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THE WEATHERTIGHTNESS OF FLASHING DOWNTURNS

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Greg Overton

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Preface

This is the third of a series of reports developing a performance description of the weathertightness of junctions between wall cladding materials.

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 intended primarily for researchers, but it will assist with the review of Acceptable Solutions to clause E2 of the New Zealand Building Code when the weathertight performance of flashing downturns is discussed.

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Abstract

This paper explores the weathertight performance of the downturned legs of flashings. The weathertightness of window head flashings has recently been questioned. They are more often procured from a limited range of sizes than folded for a specific joint and may no longer be as tight fitting as was the tradition. The pressure at the onset of leakage through these downturned flashings has been measured for a variety of leg lengths, fit quality and end details. As expected, the onset of leakage through tight-fitting joints occurred at close to the hydrostatic head equivalent of the flashing leg height. Adding a kick-out and bird's beak end effectively rainscreened the joint against rain entry and easily doubled the pressure at which the joint started to leak. All of the joints in wide use in New Zealand have leg lengths in the range of 10–90 mm. They are sufficiently weathertight to pass the 50 Pa wetwall test in E2/VM1 for low-rise buildings.

Joints with continuous gaps under the flashing exceeding 1–2 mm allowed air leakage to entrain raindrops and carry them deep into the joint. The consequential lower leakage onset pressures were unaffected by the leg length of the flashing. However, they could be increased by 50% or 100% by adding a kick-out or bird's beak end respectively. Installing loose-fitting flashings so they sit tight against the top of the cladding (or window facing) and with the leg protruded out from the cladding were particularly effective. This is the best approach to fitting off-the-shelf flashings. With fluctuating air pressures in the frequency range 0.1–0.7 Hz, the tight-fitting joint behaved as though there was little inertia or storage in the leakage path. This led to leakage onset pressures that could be calculated from the steady pressure leakage function. For loose-fitting joints, there was a tendency for the peak pressures to exceed the steady state leakage onset pressure.

Key Words

Weathertightness, Downturns, Flashings, Junctions

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1. INTRODUCTION

The downturned leg of flashings contributes to the weathertightness of a building façade by shedding water from junctions between components such as windows and claddings. The joints formed by the flashing downturn are generally expected to be tight fitting and unvented. However, because flashings are increasingly procured from a limited range of sizes rather than being folded on site, it may be necessary to think of them as vented junctions. Another argument for investigating the weathertightness of these joints is the wide range of leg lengths (10–90 mm) required for essentially similar applications. These dimensions will have been influenced over time by fixing considerations, but it means that the leg lengths required for purely weathertightness reasons are no longer obvious. Flashings manage rainwater with the following components:

- An upstand or inner leg on the dry side of the cladding (or cavity). This leg must be lapped shingle-fashion with the wall underlay an appropriate distance up behind the cladding.
- A drainage path to flash water leakage back outside. Horizontal flashings are sloped at 15 degrees or greater for drainage.
- Stop-ends or terminations to control water at the ends of horizontal flashings.
- A downturn leg that is tight fitting against the wet line of the cladding and includes a kick-out to promote run-off from the building.

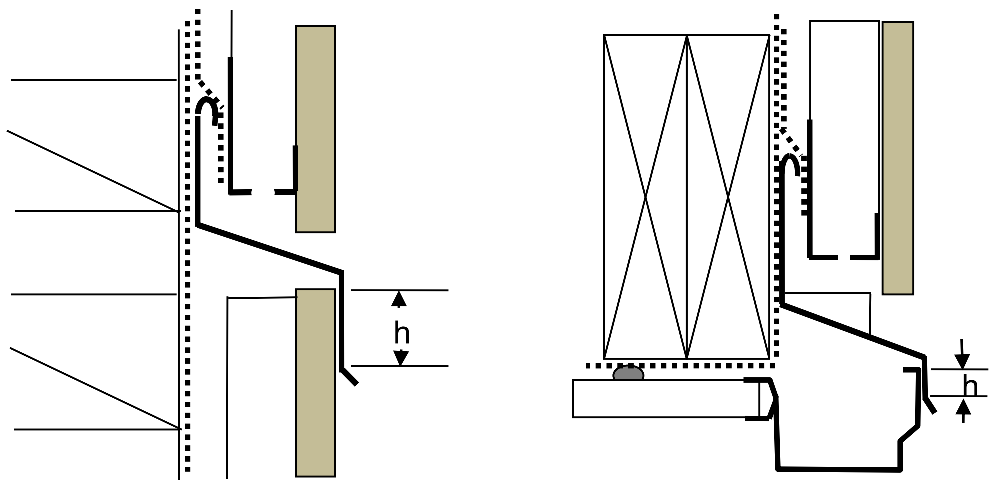
An earlier study (Bassett and Overton 2014) measured the weathertight properties of the upstand leg of horizontal window and apron flashings. This paper deals with downturn legs of horizontal flashings found, for example, where window head and sill flashings turn down over the cladding. These downturned legs are generally not expected to offer rainscreen protection to vents, as is the case for the upstand portion of a window head flashing. As such, they are generally shown fitting tight to the cladding or window frame.

A general trend was observed for the upstand to resist water leakage to pressures in line with the equivalent hydrostatic head of water as long as there were no air leakage paths through the joint. Adding vents for cavity walls or gaps due to construction tolerances allowed air-carried water past the upstand at lower pressures. However, this was always well above the 50 Pa wetwall test pressure adopted in E2/VM1 for claddings on a cavity wall. For H and Z jointers, the leakage onset pressure was 100–300 Pa when the gap between flashing and cladding exceeded 2–3 mm. With an air leakage path in the joint, both upstand height and the presence of a hem did little to resist water entry.

The most widely used New Zealand source of flashing shapes and dimensions for residential buildings is the compliance document E2/AS1 *External moisture* of the New Zealand Building Code (NZBC). A selection of flashings from this source along with downturn dimensions are given in Figure 1. It is clear that the downturn leg dimension depends on a variety of factors including wind zone, joint type and location on the building. The downturn dimensions in Figure 1 range from 10–90 mm.

