STUDY REPORT

SR322 (2015)

WEATHER GROOVES IN WEATHERBOARD CLADDINGS

Mark Bassett and
Greg Overton

The work reported here was jointly funded by BRANZ from the Building Research Levy and the Ministry of Business, Innovation and Employment.

ISSN: 1179-6197

Preface

This is part of a series of reports prepared during research into the weathertightness of junctions between building materials and systems.

Acknowledgements

This work was funded by the Ministry of Business, Innovation and Employment and the Building Research Levy. The assistance of Roger Stanford is gratefully acknowledged.

Note

This report is primarily intended for building science researchers, but it also contains material that will be of value to cladding manufacturers.

WEATHER GROOVES IN WEATHERBOARD CLADDINGS

BRANZ Study Report SR322 (2015)

Mark Bassett and Greg Overton

Abstract

Capillary grooves (more commonly referred to as weather grooves) have been formed into the lap joints in timber weatherboards in New Zealand from the late 1970s to this day. They are rarely seen in fibre-cement and wood fibre composite claddings. This study set out to measure the improvement in weathertight performance that could be attributed to weather grooves in timber claddings.

Within the margins of experimental uncertainty, no significant performance gains were seen in large-scale timber-clad walls that could be attributed to weather grooves. Other leakage paths around fixings and through natural knots and defects in weatherboards dominated leakage through the lap joints.

More tightly controlled measurements in small lengths of joint found some performance improvements in tight-fitting joints due to weather grooves. Higher peak wind pressures in fluctuating wind conditions were required to cause leakage than was the case in joints without a weather groove. These performance gains were seen at wind pressures beyond the normal working range of domestic claddings.

The passage of water through these joints was modelled to resolve the relative importance of surface tension effects and the reservoir capacity within the weather groove. A differential equation representing the equation of motion for water in the joint was solved to show that a weather groove can improve the weathertightness of lap joints in weatherboards. However, as demonstrated experimentally, this is only where the more common leakage paths have been eliminated. The theoretical advantages of the weather groove derived from the storage capacity reducing the leakage rate in fluctuating wind conditions.

Keywords

Weathertightness, Capillary Grooves, Weatherboards, Claddings, Junctions

Contents Page

Figures Page

Tables

1. INTRODUCTION

The physical principles of surface tension and capillary-transported water are well enough understood, but they have not been consistently applied in New Zealand buildings. In particular:

- Some weatherboard profiles include weather grooves in lap joints, but in others, the groove is either missing or very small. This paper asks if weather grooves contribute significantly to the overall weathertightness of wall claddings and offers guidelines for their application.
- Capillary breaks have a similar role to weather grooves in preventing free water from reaching absorbent materials such as stucco and the end grain of timber. They are typically much larger than weather grooves and better defined in existing guidelines but not always applied.

The second of these capillary transport problems played a significant part in the leaking building crisis between 1990 and 2005 in New Zealand. Mediterranean-style buildings were popular at the time, with barrier wall claddings joined seamlessly with decks and to the ground. The absence of a capillary break at ground level led to failure in 24% of cases with this particular detail. There was also failure in 53% of cases with no capillary break between fibre-cement or stucco claddings and decks (Bassett et al. 2003). In fact, this was the most common failure associated with decks in this early building failure dataset. In contrast, missing weather grooves in claddings were never associated with water leakage problems. In fact, weatherboard houses were under represented in the population of leaking buildings compared with monolithic-clad houses, as is shown in Figure 1 (Bassett et al. 2003).

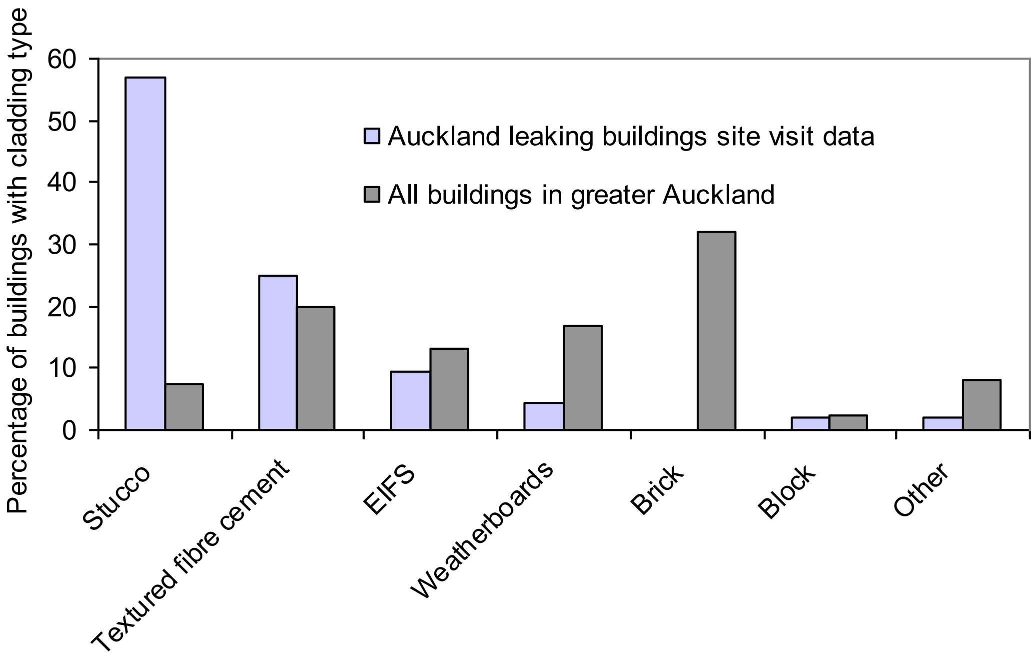


Figure 1. Proportions of houses with single cladding types built in the greater Auckland area between 1990 and 2002 compared with proportions of leaking buildings with the same claddings from the same period.

The data in Figure 1 must be interpreted with some caution because other factors might have led to these differences. In particular, the relative low numbers of leaking weatherboard- clad homes might be due to wider eaves or the ability of weatherboards to manage water leakage more effectively than monolithic cladding types. In fact the most common leaks in all wall types were at junctions between different cladding types and between windows and claddings. Leaks through the claddings themselves were comparatively uncommon. The ability of weatherboard walls to manage water with drainage and ventilation drying paths has since been investigated (Bassett et al. 2014). However, the role of weather grooves in reducing water leakage rates has not been quantified in the context of the whole wall leakage.

Weather grooves are shown in the lap joints of timber weatherboards in NZS 3617:1979 *Specification for profiles of weatherboards, fascia boards, and flooring* (see Figure 2) but not in the earlier superseded standard NZS 495:1948 *Profiles of weatherboards, flooring, and matchlining*. The rationale for this change is uncertain, but weather grooves are now common in New Zealand-sourced timber (see BRANZ Bulletin 411 *Recommended timber cladding profiles*). Internationally, there is much less emphasis on capillary-transported water in the lap joints of weatherboards.

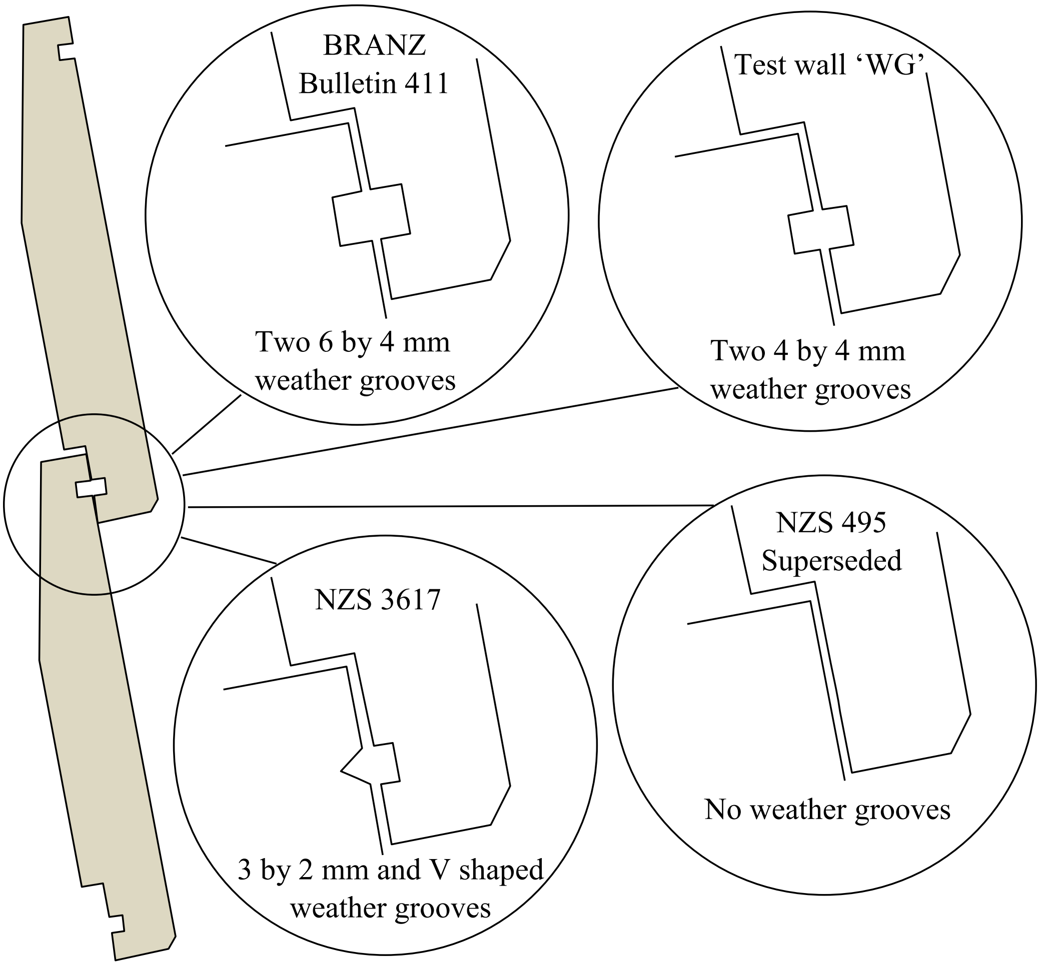


Figure 2. Weather groove variations in rebated bevel-back weatherboards.

