisture maps and no response in the relative humidity levels in the insulated stud-space.

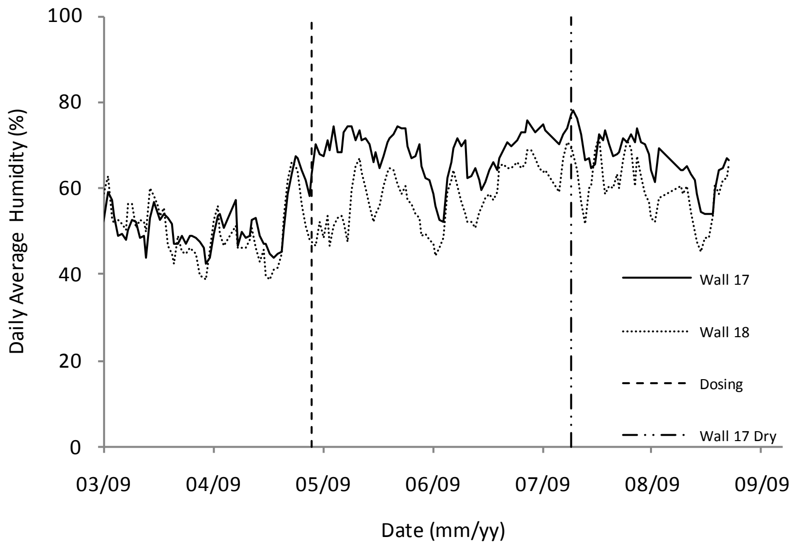

Figure 8. Relative humidity in Walls 17 and 18

Wall 17, with an absorbent cladding, exhibited quite different behaviour: 625 ml of the delivered water failed to drain out and was absorbed into the fibre-cement sheet. The moisture maps show that the wall did not dry out until approximately 10 weeks after this single dose. The relative humidity in the insulated space also increased in comparison with its neighbouring wall (Figure 8). This is not automatically a problem as there was no frame wetting in either of these walls. However, the presence of long-term moisture in the cladding material could potentially lead to durability issues.

3.3.3 Cavity type and orientation

Figure 9 and Figure 10 illustrate the drying from the back of the cladding for various wall types. Only walls with exact duplicates on each face of the building are shown i.e. walls with non-absorbent claddings on the north face are not shown.

The orientation of the wall had a large effect on the drying rate. Although there were variances in the drying times from the different types of wall on the north face, they all dried after several weeks. On the colder south face all walls with absorbent claddings took far longer to dry, as essentially they did not dry out until the beginning of the summer.