General inter-storey junction

Window head flashing



Location of downturn	Wind zone	Downturn (h)
Window head flashing	All	10 mm
Inter-storey junction flashing	L, M, H, and VH	35 mm
	EH	60 mm
Barge flashing and capping	L, M, and H	50 mm
	VH	70 mm
	EH	90 mm

Parapet and enclosed balustrade

Barge flashing for profiled metal

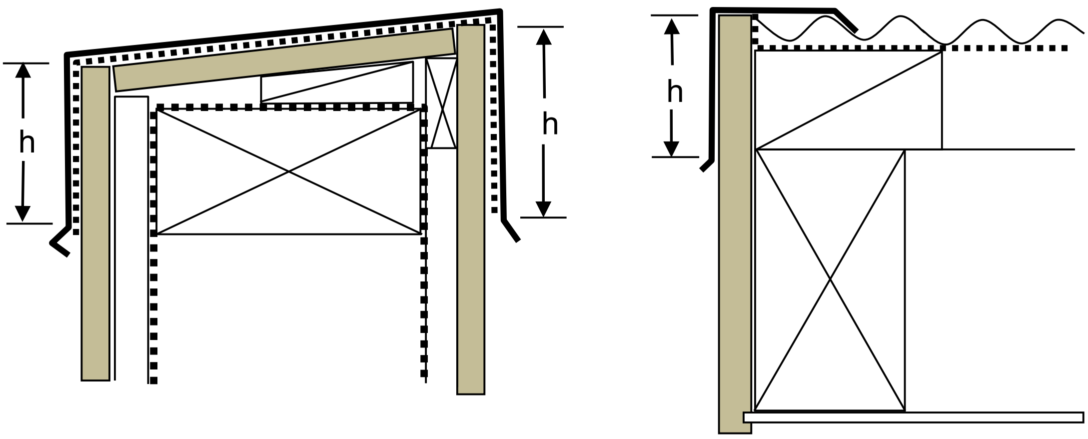


Figure 1. Examples of flashing downturns over cladding components taken from E2/AS1.

Junctions between claddings and components such as windows are known to be common sites for rainwater leaks. This was confirmed by a survey of leaking buildings in New Zealand (Bassett, Clark and Camilleri 2003) during the leaking building crisis in the late 1990s and early 2000s. Figure 2 shows over 60% of leakage sites in this survey were at junctions between claddings and other components, and less than 40% were in the field of roof and wall claddings.

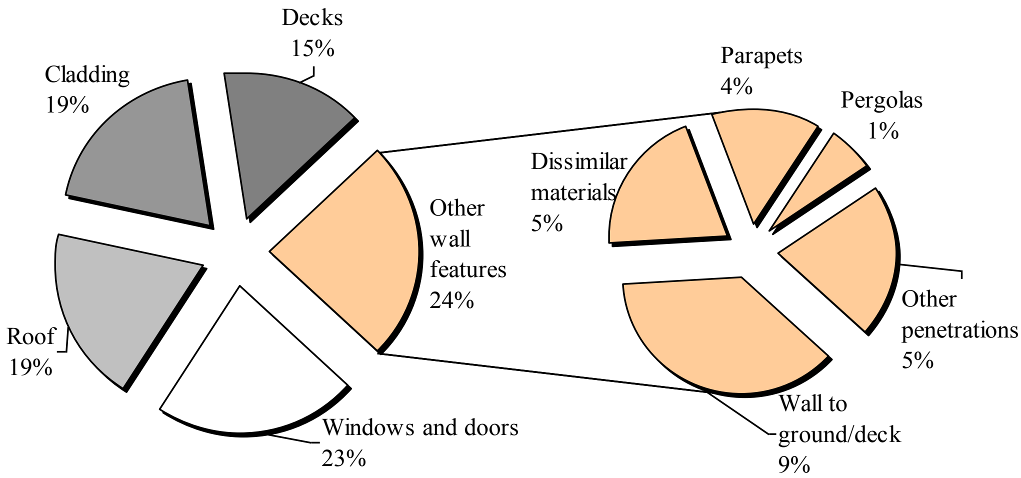


Figure 2. Location of water entry in New Zealand leaking buildings.

Traditional metal flashings were found to have been replaced with sealants in this survey, and few of the leakage sites identified fundamental deficiencies in metal flashings. A similar fraction (26%) of water entry points in Canadian buildings were identified around window and door junctions with claddings in a survey of leaking buildings in British Columbia (Morrison Hershfield Limited 1996). In this survey, 90% of water leakage sites were found to be at junctions between materials and components or at penetrations through the cladding.

Flashings appear to have evolved over time in New Zealand on the back of field experience rather than from testing or research. Their shape and dimensions reflect the best location for fixings and the practical need for flashings that can be transported and handled without being damaged. This study is attempting to separate out the weathertightness performance requirements from the practical requirements so that changes in dimensions for more exposed applications can be better worked out.

An earlier study of the weathertightness of window to wall junctions in walls with direct-fixed claddings (Bassett, Burgess and Camilleri 2003) found the following factors to be important to the weathertightness of the junction:

- The leakage area ratio between the rainscreened vents and the air seal at the internal lining, which should be at least 10 to 1.
- The trim cavity clearance to avoid capillary-transported water
- Whether the jamb lines of the window facing were sealed.
- The extent of facing cover over the wall cladding.

All of these factors were found to be important in steady pressure tests, with a minimum 10 mm of window facing cover over the cladding being required for low-rise buildings. Leakage past the downturned head flashing was not specifically investigated. More recent laboratory-based studies have measured the weathertight properties of flashing upstands in vented and non-vented horizontal joints (Bassett and Overton 2014) and the role of weather grooves in horizontal joints between weatherboard claddings (Bassett and Overton 2015). These studies developed the equipment and method for measuring leakage rates used in this study. They also draw attention to the significance of aerosols carried by air leakage and the significance of this mode of water leakage to junction design.