The National Association of Forest Industries in Australia (2005) makes no mention of weather grooves in the lap joints of horizontal weatherboards or in vertical board and batten timber. However, but it does call for capillary breaks in the form of clearance between claddings and the ground, along with drip edges to shed water from claddings. A similar approach is advocated in the UK by TRADA (2000) where timber claddings are promoted as rainscreens on a drained and ventilated battened cavity. Weatherboard claddings in Canada are similarly described as rainscreens where the cavity is seen as the primary capillary break between the wet cladding and dry interior components (Chown 2001).

The physics of capillary-transported water in the lap joints of weatherboards has been investigated by Burgess (1992) where weather grooves are shown to resist the passage of wind-driven rain. Surface tension is shown to be disrupted by the geometry of a weather groove, effectively adding 30–250 Pa to the steady air pressure needed to breach the joint. In this study, measured breaching pressures were less than expected and somewhat uncertain. This left open the question of whether performance gains due to weather grooves will be significant compared with leakage through cracks, knot holes and other defects commonly seen in timber weatherboards. An additional unanswered question concerns the role of the weather groove as a storage volume to buffer transient water flows through lap joints driven by fluctuating wind pressures.

2. EXPERIMENTAL METHODS

The weathertight properties of lap joints in weatherboards were measured on a large-scale specimen (2.4 m x 2.4 m) and on a much smaller scale using a 600 mm length of joint. Equipment illustrated in Figure 3 was used for large-scale water measurements. It consists of a pressure chamber linked to a centrifugal fan and a fluctuating damper that together apply a steady pressure with a superimposed fluctuating pressure across the specimen. The pressure amplitude could be changed by adjusting the start and end points of the damper stroke. For the measurements described here, it was adjusted to cycle the air pressure over a 2 to 1 range. The chamber has a 2.4 m by 2.4 m opening for wall specimens. For the measurements described here, two wall specimens measuring 1.2 m by 2.4 m (area 2.88 m^2) were mounted side by side in the chamber.

The chamber was set up to deliver spray rates in the range 0.08–3.4 l/m^2.min, with the highest value corresponding to the minimum rain load called for in Verification Method E2/VM1 (2011). This wide range of rain loads was used in earlier studies (Bassett et al. 2014) to develop rain leakage functions of pressure and rain intensity for a range of weatherboard claddings. The measurements described in this paper were all completed with the spray rate set at 3.0 l/m^2.min.

Water leakage rates through the lap joints between weatherboards were measured gravimetrically by collecting leakage run-off from the wall or collecting water in an absorbent material placed close to leakage sites. This absorbent material was a commercial cleaning material (Wettex) composed primarily of cotton and cellulose fibres. An uncertainty in the leakage rate of 50% is considered appropriate because it was difficult to collect all of the water leakage from the large wall area. This was especially the case at high pressures where water spattering through the joints was difficult to catch. The uncertainty also reflects the repeatability of measurements and other problems discussed in the results.

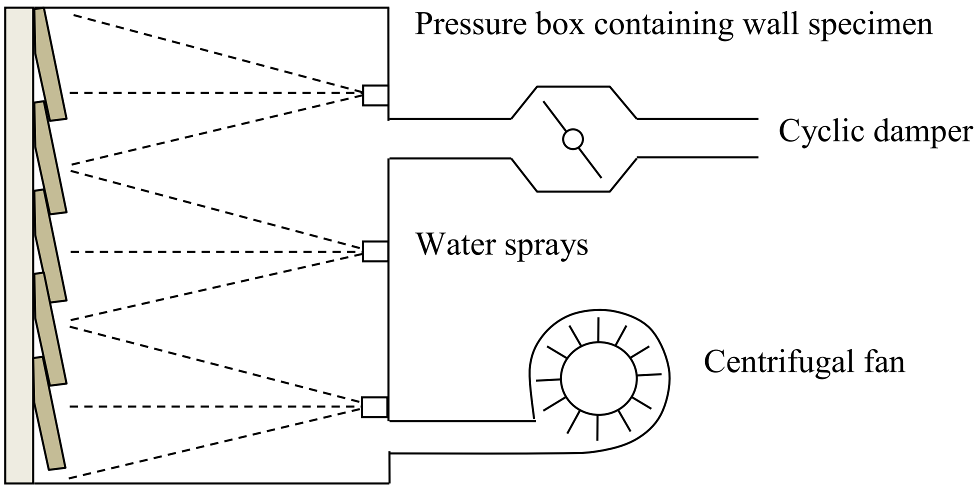


Figure 3. Equipment for measuring the weathertightness characteristics of wall claddings.

Smaller-scale measurements were conducted using a much smaller pressure chamber illustrated in Figure 4. The water spray was on the outside, and water leakage rates were measured gravimetrically using an absorbent pad placed inside the chamber at the point where leakage through the joint would have entered the wall cavity. The absorbent pad was the same commercial cleaning material (Wettex) used to trap water leakage in the large-scale experiment. The primary advantage of this smaller-scale equipment was that it gave better control over the joint geometry, in particular, the gap between weatherboards. As with the large-scale specimen, water sprays were set up to deliver rain loads in the range 0.08–3.4 l/m^2.min (with the highest value corresponding to the minimum rain load called for in E2/VM1 (2011).

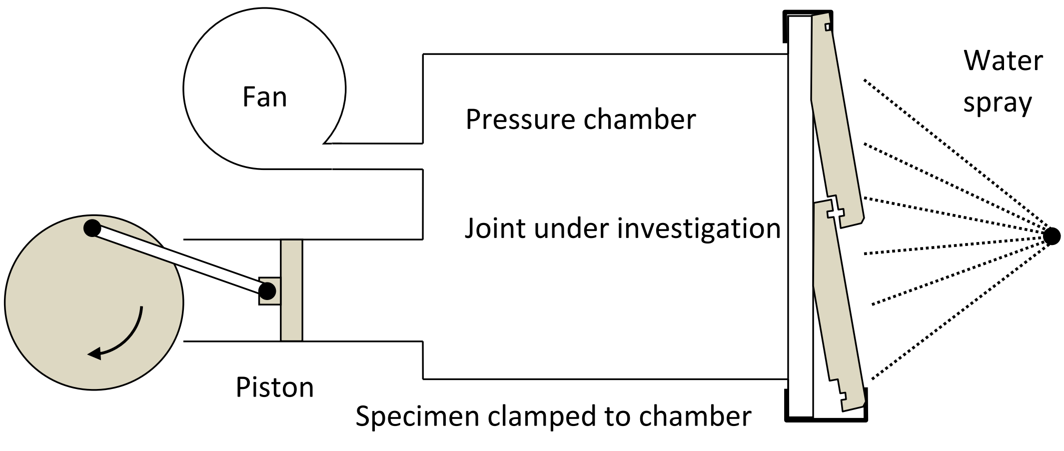


Figure 4. Equipment for measuring the weathertightness characteristics of a joint.

2.1 LARGE-SCALE WATER LEAKAGE AT STEADY PRESSURES

Two specimen walls 1.2 m wide by 2.4 m tall were built with 135 mm wide, primed, bevel-back weatherboard claddings. One wall (WG) included a single 4 mm by 4 mm weather groove in each lap joint, while in the second wall (NWG), there were no weather grooves. The walls were carefully constructed using clear defect-free timber to avoid common water leakage paths around fixings and through defects such as knots. This was necessary because earlier studies (Bassett and McNeil 2009) had shown that these leakage paths dominated water leakage through the lap joints. Therefore, they had to be eliminated to resolve any difference due to the presence of a weather groove. The airtightness of each cladding was measured to confirm that leakage paths through the lap joints were in a similar range for each wall. At 50 Pa, the air leakage rate through the weather groove wall was 0.27 l/s.m^2 compared with 0.25 l/s.m^2 for the non-weather groove wall. As such, the walls appeared to be similar to each other and about 10 times as airtight as similar walls assembled by tradespeople using non-selected timber. There was nevertheless some variation in the gap widths within each wall measured in the range of 0–1 mm.