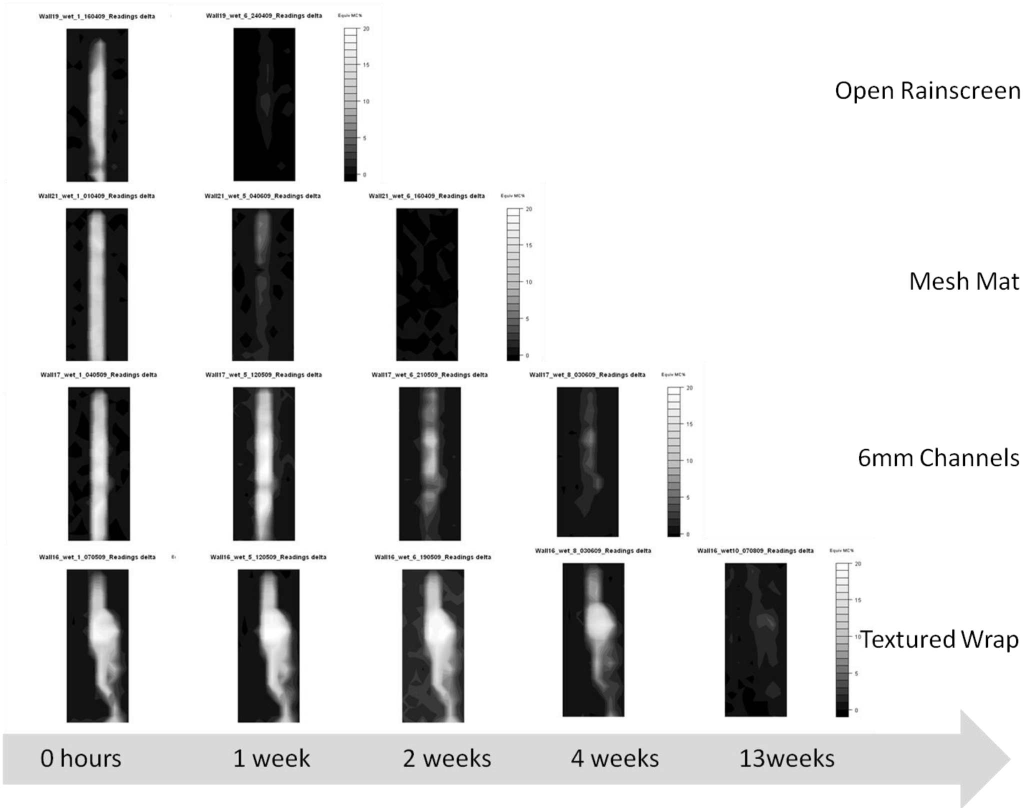

Figure 9. Drying of walls on the north face

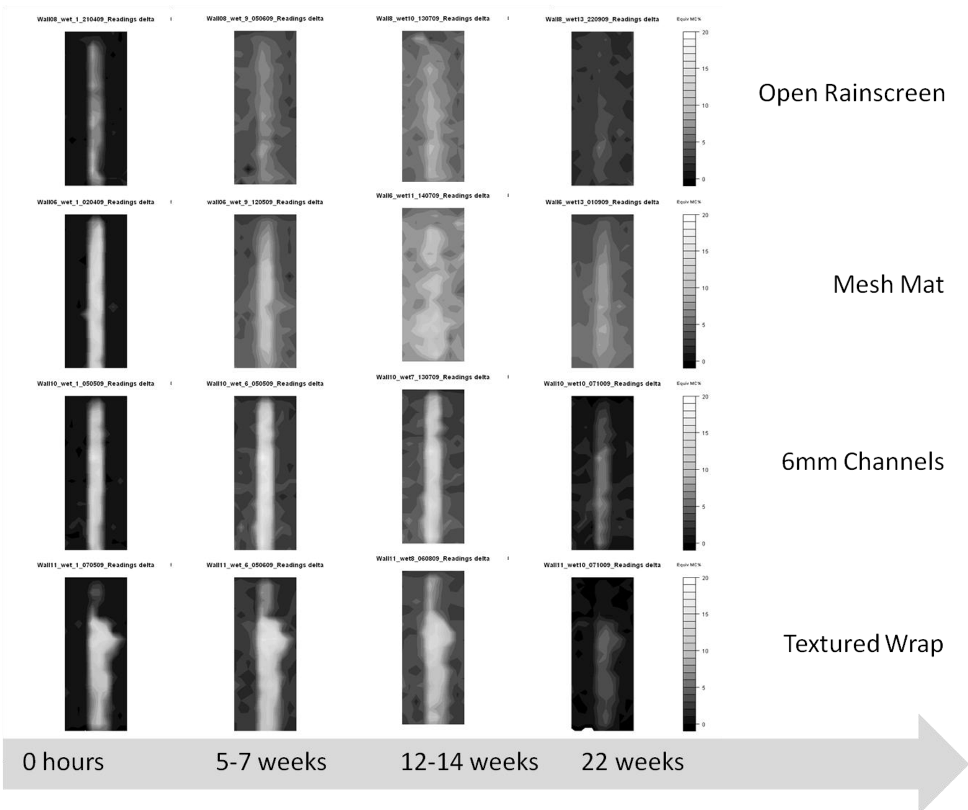

Figure 10. Drying of walls on the south face

4. Discussion & Conclusions

The quantity of water retained in the specimen walls was primarily dependent on the absorbency of the cladding. Where this was unpainted fibre-cement, approximately half of the 1 L of water applied was retained in the cladding. Where this was non-absorbent (pre-primed or the EIFS specimens), then similar quantities of water were retained to those measured by Onysko et al (2008). For this reason, a non-absorbent cladding must be regarded as an essential requirement for effective drainage.