There are few recent scientific investigations of the water leakage performance of joints, as well as how their design might be improved to cope with extreme exposure. Some of the earliest investigations were carried out at the Norwegian Building Research Institute in a laboratory-based pressure chamber that simulated rain, steady and cyclic wind causing lateral pressure variations (Isaksen 1972). Water leakage rates through horizontal and vertical baffled joints were measured to develop guidelines for joints that drained freely and supported wind pressures at dry inner parts of the joint. A slightly later study (Ishikawa 1974) measured the leakage characteristics of joints in a metal curtain wall. It concluded that the key elements were a large external opening to prevent a water film from bridging the gap and an airtight internal joint to support wind pressures. A similar conclusion was reached by Herbert and Harrison (1974) using natural weathering measurements of water leakage through joints mounted on a test rig in Plymouth, UK. These studies measured water entry rates through labyrinth-type joints exposed to driving rain in field trials. They showed that successful joints had an airtight inner wall and sloped drainage to deal with water entering the joint. The lesson that can be carried through to this study of downturned flashings is that any restriction to air should be as deep in the joint as possible. A well rainscreened but free-draining outer joint is also important.

More recent rain-entry studies have tended to measure water leakage rates on the way to determining the time required for water management capabilities of the wall to cope with these rain leakage loads. One such study by Lacasse et al. (2003) measured leakage rates through specific defects in walls such as missing lengths of sealant. They used the leakage function of wind pressure and rain load to estimate the moisture loads that have to be managed by vapour diffusion and ventilation drying. Water leakage rates were measured as a function of run-off rates and static wind pressure. These were fitted to an empirical relationship that was then used to estimate moisture entry loads in a range of North American climates. Another recent study by Van Den Bossche et al. (2012) has begun to look at the fundamentals of water leakage through defects in claddings. In particular, the study looked at the role of surface tension and capillary and hydrostatic forces in water leakage rates through circular defects.

In this study, the focus is on the performance of the flashings themselves – how a joint flashing performs when it is subject to a particular pressure and rain load. In reality, factors such as pressure equalisation have a role to play in minimising the pressure difference across the outer cladding (including the flashing). Additionally, it will be necessary to have rain load and run-off rate data for façades before the joint leakage functions can be interpreted as leakage rates that will have to be appropriately managed. Possible future directions for this junction performance-based research are outlined later in the report.

2. EXPERIMENTAL METHOD

The weathertight properties of flashing downturns were measured in small scale using a 600 mm length of flashing. The equipment illustrated in Figure 3 consisted of a pressure chamber linked to a centrifugal fan and a fluctuating piston that together apply a steady pressure with a superimposed fluctuating pressure across the specimen. It has been used earlier to study the upstand leg of the flashings studied here (Bassett and Overton 2014). The pressure amplitude could be changed by adjusting the start and end points of the damper stroke. Where possible, it was adjusted to cycle the air pressure with an amplitude ratio of 2 and a frequency in the range 0–0.7 Hz. The flashing was mounted with screw adjustment of the lateral and vertical position. This meant the gap dimensions w and t could be adjusted to reflect various levels of fit quality between the downturned leg and underlying cladding. Water was sprayed from the outside and water leakage rates measured gravimetrically using an absorbent pad placed inside the chamber at the point where leakage through the joint would have entered the wall cavity. This was removed and weighed to calculate the water leakage rate over a period of typically 1 minute. The absorbent pad was a commercial cleaning material (Wettex). The primary advantage of this small-scale equipment was that it gave good control over the joint geometry, in particular, the gap between the downturned flashing and the underlying cladding. Water sprays were set up to deliver rain loads in the range of 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).

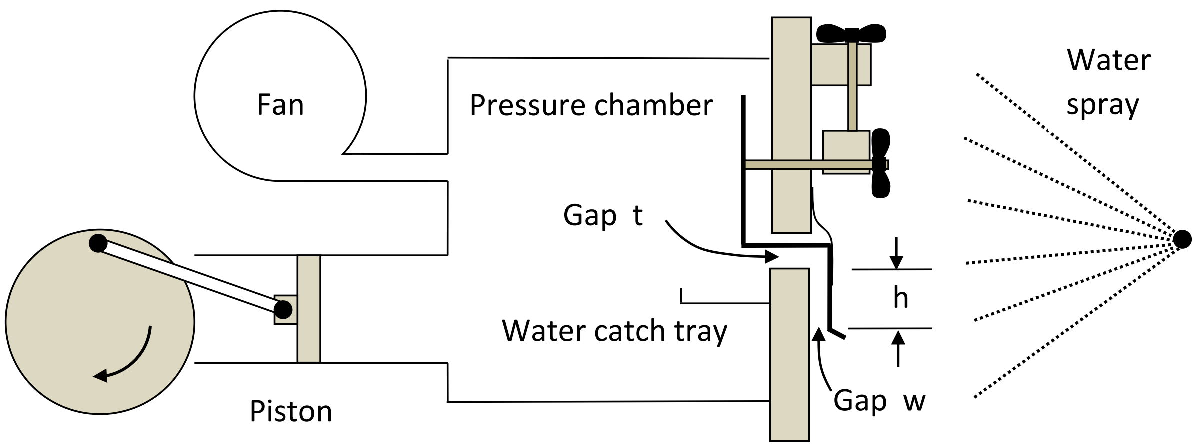


Figure 3. Equipment for adjusting flashing and measuring water leakage rates through a downturned flashing.

3. WATER LEAKAGE AT STEADY PRESSURES

Water leakage past the downturned legs of flashing will depend on a number of variables including the following:

- The geometry of the flashing (the downturned leg height (*h*) and the end treatment at the bottom of the leg (plain, kick-out or bird's beak).
- The standard of fit to the cladding or window frame (dimensions *w* and *t*).
- The driving wind pressure (static and dynamic). We have ignored the effect of rain carried by the wind in this study but accept that raindrops deflected off nearby ledges may penetrate downturned flashings with large values of *w*.