The water leakage characteristics of the two weatherboard walls were measured over a range of air pressure differences at a rain intensity 3.0 l/m^2.min and plotted in Figure 5. With these two walls, the experimental error of 50% reflects measurement repeatability and the following systematic issues:

- Leakage rates were not uniform over the wall area, with the major leaks associated with wider gaps in lap joints. It is possible that these dominant leakage paths were not distributed equally between the two walls even though airtightness results suggest they were similar from an airtightness point of view.
- The walls were found to tighten up as the wall absorbed water, introducing time dependency in the results. This was compensated for by irrigating the wall for at least 30 minutes before taking leakage rate measurements.
- Water leakage spattering through joints at the higher pressures was difficult to capture.

Overall, these whole wall measurements usefully place leakage through lap joints in context with other leakage sites in timber weatherboard walls. However, they may not adequately resolve difference due to the presence of weather grooves in lap joints because gap widths have not been adequately controlled. Figure 5 compares the water leakage characteristics of the WG and NWG walls, showing their performance is indistinguishable in these measurements.

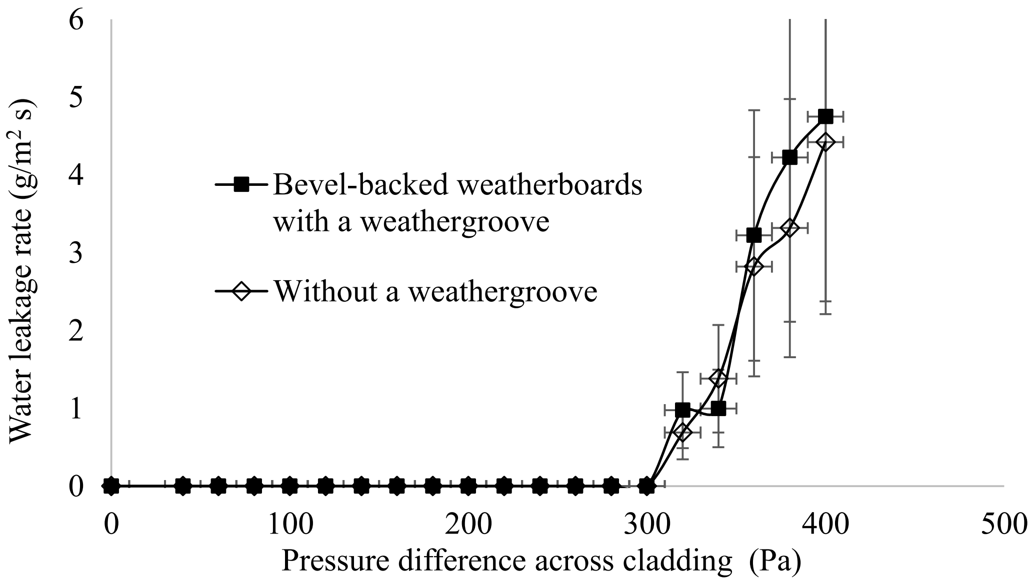


Figure 5. Water leakage at a range of air pressure differences through bevel-back weatherboard wall claddings with and without weather grooves.

The second observation is that no water leaks were seen at pressures below the hydrostatic equivalent of the lap joints (300 Pa). In contrast, the weathertight properties of trade-built walls described in Table 1 and measured in earlier studies (Bassett et al. 2014) are plotted in Figure 6. It is clear they leak at much lower pressures, which are in the normal operational range for residential claddings. Beyond 300 Pa, leakage through the WG and NWG specimen walls are in the same range as the other trade-built walls. This indicates that weather grooves machined into the lap joints of bevel-back weatherboards have not lifted their weathertight performance above the range expected of other trade-built claddings.

Table 1. Wall cladding descriptions relating to water leakage characteristics in Figure 6.

Wall	Cladding type	Weather grooves	Painted exterior
0	Bevel-back timber reference	No	Primed
1	Bevel-back timber weatherboards	Yes	Primed
2	Rusticated timber weatherboards	Yes	Primed
3	Fibre-cement weatherboards	No	Primed
4	Interlocking PVC weatherboards	No	No
5	Rusticated timber weatherboards	Yes	Primed
6	Bevel-back cedar weatherboards	Yes	Painted
7	Rusticated timber weatherboards	Yes	Primed
8	Bevel-back fibre-cement	No	Primed
9	Bevel-back timber weatherboards	Yes	Primed

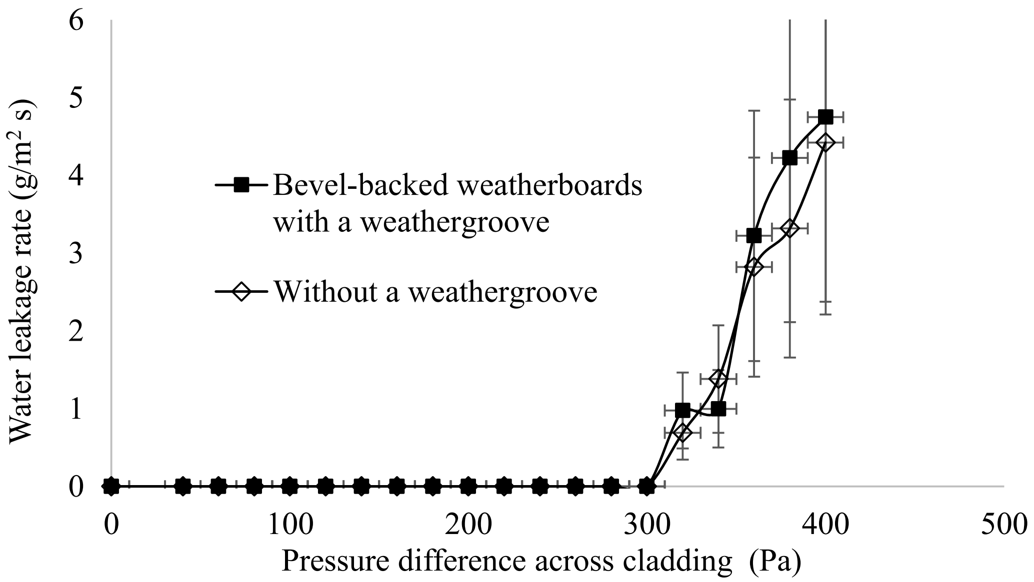


Figure 6. Leakage characteristics of nine trade-built weatherboard claddings plotted to 300 Pa and compared with the reference bevel-back weatherboard wall without weather grooves.

As in the earlier study (Bassett et al. 2014), water leakage rates were found to relate more to build quality than to the profile of the weatherboards. Water leakage sites were often at cracks, fixings and at openings in the lap joints between poorly fitted weatherboards that were large enough to allow air-entrained water leakage. The fundamental geometry of the overlap joint was found to be a secondary factor in water entry. This dependency on condition and build quality means that accurate water leakage rates are not generic to the cladding types examined here. This makes it difficult to predict water leakage rates through these claddings in practice. From a drainage perspective, it was noted that bevel-back board designs drained out water at lap joints more effectively than rusticated designs.

2.2 LARGE-SCALE WATER LEAKAGE WITH FLUCTUATING AIR PRESSURES

Water leakage rates were measured with the air pressure difference fluctuating over a 2 to 1 range at three frequencies – 0.1 Hz, 0.33 Hz and 1.0 Hz. Figure 7 and Figure 8 give the leakage rates for the WG and NWG walls plotted against maximum air pressure difference.

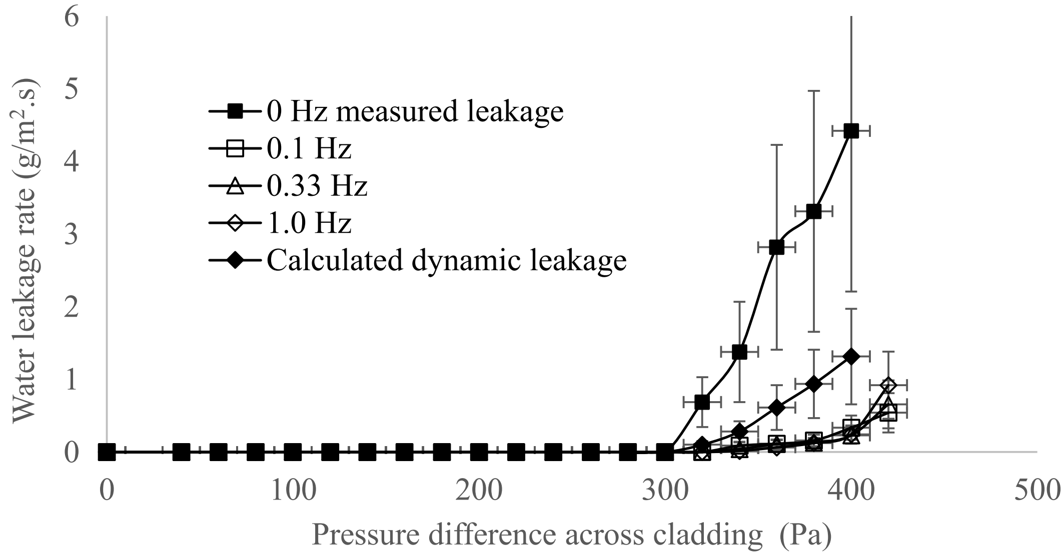


Figure 7. Frequency-dependent leakage through the weatherboard wall without weather grooves.