None of the specimen walls appeared to allow water to track through to the framing, although there were three instances where water reached the bottom plate because the drainage mat and building wrap had not extended low enough to prevent capillary tracking across to the frame. This defect can be easily corrected by terminating the building wrap and drainage media well below the bottom plate or by fitting an appropriate flashing. The more important question of how exposed these drainage solutions are to a defect in the building wrap has yet to be explored. The walls in this study were carefully built to minimise penetrations and tears in the building wrap.

After the absorbency of the cladding, the next most important factor in wall drying was orientation. The various levels of drying ability offered by the different products were really only visible on the warm face of the building. In winter and on the cold face of the building it would appear that the choice of drainage product is almost irrelevant. Even the standard water-managed solution in New Zealand, the ORS, still showed signs of moisture 22 weeks after a single dosing event. If there are no long-term consequences arising from the presence of moisture on the back of the cladding, then this is not a problem.

Not all of the drainage products investigated are necessarily intended for use in the same form as the specimen walls. Textured wraps in particular are often marketed for use with stucco. The study aimed to see what issues might arise if they were used instead of a conventional wrap in a direct-fixed wall. In this study the use of a textured wrap resulted in a longer drying time than that using a plain building wrap. This may be because moisture was held within the texture of the wrap itself, although the limited number of specimens suggests that further investigation may be needed.

The next phase of this program will investigate drying rates in the summer months and the effect of wrap defects. Analytical models of drying to generalise the data to other parts of the country will be developed. Other outcomes from the program will include recommendations for a verification method for the use of drainage products. E2/AS1 includes one such test for cavity walls whereby a wall specimen is subjected to a series of water spray tests under pressure. However, in its current form it is not applicable to walls without a cavity. Some modification will be necessary to accommodate walls with a cavity substantially less than 20 mm in depth.

References

Gibson A. (2009). ‘Rotting Homes Bill Tipped to Top $11b’. *NZ Herald*, 19 August 2009.

Groufsky G. (2008). *Build* 103: 47-48. BRANZ Ltd, Judgeford, New Zealand.

Department of Building and Housing. (2005). *Approved Document E2/AS1 External Moisture*. DBH, Wellington, New Zealand.

Onysko D, Thivierge C, Plescia S & Craig B. (2008). 'Drainage and Retention of Water by Cladding Systems'. *Proceedings of the 2008 ICBEST Conference*. Minneapolis, USA.

Onysko D, Edgar J, Alkhoury E & Nabhan F. (2009). 'A Study of Drainage and Retention of Water by EIFS Materials and Systems'. *Proceedings of the 12th Canadian Building Science and Technology Conference*. Montreal, Canada.

Bassett MR & McNeil S. (2006). *Measured Ventilation Rates in Water Managed Wall Cavities.* 3rd International Building Physics Conference, Montreal, Canada.

McNeil S & Bassett MR. (2007). 'Moisture Recovery Rates for Walls in Temperate Climates'. *Proceedings of the 11th Canadian Conference on Building Science and Technology*. Banff, Canada

Davidovic D, Srebric J & Burnett EFP. (2005). 'Modelling Convective Drying of Ventilated Wall Chambers in Building Enclosures'. *International Journal of Thermal Sciences* 45: 180-189.

Smegal J. (2006). *Drainage and Drying of Small Gaps in Wall Systems*. MSc Thesis, Waterloo University, Ontario, Canada.

Straube J & Burnett E. (1998). 'Drainage, Ventilation Drying, and Enclosure Performance'. *Proceedings Thermal Performance of the Exterior Envelopes of Buildings* VII: 189-197.

ASTM E 2273-03 *Standard test method for determining the drainage efficiency of exterior insulation finish systems (EIFS) clad wall assemblies*. American Society of Testing Materials, Philadelphia, USA.

Bowen JJ. (1976). *A Wind Tunnel Investigation Using Simple Building Models to Obtain Mean Surface Wind Pressure Coefficients for Air Infiltration Estimates*. Report LTR-LA-209. National Research Council of Canada,. Ottawa, Canada.

Liddament MW. (1986). *Air Infiltration Calculation Techniques – An Applications Guide.* Air Infiltration Centre, Bracknell, UK.