The run-off rate over joints in claddings has been previously shown (Bassett and Overton 2014) to be an important factor in air-carried water leakage past the upstand of vented window head flashings. This earlier study found that high run-off rates partially bridged the vented opening, resulting in higher velocity air flows carrying an aerosol of droplets deep into the joint. Even higher run-off rates were found to bridge the opening, closing off the ventilation path and allowing the full wind pressure difference to sit across the wet joint. In steady wind conditions, this flooded the joint, but it quickly drained out when the wind pressure relaxed. The downturned legs of flashings are different from these window head junctions because they are not expected to be vented. However, the trend away from bespoke flashings to standard sizes means that these joints may need to be sized as though they are vented joints. Normally, the flashing is expected to fit tightly against the cladding or against other components such as a barge or window. Therefore, the leakage onset pressure should equal or exceed the hydrostatic pressure equivalent of the downturned leg dimension *h* shown in Figure 3. Of course, there are building tolerances to consider, and the downturned leg may not always fit tightly as illustrated in Figure 1. With this in mind, the leakage onset pressures have been measured as a function of run-off rate for tight and loose-fitting joints and the results plotted in Figure 4. The joint in this case had a downturn length of *h* = 35 mm and included a kick-out end. Figure 4 also appears to show a weak relationship between run-off rate and leakage onset pressure, but it is mostly lost in experimental uncertainty.

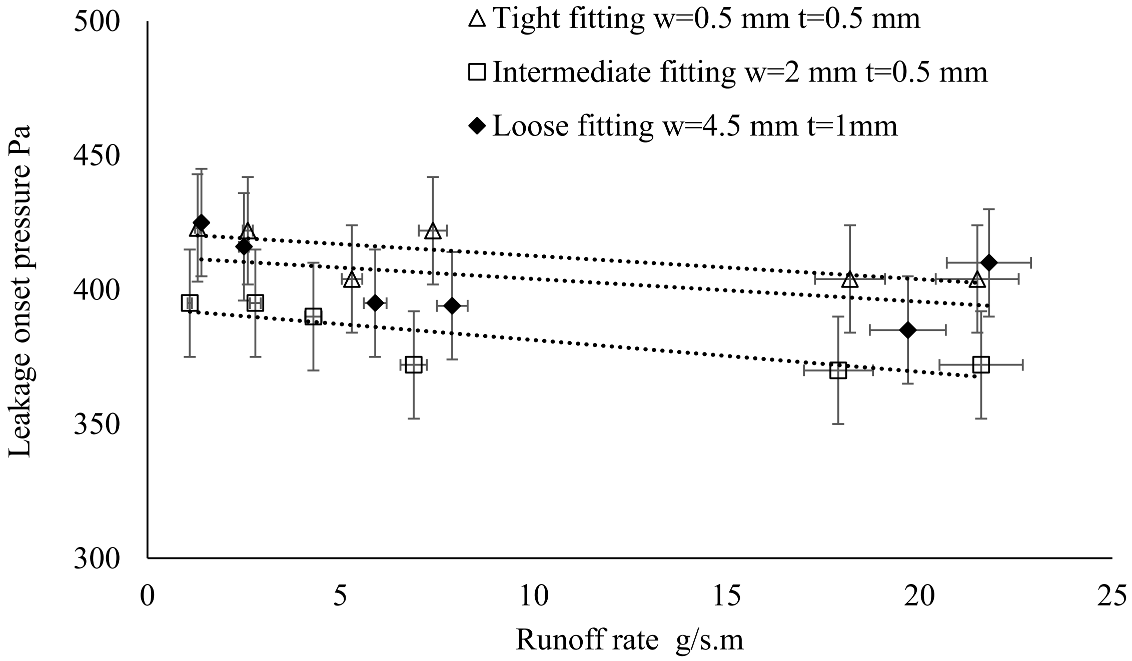


Figure 4. Leakage onset pressures as a function of run-off rate for a 35 mm flashing downturn and a kick-out end.

The significance of dimensions *w* and *t* has also been measured as leakage onset pressures for three 35 mm flashing downturns with a plain leg, a kick-out and a bird's beak termination.

3.1 Tight-fitting flashing downturns discourage air-carried water leakage

The leakage onset pressures for tight-fitting flashing downturns are shown in Figure 7, Figure 9 and Figure 11 to be sensitive to the *w* and t dimensions and to the presence of a plain, kick-out or bird's beak termination. The measurements were made with a run-off rate over the joint of 18 g/m.s (approximately 3 l/m^2.min for a small sample area). With the 450 mm length of joint fitting as tightly as possible (*w* and *t* in the range 0–0.3 mm), the onset leakage pressures for 35 mm downturns varied. This ranged from 400 Pa with plain-ended flashings to above the experimental limit of 1200 Pa for bird's beak flashings. The kick-out and bird's beak terminations were clearly effective at rainscreening the joint and keeping water away from the tight-fitting outer sections of the joint where capillary attraction would take over and carry water into the joint. It is generally accepted that sub-millimetre tolerances cannot be relied upon in a building context and therefore the following observations for less tight-fitting flashings are more relevant.

Where *w* and *t* were about 1 mm, the leakage onset pressures for all of the flashings were equal to or exceeded the hydrostatic pressure equivalent of the downturn dimension. (This was 350–400 Pa for a 35 mm downturn and plain ending.) This result is consistent with earlier results for flashing upstands fitting tightly against the cladding (Bassett and Overton 2014). The leakage onset pressures will include a component due to surface tension, but in general, this has not been resolved in these experiments. The leakage onset pressures for the kick-out flashing were similar to the plain-ended flashing but were much higher for the bird's beak end. There is no obvious reason for this difference.

The effect of changing the downturn length *h* is explored in Figure 5 for flashings with a kick-out end. These experiments required flashings with downturn lengths in the range 20–70 mm to be fixed in place with *w* values of 1 and 3 mm representing tight and loose-fitting joints. The value of *t* was always much greater than *w* so as to not be a rate-limiting variable. As expected, the leakage onset pressure for the tight joint tracks with the hydrostatic head equivalent of the downturn length, and for the loose-fitting joint, there was no dependency on *h*. The leakage onset pressure changed little as the flashing length *h* was changed in steps from 5 mm to 60 mm. This indicated that, for the case where *w* = 3 mm and *t* > 3 mm, the leakage process depended on air speed through the joint. The results are characteristic of two-phase flow of air and water droplets.