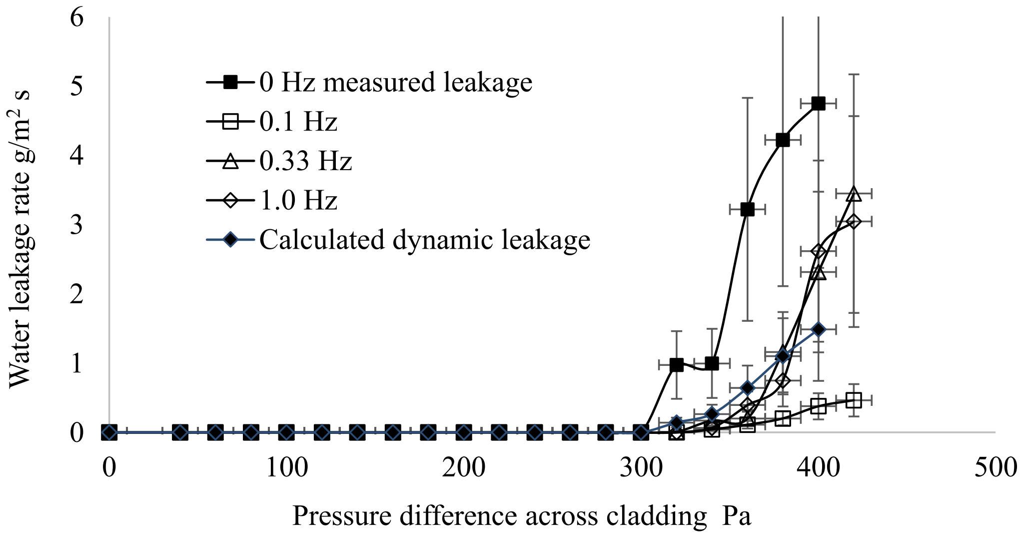


Figure 8. Frequency-dependent leakage through the weatherboard wall with weather grooves.

Observations showed that water accumulating inside and relaxing out of the joint were in phase with pressure fluctuations up to 1 Hz. This suggested that the leakage rate at any time in the cycle might simply be calculated from the steady pressure leakage rate function and the applied sinusiodal pressure as follows:

The applied pressure difference

$$\Delta p = A + B \sin \omega t \tag{1}$$

where:

Δp = the applied pressure difference (Pa)
t = time (s)
A = the average pressure (Pa)
B = the amplitude of pressure fluctuation (Pa)
ω = the frequency of the fluctuating pressure (rad/s)
L = the instantaneous joint leakage rate (g/m.s) and average leakage rate (L_{av} g/m.s)

where the static leakage function is a function of the pressure

$$L = f(\Delta p)$$

and the average leakage rate

$$L_{av} = \frac{\omega}{2\pi} \int_0^{2\pi/\omega} f(A + B \sin \omega t) dt \tag{2}$$

Calculated and measured leakage rates are plotted in Figure 7 for the NWG wall and in Figure 8 for the WG wall using equation 2. It is clear that the calculated dynamic leakage rates are not a good fit to the measured leakage rates in both cases. However, the experimental uncertainties are large enough for this to be not particularly significant. It was clear that a more controlled study using smaller lengths of lap joint would be needed to resolve any differences due to weather grooves.

2.3 SMALL-SCALE LEAKAGE AT STEADY PRESSURES

The leakage characteristics of a lap joint between primed timber bevel-back weatherboards were measured using equipment illustrated in Figure 4. Water leakage rates were measured through joints with weather grooves (joints A and C) and without weather grooves (joints B and D), and with two overlap dimensions (30 mm and 20 mm) as illustrated in Figure 9.

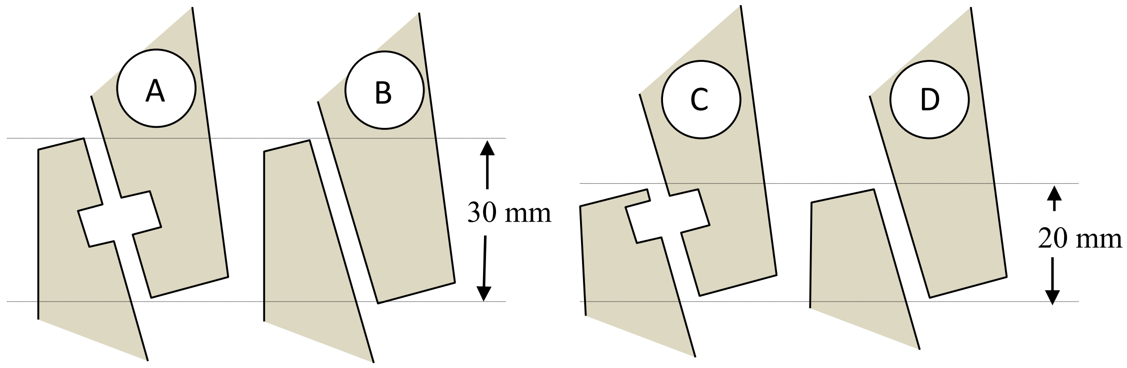


Figure 9. Geometry of bevel-back weatherboard joints investigated in this study.

The larger overlap dimension is the design value for these weatherboards that ensures the weather grooves line up. The smaller upstand height of 20 mm was chosen to help resolve differences due to the weather groove. This reduced the hydrostatic pressure of the upstand in relation to capillary pressures resisting the progress of water through the weather groove. In these weatherboards, the weather grooves were on average 7 mm wide by 5 mm deep and therefore larger than those in the large wall specimen examined earlier. The surface run-off over the joint in all measurements was 7 g/s.m. Expressing the rain intensity in terms of joint length has been found to be more useful in the context of joint studies than an area-related rain intensity (Bassett and Overton 2014). In fact, a run-off rate of 7 g/s.m would be exceeded over much of a façade tested with the 3 l/m^2.min rain load called for in E2/VM1.

The leakage characteristics of joints A–D were found to depend primarily on the gap between the boards but also on the overlap dimension and the presence of a weather groove. The gap between timber weatherboards is generally very small in a newly built and freshly painted wall but can be up to 2–3 mm where weatherboards have cupped and distorted in the sun. Earlier measurements of water leakage rates through large wall samples (Bassett et al. 2009) identified air-carried water leaks through 2–3 mm gaps. These occurred at much lower pressures than were needed to support a column of water in the joint and drive water through gaps less than 1 mm. Visually, the leakage through large gaps appeared as small droplets of water spattering through the joint and is therefore a complex two-phase flow of air and water through the joint.

The leakage rate through joint B is plotted in Figure 10 as a function of air pressure difference for several gap widths. With gaps less than 0.5 mm, the pressure needs to reach the head of water equivalent of the lap joint (30 mm for joint B and 294 Pa) for water to reach the top of the joint. For gaps exceeding 2 mm, leakage occurred at pressures as low as 50 Pa, gradually increasing with pressure, unlike the more tight-fitting joints where the onset of leakage occurred suddenly.

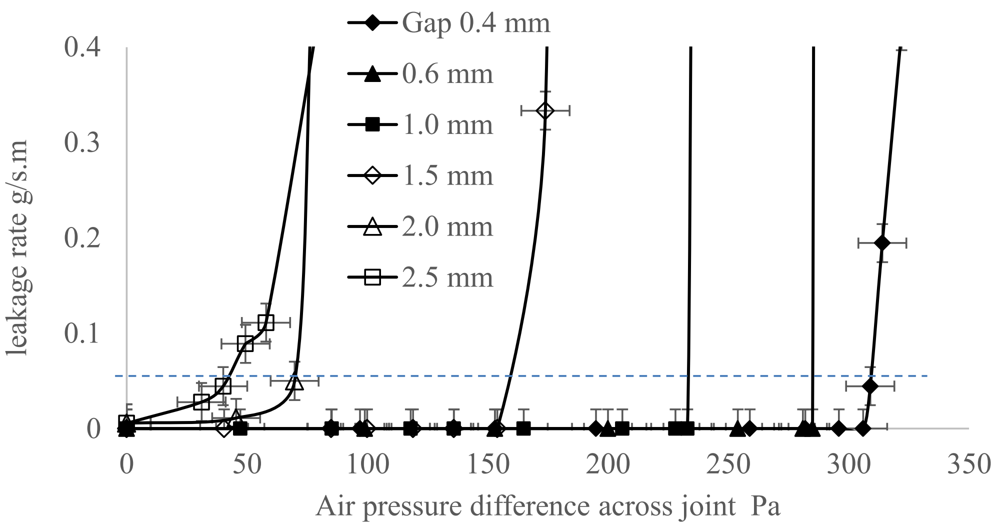


Figure 10. Onset leakage pressures (at 0.05 g/s.m indicated by dashed line) for joint B and variable joint gap widths.