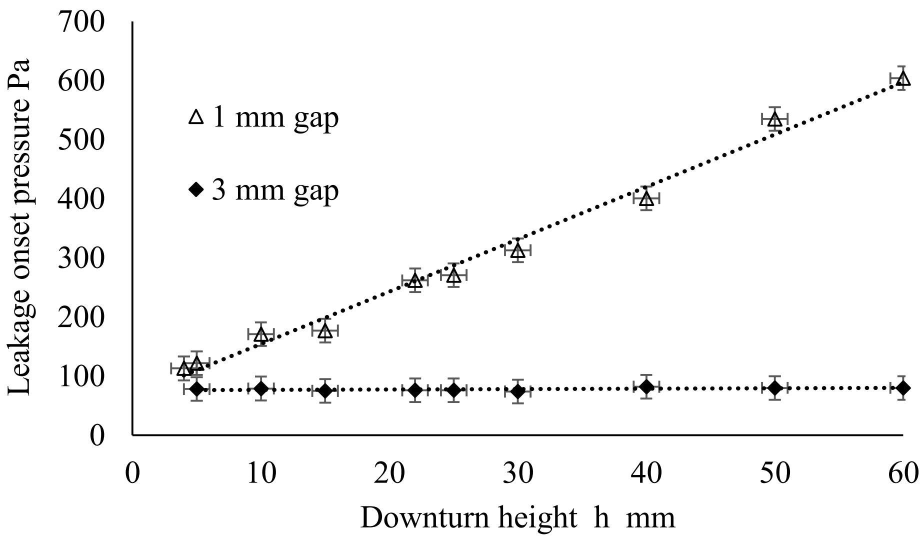


Figure 5. Leakage onset pressures as a function of downturn height (*h*) for a 35 mm downturned flashing with a kick-out and two values of gap width (*w*).

3.2 Loose-fitting flashings allow the passage of air-carried water droplets

Where *w* and *t* both at 2 mm, the leakage onset pressures were less than 350 Pa generally but as low as 120 Pa for the flashing with a plain end. The leakage process was observed to involve air flow entraining an aerosol of water droplets in the air near the flashing end. This two-phase flow has been previously seen carrying water into traditionally vented junctions such as a window head flashing on a cavity wall. This earlier work by Bassett and Overton (2014) measured leakage rates and showed they diminished rapidly above the cavity closer.

Perhaps the best arrangement of a flashing that is wider than ideal is for it to fit tightly against the top of the window or cladding (t = 0) and for the flashing leg to protrude significantly from the cladding (w might be a few mm). In this case, the tight-fitting part of the joint controls air and water entry, while the protruding flashing leg acts as a rainscreen. This fits with the observations by Herbert and Harrison (1974) of weathertight joints having an airtight inner section and an open and sloped drainage path to drain water from the joint. Adding a kick-out or bird's beak end is shown in Figure 8 and Figure 10 to further improve the performance of the joint.

3.3 Bird's beak and kick-out ends improved flashing performance

An indicator of the value of adding a kick-out or bird's beak end to downturns is the leakage onset pressure ratio R_p defined as: $R_p = \frac{P_{\mathrm{mod}}}{P_{plainend}}$

This has been plotted in Figure 6 against w for the bird's beak and kick-out flashings. Here, the value of P_{mod} is the leakage onset pressure for the kick-out or bird's beak terminations. $P_{plainend}$ is the leakage onset pressure for the plain-ended flashing with identical values of w and t. Values of R_p range from 1 to 3 for the kick-out flashing and 2 to 5 for the bird's beak case, indicating both of these terminations improve the weathertight performance of downturned flashings. There is no obvious reason why the bird's beak is better than the kick-out. They both deflect water from the junction.

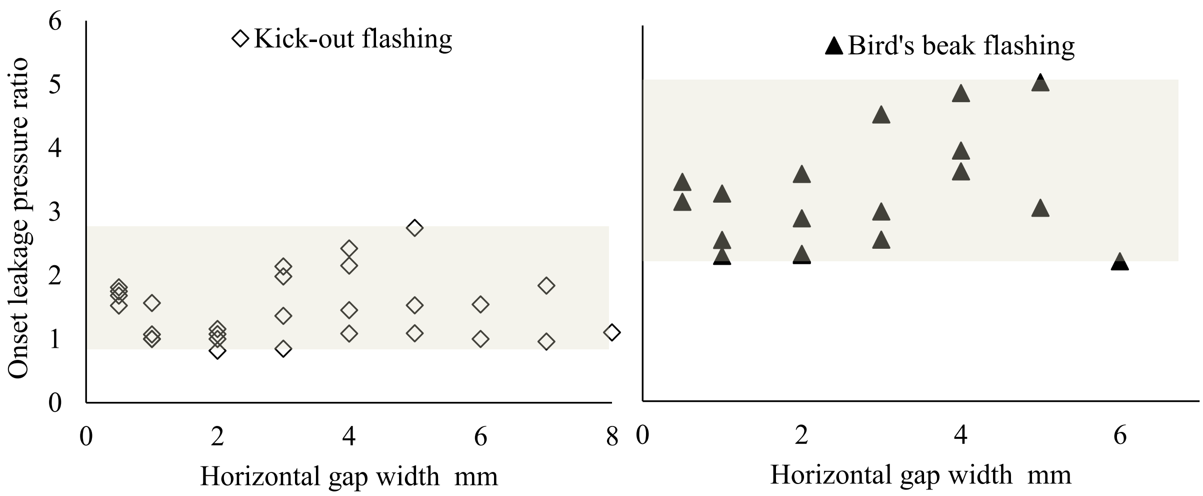


Figure 6. Onset leakage pressure ratios for kick-out and bird's beak flashings compared with a plain-ended downturned flashing.

3.4 Leakage data and observations for three flashing types

The following Figures 7–11 plot the leakage onset pressure for three downturned flashings with h = 35 mm and a range of values for the horizontal gap width w and the top gap t.

Plain-ended flashings. Figure 7 gives leakage onset pressures for the plain-ended flashing as a function of w and t. This shows that, for a significant range of fit quality, the leakage onset pressures are below the hydrostatic pressure equivalent of the joint (about 350 Pa). When $w > t$, the leakage onset pressures are shown to increase above the equivalent hydrostatic head. The illustration in Figure 8 records observations of water leaking through the plain-ended flashing. Where w < 0.5 mm, the path for run-off stayed close to the wall and surface tension partially filled the joint with water. The leakage path changed little with an airtight but loose fit (w > 2–3 mm), and the leakage onset pressures changed little. To make any real progress towards higher leakage onset pressures required a relatively airtight joint (t < 0.7 mm) and a large well drained rainscreen formed by the downturned leg standing out from the cladding (w > 5 mm).

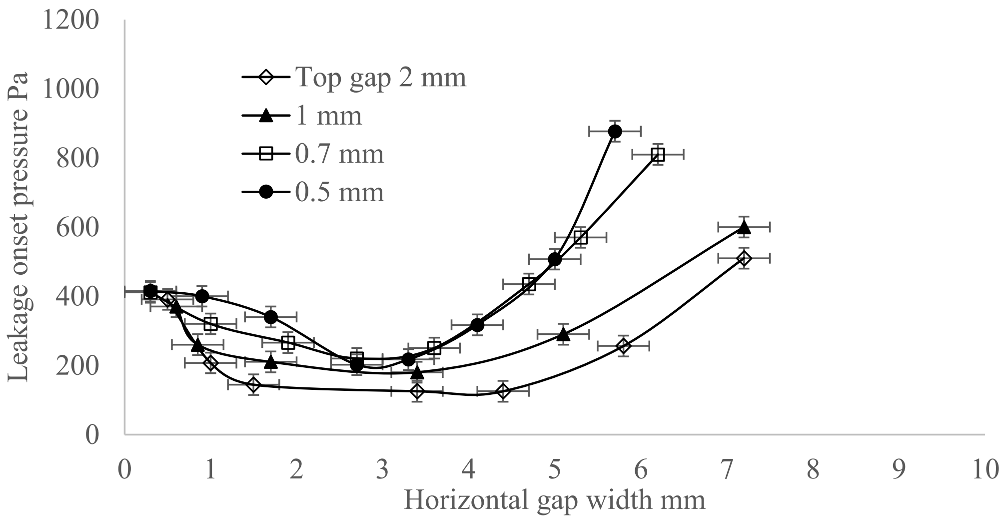
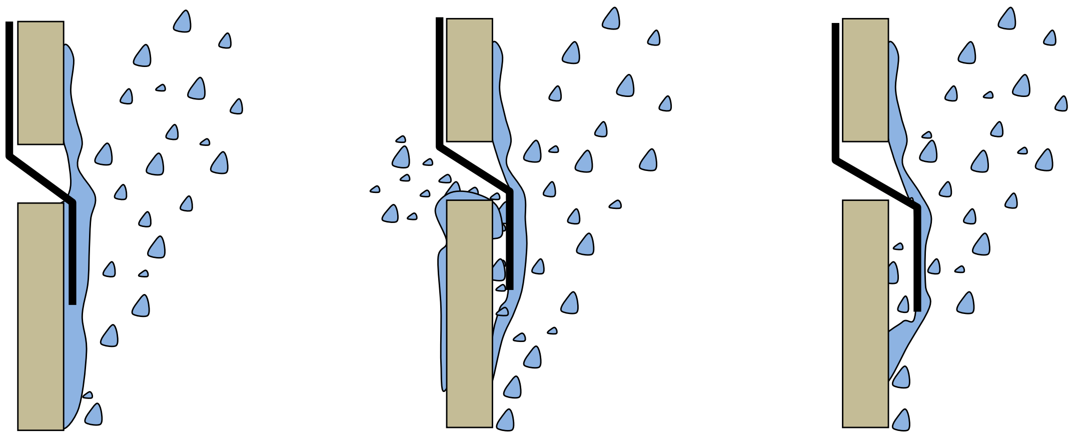


Figure 7. Leakage onset pressures for a 35 mm flashing with a plain leg as a function of downturn gap (*w*) and top gap (*t*) dimensions.



Flashing with a plain end		
Airtight case with tight fit	Loose fit allowing air flows	Airtight but with loose fit
t & $w \leq 0.5$ mm	t > 0.5 mm & 4 mm > w > 1 mm	t = 0 & w > 2–6 mm

Figure 8. Illustration of water run-off and leakage through a downturned flashing with a plain end.

Flashings with a kick-out end. Figure 9 gives leakage onset pressures for the kick-out flashing as a function of w and t. This shows a significant improvement in performance over the plain-ended flashing except for the high t and w range where air flows drive the leakage process. Outside this range, the leakage onset pressures are well above the hydrostatic pressure equivalent of the joint. The illustration in Figure 10 shows the kick-out flashing deflecting water from the junction with the cladding. Where w < 0.5 mm, the joint remained dry until high wind pressures partially filled the joint with water. The kick-out appeared to effectively increased the size of gap w, reducing air speed and hence air-carried water into the joint. With an airtight but loose fit (*w* > 2–3 mm and t < 0.7 mm), the joint drained water leakage, and the leakage onset pressure exceeded 400 Pa. Figure 10 shows the loose-fit case allowed air-entrained water to pass through the joint at onset leakage pressures well below 400 Pa.

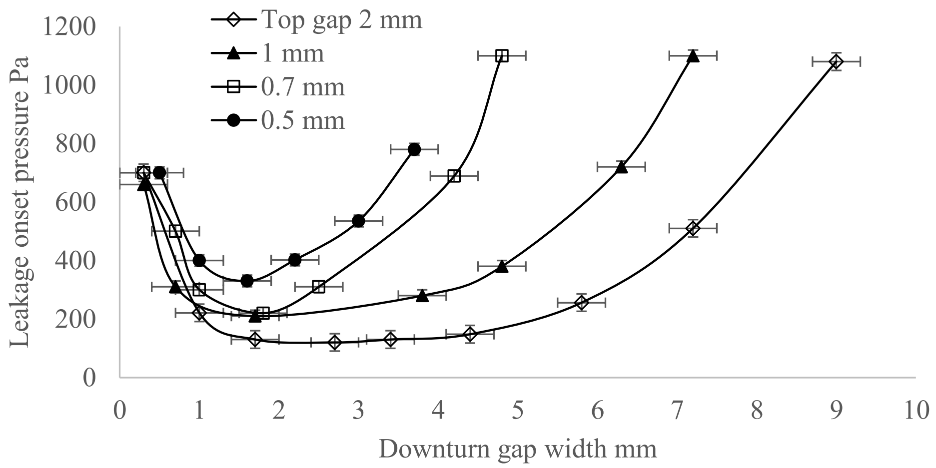
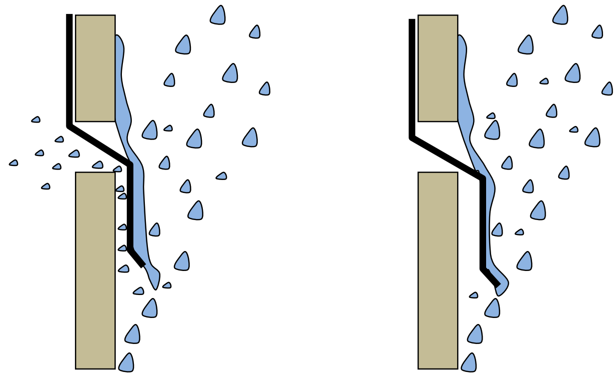


Figure 9. Leakage onset pressures for a 35 mm flashing with a kick-out leg as a function of downturn gap (*w*) and top gap (*t*) dimensions.