On examining water run-off over the joint, it was clear that the smaller gaps between weatherboards were totally occluded by run-off. For larger gaps, the air gap through the joint remained clear because the trailing edge of the outer board acted as a drip edge. Figure 11 illustrates this difference and partly explains why the leakage characteristics of joints with large and small gap dimensions are so different.

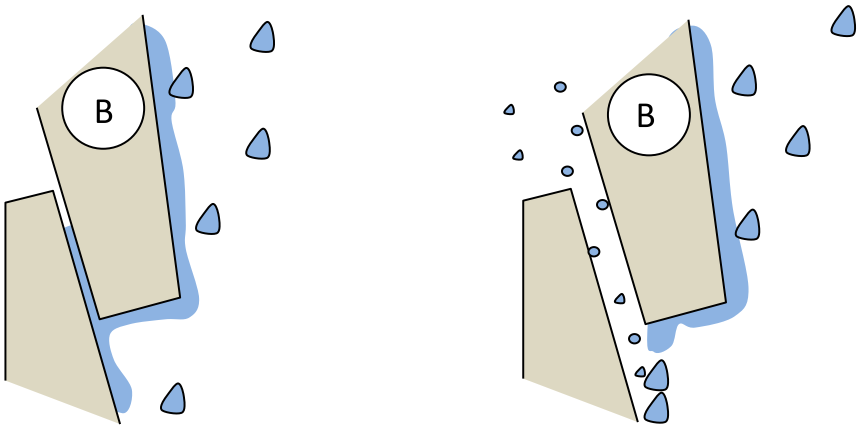


Figure 11. An illustration of rainwater run-off over two weatherboard lap joints with small and large gap widths.

The pressure at a leakage rate of 0.05 g/s.m has been chosen somewhat arbitrarily as the onset leakage pressure and plotted against gap width for joints A and B in Figure 12. For both joints, the onset leakage pressure is close to hydrostatic head equivalent of the 30 mm upstand height (294 Pa) at gap widths below 0.5 mm. At gaps greater than 2 mm, the onset leakage pressure is closer to 50 Pa and is caused by air-carried spatter through the joint. The most important observation is that, within the limitations of experimental error, these measurements have not resolved a significant difference between the steady pressure leakage rates through joints with and without a weather groove.

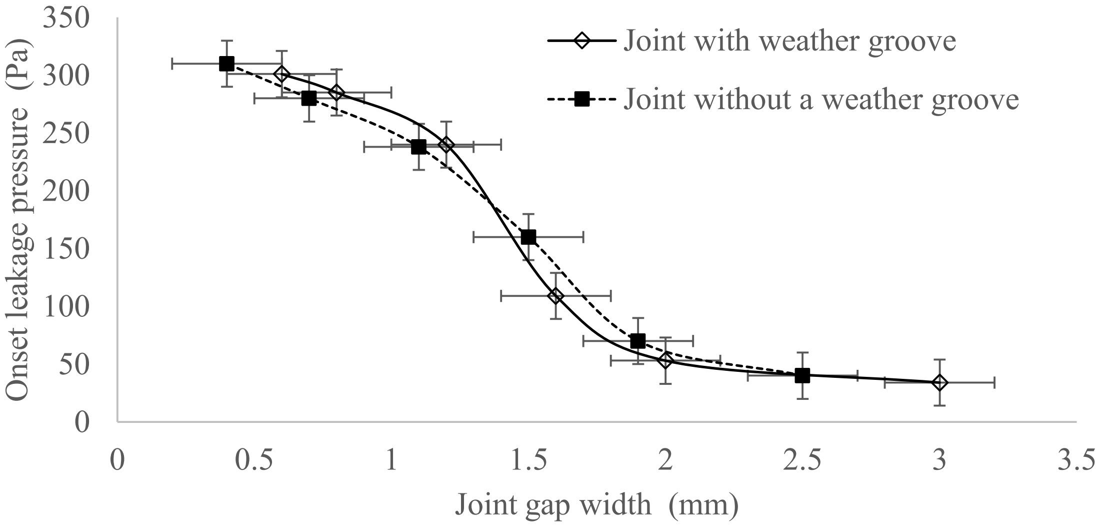


Figure 12. Onset leakage pressures for bevel-back weatherboards with a 30 mm upstand height and variable joint gap widths.

Onset leakage pressures for joints C and D are plotted in Figure 13 and also fail to resolve any difference due to the presence of a weather groove. One possible reason for this is the natural weather groove at the top of all lap joints between bevel-back weatherboards. A significant proportion of the capillary forces that oppose the passage of water past a capillary break in the joint will also oppose the flow of water out through the top of these joints. These are effectively one-sided weather grooves in shape. There is an argument against there being any significant effect of surface tension. The onset leakage pressures for tight joints (0.5 mm wide) are about equal to the hydrostatic head height of both the 20 mm and 30 mm joints.

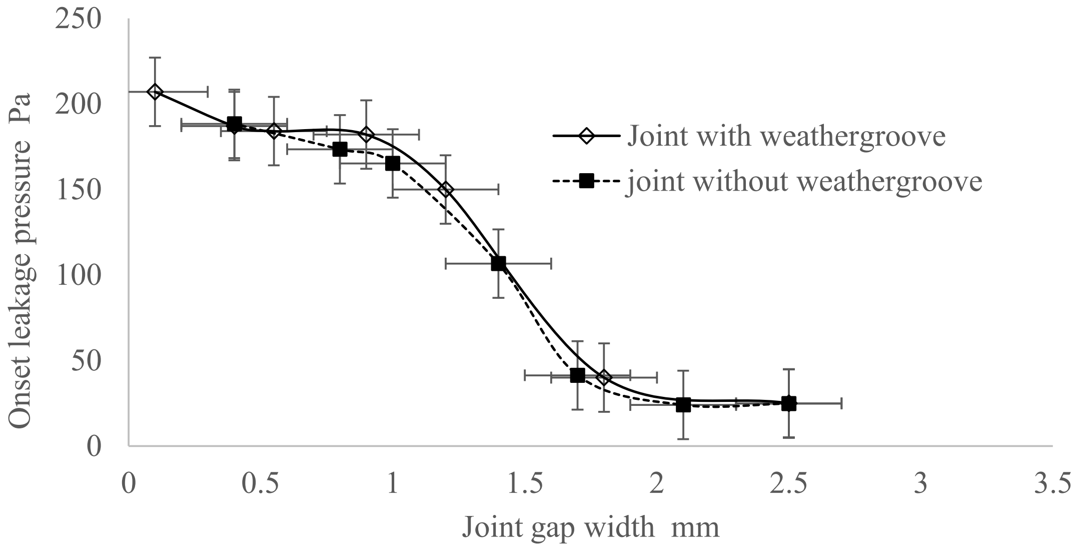


Figure 13. Onset leakage pressures for bevel-back weatherboards with a 20 mm upstand height and variable joint gap widths.

2.4 SMALL-SCALE LEAKAGE WITH FLUCTUATING PRESSURES

The conditions that drive water through façades are much more likely to involve fluctuating pressures and rain intensity than the steady conditions simulated in the previous measurements. In particular, weather grooves are likely to store water during peak wind pressures, which later drains away harmlessly when the wind pressure relaxes. Capillary forces at the entry and exit points in the weather groove are also thought to oppose the passage of water through the joint and improve the weathertightness of the joint. These effects should be seen as higher peak onset leakage pressures than those measured in steady wind pressures and rain intensity. Figure 14 and Figure 15 compare the dynamic leakage characteristics of lap joints C and D as illustrated in Figure 9. The peak maximum and minimum pressures are plotted for onset leakage (0.05 g/m.s) and frequencies between 0.19 Hz and 0.7 Hz and for a relatively tight-fitting joint (gap of 0.4–0.5 mm). In the case of joint C with a weather groove, it is clear that peak pressures as high as 400 Pa are required to initiate leakage compared with 200 Pa steady pressures as shown in Figure 13.