Flashing with kick-out at the bottom edge		
Airtight case with tight fit	Loose fit allowing air flows	Airtight but with loose fit
Tight fitting *t* & *w* ≤ 0.5 mm	t > 0.5 mm & 4 mm > *w* > 1 mm	*t* = 0 & *w* > 3 mm

Figure 10. Illustration of water run-off and leakage through a downturned flashing with a kick-out end.

Flashings with a bird's beak end. Figure 11 gives leakage onset pressures for the bird's beak flashing as a function of *w* and *t*. This shows another performance improvement over the kick-out flashing throughout the experimental range of *w* and *t*. In fact, the leakage onset pressures were well above the hydrostatic pressure equivalent of the joint throughout the range of *w* and *t* except for a region where *w* = 2 mm. The illustration in Figure 12 shows the bird's beak flashing deflecting water from the junction with the cladding. It proved to be a more effective rainscreen than the kick-out, but there were no visible differences other than the bird's beak projecting further out and therefore shedding water more effectively from the cladding. Figure 12 shows the loose-fit case allowing air-entrained water to pass through the joint when *t* = 2 mm and with *w* in the range 1–4 mm. Outside this range, the leakage onset pressures were well above 400 Pa.

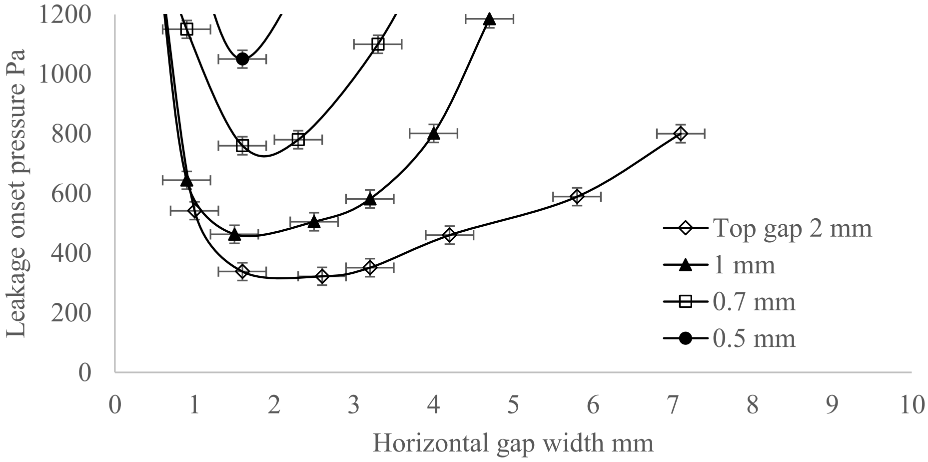
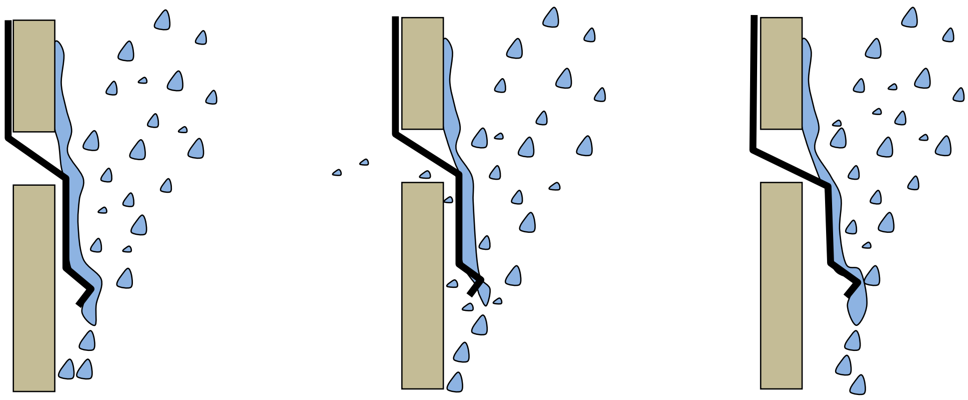


Figure 11. Leakage onset pressures for a 35 mm flashing with a bird's beak leg as a function of downturn gap width (*w*) and top gap (*t*) dimensions.



Flashing with bird's beak at the bottom edge		
Airtight case with tight fit	Loose fit allowing air flows	Airtight but with loose fit
Tight fitting t & $w \leq 1$ mm	$t \geq 2$ mm & 4 mm > w > 1 mm	t < 1 mm and $w \leq 2$ mm

Figure 12. Illustration of water run-off and leakage through a downturned flashing with a bird's beak end.

4. LEAKAGE CHARACTERISTICS MEASURED 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, larger volumes in vented or loose-fitting joints are likely to store water during peak wind pressures, which later drains away harmlessley when the wind pressure relaxes. The frequency dependency of leakage has been measured for two of the downturned flashing legs at frequencies between 0.1 and 0.7 Hz. The two flashing downturns were as described in Table 1.

Table 1. Flashing downturn dimensions.