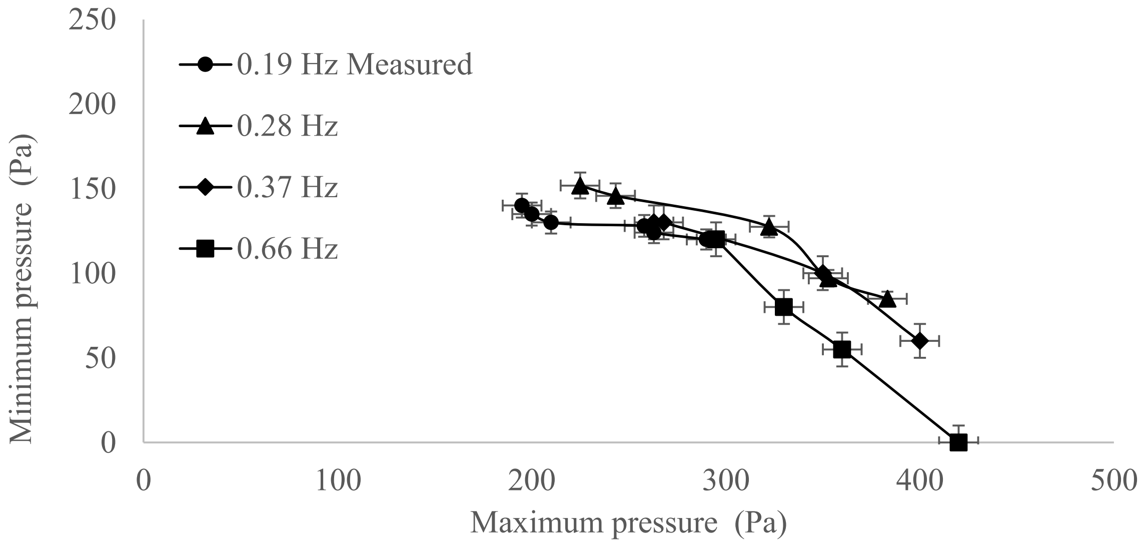


Figure 14. Maximum and minimum pressures plotted for onset leakage through joint C with a gap width of 0.4–0.5 mm.

The dynamic leakage characteristics of joint D are shown in Figure 15 to be effectively independent of frequency.

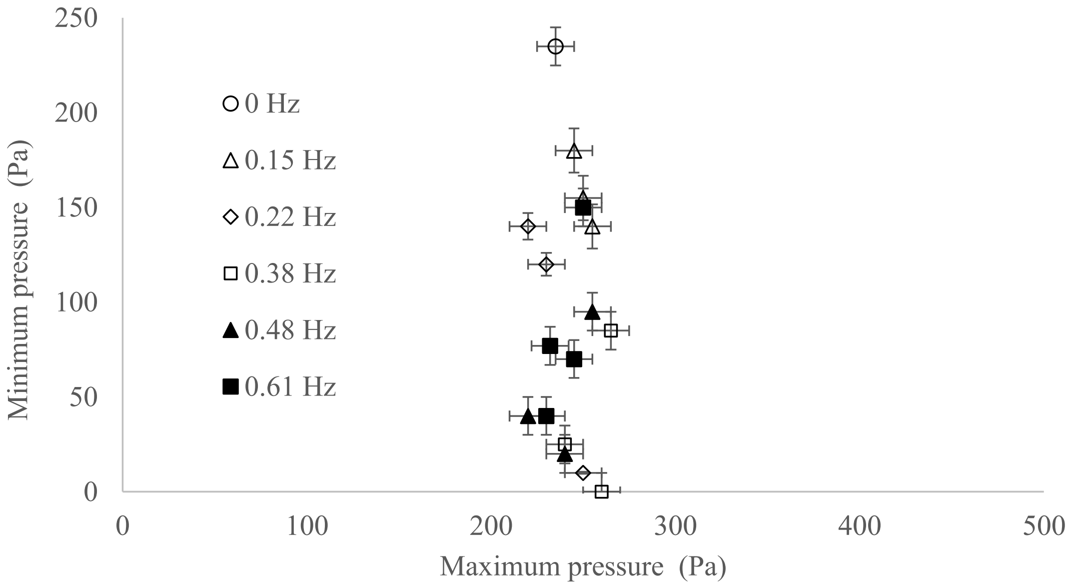


Figure 15. Maximum and minimum pressures plotted for onset leakage through joint D with a gap width of 0.4–0.5 mm.

All of the peak pressures are in the range 220–260 Pa, and the appearance of water leakage at the top of the joint appeared in phase with the applied pressure. Within the frequency range 0–0.6 Hz, there was no indication that either the inertia of water in the joint or the storage capacity of the joint are factors in the onset leakage pressures. When the gap width in joint C was increased to 2 mm, air-carried water spattered through the joint as demonstrated in the earlier steady pressure results in Figure 13. There was no indication of any dependence on the frequency of applied pressure in the range 0–0.6 Hz in Figure 16 as is shown in Figure 14 for much smaller gap dimensions.

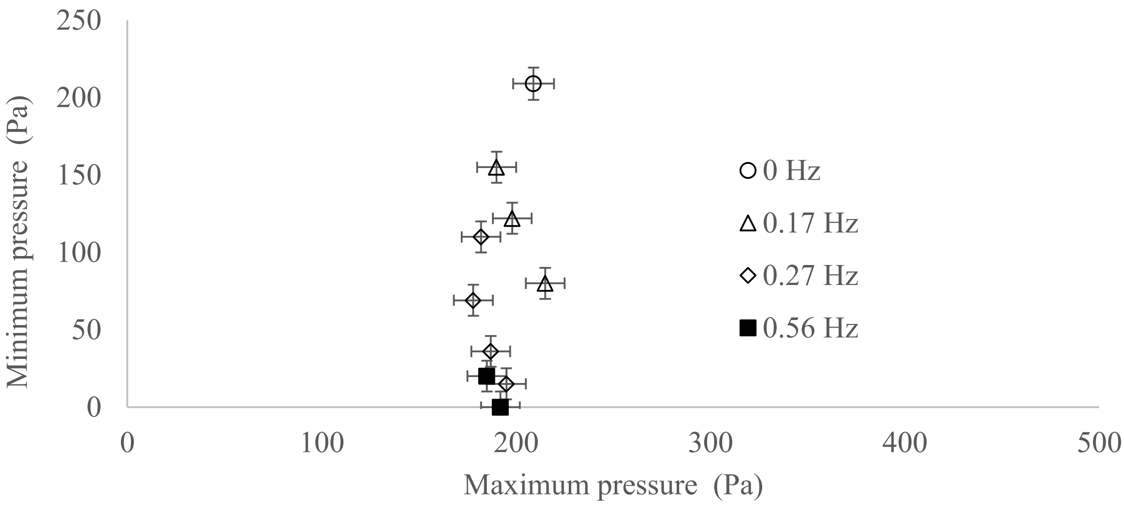


Figure 16. Maximum and minimum pressures plotted for onset leakage through joint C with a gap width of 2 mm.

Applying the simple dynamic pressure model of water leakage used earlier for large-scale specimens, leads to the comparison between modelled and measured results for joint C in Figure 17. Once again, this simplified model does not fit the data, suggesting a more sophisticated model is required. This would involve the inertia of water in the joint, the storage capacity of the weather groove and surface tension forces in order to predict leakage rates through tight-fitting lap joints with weather grooves.

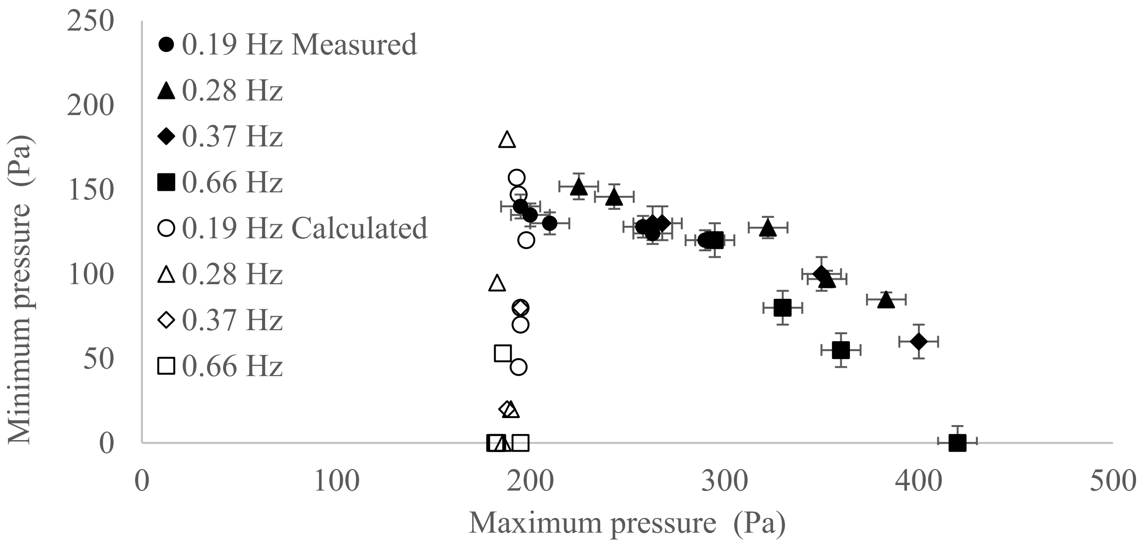


Figure 17. Measured cyclic pressures for the 20 mm joint with a weather groove (solid markers) and calculated pressures based on the static pressure leakage function for this joint.

3. MODELLED LEAKAGE CHARACTERISTICS

A more detailed model of water flow through the lap joint between weatherboards has been developed to account for the change in surface tension at the entrance to the capillary and the reservoir formed by the weather groove. Additional physical forces due to the viscosity of water, gravity, wind pressure, turbulence at discontinuities in the joint and the inertia of water in the joint are included and are described here using the following nomenclature:

Nomenclature

σ = surface tension for water at 20°C = 0.072 (N.s/m^2)
θ = contact angle of water with the building materials in degrees
g = acceleration due to gravity 9.8 (m/s^2)
μ = viscosity of water at 20°C = 0.001 (N/s)
ρ = density of water 1000 (kg/m^3)
Q = volume flow of water per m of joint (m^3/s.m)
r = gap between weatherboards (m)
w = gap in the weather groove (m)
a = height at which the weather groove starts (m)
b = height of the weather groove (m)
l = length of joint (nominally 1 m)
H = height of water in the joint (m)
h = height of sessile drop formed in the base of the weather groove (m)
m = mass (kg)
t = time (s)
P = pressure (Pa)

p = pressure expressed as a head of water (m)
F = force per m length of joint (N/m)

The following simplifications have been made:

- Water flow in the joint will be described as laminar. The velocities observed in earlier laboratory studies in joint spacings 0.5–1 mm were well below those leading to a Reynolds number at the transition between laminar and turbulent flow.
- The transition from the positive capillary force at A to a negative force at B has been modelled as a smoothed Gaussian function. The same approach is taken with the transition between B and C.
- There is assumed to be no change in the capillary force in the transition between C and D.
- The model applies to joint gaps less than 1 mm where the flow of water is laminar. The measurements showed water to be entrained in air leakage at larger gaps, and this two-phase flow is outside the scope of the model.
- Losses associated with turbulence at dimensional changes due to the capillary break are ignored.

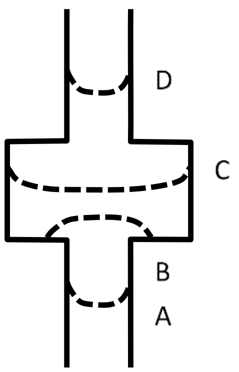
Forces due to surface tension – Figure 18 shows where capillary forces change as a column of water progresses through the joint.

At point B, a sessile drop is formed in the weather groove where the pressure due to surface tension is balanced by the pressure due to gravity. The height of this sessile drop has been expressed by Newman and Searle 1965 as equation 3:

$$h = \left[\frac{2\sigma(1-\cos\theta)}{\rho g} \right]^{0.5} \quad (3)$$

The height of this sessile drop varies with contact angles (1–3 mm for Θ = 30–80 degrees). This must be exceeded by the height of the capillary break (*b*) to prevent the sessile drop from bridging across the groove. The pressure opposing the passage of water through the joint will be as follows:

$$P_s = \rho g h = \left[2\sigma\rho g(1-\cos\theta)\right]^{0.5}$$



A	Surface tension helps support the column of water. The force is $F_s = 2\sigma\cos\theta$ (N/m), and the pressure at the base of the joint is $P_s = (2\sigma\cos\theta)/r$ (Pa)
B	Surface tension opposes spread of water across the capillary break with the opposing pressure calculated below as $P_s = \left[2\sigma\rho g(1-\cos\theta)\right]^{0.5}$ the gravitational pressure of the sessile drop
C	Surface tension helps support the column of water. The force is $F_s = 2\sigma\cos\theta$ [N/m]
D	The transition from the weather groove to the smaller gap in the joint is ignored. The force is $F_s = 2\sigma\cos\theta$ [N/m]

Figure 18. Capillary forces as water passes through a weather grooved lap joint.

The sessile drop is modelled as expanding to reach the sides of the weather groove, at which point, it attaches to the sides of the groove. Once again, suface tension acts to assist the passage of water through the joint. The surface tension at the transition between points C and D is assumed to remain constant. The arguments for simplifying the effect of surface tension in the joints between weatherboards are as folllows:

- The contact angle is poorly defined for painted and unpainted timber building materials because it varies with the moisture content of the surface. Contact angles in the range 40–70 degrees were measured for wet and dry primed weatherboards used in this study.
- The wind pressures that drive water through joints in claddings are dynamic, and the effects of surface tension should reflect the difference between advancing and receding contact angles. These differences also depend on the roughness and moisture content of the surface and are currently poorly defined.

The viscous forces opposing the flow of water through a plain joint can be developed from the Navier-Stokes equation for laminar flow between parallel plates as in equation 4 (Klimczak et al. 2010).

$$Q = -\frac{\rho g r^3 \nabla p_v}{12\mu} \qquad (4)$$

Here, ∇p_v is the pressure gradient due to viscous forces expressed as a head loss gradient with units (m/m). The volumetric flow rate of water in the joint can be expressed in terms of the velocity and the geometry of a plain joint (with no weather groove). This leads to the following expression (5) for the pressure due to viscous forces (now with units Pa/m):

$$\nabla P_v = -12\mu H \frac{dH}{dt} \Big/ \rho g r^2 \text{ (Pa/m)} \qquad (5)$$

Multiplying both sides of this equation by $(\rho g r)$ gives the viscous force opposing water flow through the joint as F_v:

$$F_v = -\frac{12\mu H}{r} \frac{dH}{dt} \text{ (N/m)} \qquad (6)$$

In addition to the effect of viscosity in the water will be pressure losses due to discontinuities at both ends of the joint and at entry and exit transitions between narrow sections of the joint and the weather groove. These have been ignored because these forces are considered to be small with laminar flow and because there is no data applying to joints between timber weatherboards.

Finally, the force due to gravity is simply $F_g = -\rho g H / r$ N/m

and the total force resisting the passage of water through the joint is:

$$F_{total} = F_{applied} + F_v + F_g + F_s \tag{7}$$

Applying Newton's second law gives:

$$F_{total} = \sum ma = \sum \rho H \frac{d^2 H}{dt^2} \tag{8}$$

and the following differential equation of motion

$$\sum \rho H \frac{d^2 H}{dt^2} = F_{applied} - \frac{12 \mu H}{r} \frac{dH}{dt} - \rho g H + Fs \tag{9}$$

where the (*ma*) terms relate to the different regions in the joint.

Equation 9 is a differential equation of motion for water in the joint that can be solved to predict the height of water with static and cyclic applied wind pressures. This has been solved numerically, but because there are discontinuities in the force equations as water passed through the weather groove, it has been necessary to smooth these transitions out with a Gaussian function. In practice, these forces will vary smoothly at the groove transitions, reflecting the actual rounded edges of the groove as well as variations in the joint gap dimension along its length.

The height of water in a 30 mm high lap joint is shown in Figure 19 plotted against static applied pressure. This is for two gap widths (0.5 mm and 1 mm), two contact angles (40 degrees and 70 degrees) and for joints with and without a weather groove. With no weather groove present, water rises further in the narrow joint as expected, but it does not proceed beyond the top of the joint. For that to happen, the wind pressure must support the full hydrostatic head of the joint (300 Pa) plus a little extra to overcome surface tension at the top of the joint. A similar process occurs at the start of the weather groove. It is necessary for wind pressure to support the hydrostatic head of the 10 mm of joint below the groove plus a little extra to overcome surface tension at the weather groove. This delays the passage of water at the weather groove, but it does not alter the static pressure required to breach the joint. This may be useful in practice if there is a reason to limit water movement early in the joint such as an absorbent path that wicks water into the cladding or the timber frame. These results are broadly consistent with earlier predictions of surface tension effects (Burgess 1994) and with measured onset leakage pressures shown in Figure 12.

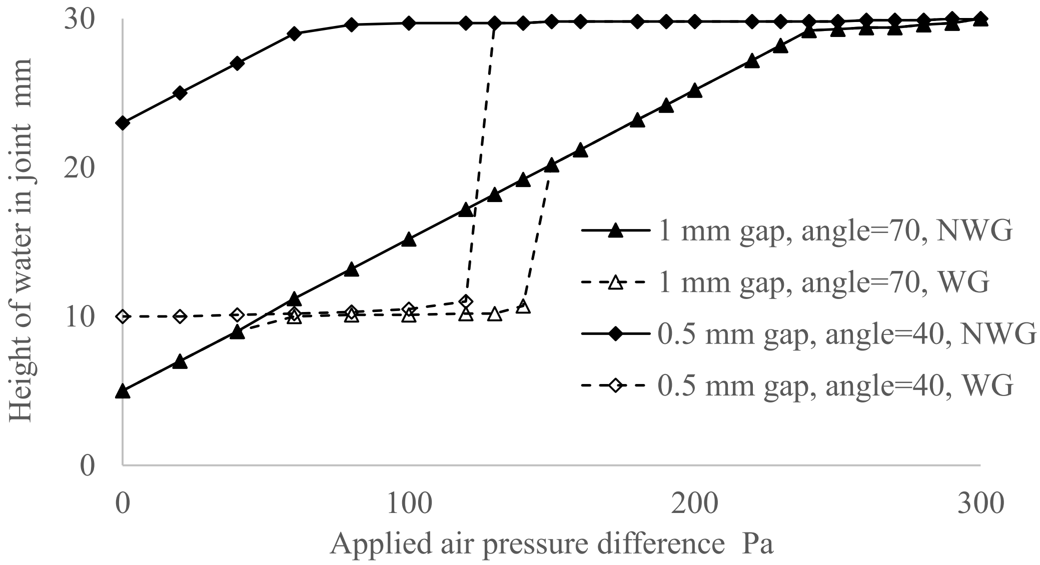


Figure 19. Static height of water in a 30 mm high lap joint with two gap widths, two contact angles and for joints with and without a weather groove.

Because wind pressures fluctuate in practice, the dynamic solutions to the differential equation of motion are more relevant. Here, the volume of the weather groove can be expected to buffer the passage of water through the joint. It acts as a reservoir that fills at peak wind pressures and then drains harmlessly away in between gusts. One way of illustrating this effect is with the filling time calculated as the time to breach the joint following a step change in the applied wind pressure. This has been calculated for a lap joint 0.5 mm wide with an upstand height of 20 mm with and without a weather groove. The time to breach the joint has been plotted in Figure 20.

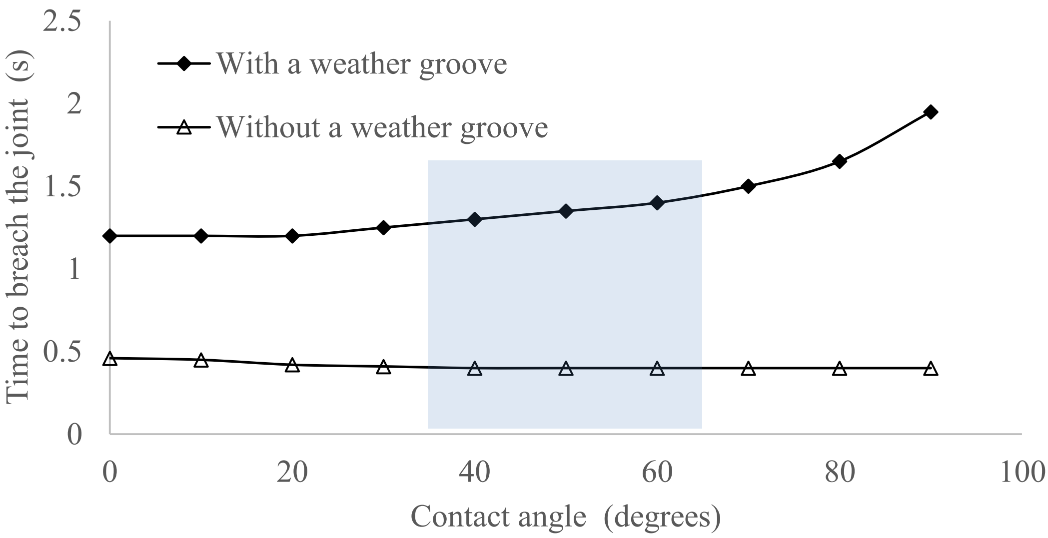


Figure 20. Time to breach a lap joint with and without a weather groove following a step change in wind pressure. The shaded area represents the range of contact angle measured for wet and dry weatherboards.

It is clear that the storage capacity in the weather groove delays breaching by (1.3–1.5 s) compared with 0.4 s for the joint without a weather groove. The drainage time will be similarly increased by water in the weather groove, but it will only drain down to the level supported by surface tension and wind pressure (which can be negative). At this stage, there is no experimental validation for the filling times in Figure 20, so they should be regarded as indicative only. Further experimental work will be needed to determine the friction coefficients for water flowing past primed weatherboards. There also needs to be some thought about how to account for the variable gap dimensions that are always present in weatherboard lap joints. The model also shows that filling times are sensitive to the gap dimension, varying from 0.6–4 s with gap dimensions in the range 1–0.3 mm. It is clear that a weather groove has the potential to reduce water leakage through a lap joint in certain wind conditions. However, the advantages are likely to be swamped by other leakage paths and only become apparent at pressures towards the top end of pressures seen by residential façades.

4. CONCLUSIONS

This experimental study set out to measure the performance advantage of weather grooves in the lap joints of bevel-back weatherboard claddings. It proved difficult to see any advantage in large-scale walls because other leakage paths swamped leakage through the lap joints. Smaller sections of lap joints were examined to eliminate these dominant leakage paths. Some improvements were seen in fluctuating pressures where the storage capacity of the weather groove acted as a reservoir to reduce leakage during wind gusts. It would appear that this storage capacity was more influential in these joints than the effects of surface tension. The conclusions in more detail are as follows:

In large-scale walls

- **Effect of weather grooves difficult to measure.** No significant difference in the static pressure leakage characteristics of 1.2 m wide by 2.4 m high walls could be attributed to the presence of weather grooves. With fluctuating wind pressures (0.1–1 Hz), differences due to weather grooves were lost in experimental uncertainty.
- **Leakage through lap joints insignificant compared with other leakage paths.** When compared with leakage characteristics of nine trade-built walls with a variety of timber weatherboard profiles, it was clear leakage paths due to cracks around fixings and defects such as knots dominated leakage through the lap joints. Build quality and degradation due to weathering were shown to be more strongly associated with rain leakage than the profile of the timber weatherboards.

In small-scale joints

- **No differences due to the weather groove in static wind conditions.** Small sections of tight-fitting weatherboard lap joints (gap less than 0.5 mm) leaked at static pressures equivalent of the overlap height. The presence of a weather groove had no measurable effect in a wetted joint, although there was some indication that surface tension initially resisted leakage in a dry joint. At gaps greater than 2 mm, air-carried spatter through the joint first appeared at around 50 Pa. The most important observation was that these measurements at steady pressures did not show that joints with weather grooves were more weathertight than those without weather grooves.
- **Joints with weather grooves were more weathertight in fluctuating wind.** The point at which water leakage occurred through small sections of weatherboard lap joints was measured with fluctuating air pressure differences in the frequency range 0.2–0.7 Hz. With tight-fitting joints (gap less than 0.5 mm), the leakage pressures at

the onset of leakage for weather grooved joints were significantly higher than those without a weather groove. With larger gaps around 2 mm, water leakage was carried by air and was unaffected by the presence of a weather groove.

Modelled water flows in lap joints

- **Weather grooves acts as a reservoir, slowing the passage of water through lap joints.** A numerical model of water passing through lap joints has included the effects of surface tension, gravity, the viscosity of water, wind pressure and the geometry of joints with and without a weather groove. It showed the capillary groove slowing the passage of water through the joint and improving the weathertightness of the joint in fluctuating wind. These improvements would only be realised in timber weatherboard walls built with tight-fitting lap joints and a freedom from other defects.

5. REFERENCES

Bassett, M.R., Clark, S. and Camilleri, M.J. (2003). *Building weathertightness failures – associated risk factors*. Presented at the BETEC symposium on building science applications at Syracuse University, New York.

Bassett, M.R. and McNeil, S. (2009). *Weathertight characteristics of weatherboard claddings*. Proceedings of the 12th Canadian Conference on Building Science and Technology. Montreal.

Bassett, M.R., Overton, G.E. and McNeil, S. (2014). *Water leakage through weatherboards and ventilation drying modelled in WALLDRY-NZ.* Proceedings of the ICBEST Conference Building for a Changing World, Aachen, Germany.

Bassett M. and Overton, G. (2014). *Weathertightness of flashings and the importance of upstand heights*. Building Research Association of New Zealand. Study Report 313.

Building Research Association of New Zealand. (2001). *Recommended timber cladding profiles*. Bulletin 411. Judgeford.

Burgess, J.C. (1992). Effectiveness of weather grooves in weatherboard cladding. *Building and Environment*, 27(1), 63–69.

Chown, G.A. (2001). *Protection from precipitation ingress through walls – parameters and criteria for invoking mandatory open-rainscreen*. National Research Council of Canada NRCC-46002, Ottawa.

Department of Building and Housing. (20011. *Approved Document E2/VM1 External moisture.* Wellington, New Zealand.

Klimczak, C., Schultz, R.A., Parashar, R. and Reeves, D.M. (2010). Cubic law and aperture-length correlation: implications for network scale fluid flow. *Hydrogeology Journal,* February.

National Association of Forest Industries. (2005). *Timber manual data file FP1 – Timber external cladding*. Deakin, Australia.

Newman, F.W. and Searle, V.H.L. (1965). *The general properties of matter* (5^{th} Ed.). Edward Arnold, London.

Standards New Zealand. (1979). NZS 3617 *Specification for profiles of weatherboards, fascia boards, and flooring*. Standards New Zealand, Wellington.

Standards New Zealand. (1948). NZS 495 *Profiles of weatherboards, flooring, and matchlining*. Standards New Zealand, Wellington.

TRADA Technology Ltd. (2000). *External timber cladding*. High Wycombe, UK.