Flashing	End type	Leg length	Dimension *w*	Dimension *t*
Tight fitting	Kick-out	35 mm	0.5 mm	0.5 mm
Loose fitting	Kick-out	35 mm	2.0 mm	2.0 mm

Observations showed that water accumulating inside and relaxing out of the tight-fitting joint was in phase with pressure fluctuations up to 1 Hz. This suggests 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 (1):

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

Where:
Δp = the applied pressure difference (Pa)
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 (2):

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

The ratio of the measured onset leakage pressure P_m (the pressure at which the leakage rate is 0.05 g/m.s) and the calculated onset leakage pressure P_c using equation 2 is plotted in Figure 13. It is clear the leakage process can be described as exhibiting little inertial or storage effects at frequencies below 0.4 Hz. However, above 0.4 Hz, the calculated leakage rates are not as good a fit to the measured leakage rates. Similarly, the loose-fitting downturned leg is much less weathertight (P_m = 110 Pa) than the tight-fitting flashing (P_m = 420 Pa), largely because it allows air-carried water to pass relatively freely through the joint. It takes some time for water to accumulate in the joint compared with the tight-fitting joint where water appears to be retained by capillary attraction and not draining out completely when the applied pressure relaxes.

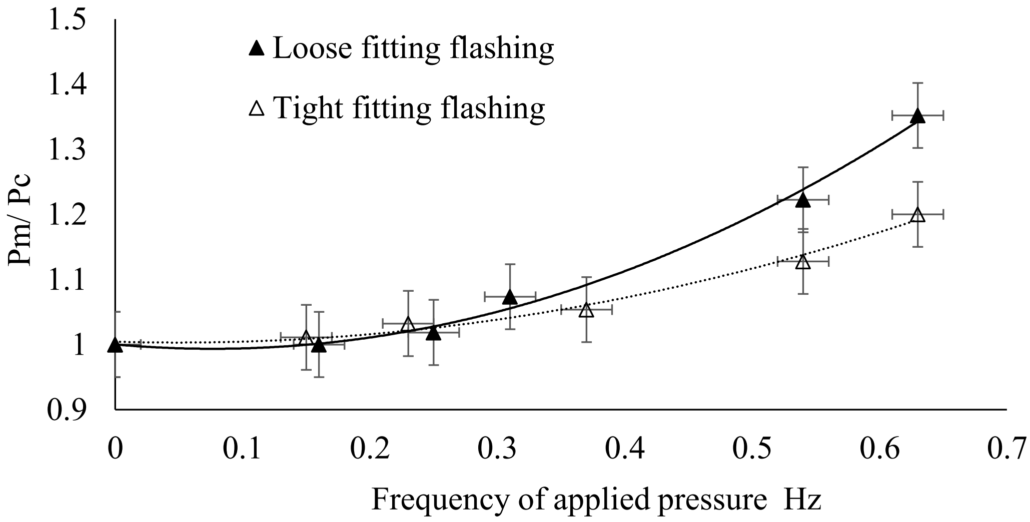


Figure 13. Ratio of measured onset leakage pressure (P_m) and the calculated onset leakage pressure (P_c) plotted against the frequency of applied air pressure.

The data in Figure 13 can be compared with the P_m/P_c ratio for two flashing upstands from earlier studies (Bassett and Overton 2015) in Figure 14. These are a window head flashing in a cavity wall, and a Z flashing in an inter-storey junction, and both incorporated 35 mm upstands. The window head was a vented joint, much like the loose-fitting downturned flashing, and the onset leakage pressures were higher than could be predicted from steady pressure leakage data at frequencies above 0.4 Hz. Similarly, the tight-fitting Z jointer has behaved like the tight-fitting downturned flashing in exhibiting little effect due to storage or inertia.

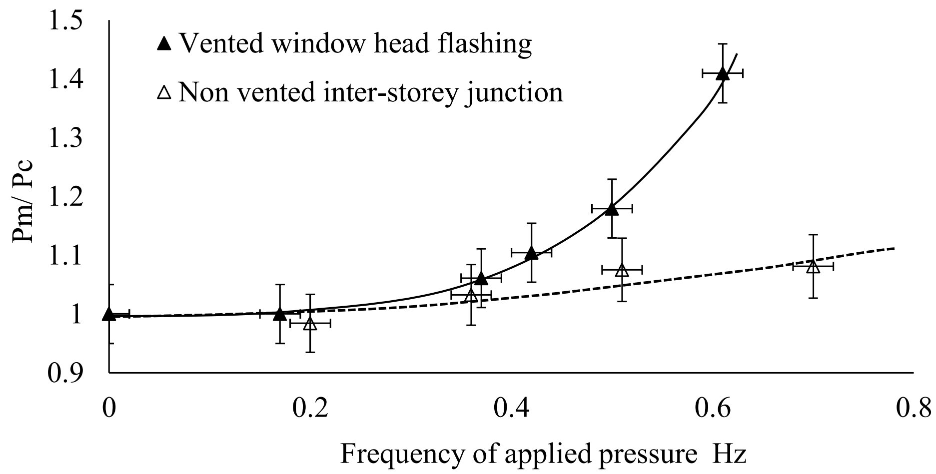


Figure 14. Ratio of measured onset leakage pressure (P_m) and the calculated onset leakage pressure (P_c) plotted against the frequency of applied air pressure. This data is for a window head flashing and a non-vented inter-storey junction.

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 and the storage capacity of the joint along with surface tension in order to predict leakage rates through joints with significant enclosed volumes.

5. CONCLUSIONS

This experimental study measured the weathertight performance of the downturned legs of flashings. The goal was to develop an understanding of the significance of leg length, airtightness of the joint and the kick-out and bird's beak terminations designed to deflect water from the joint. The conclusions are as follows:

The role of kick-out and bird's beak terminations. The weathertightness of window head joints has been shown in previous studies to benefit from features that deflect water from the building that reduce the rate of run-off over the joint. The kick-out and bird's beak terminations have been shown to achieve this for the flashing downturns studied here. They at least double the leakage onset pressures over joints with plain ends.

Tight-fitting joints. The leakage onset pressure through tight-fitting joints was generally close to the hydrostatic head equivalent of the flashing leg height. However, kick-out and bird's beak ends improved weathertight performance by screening the joint against rain entry. All of the joints with leg lengths of 10–90 mm passed the wetwall test in E2/VM1 requiring no water penetration across the cavity with a 50 Pa pressure difference across the cladding.

Loose-fitting joints. The leakage onset pressure for loose-fitting joints was shown to fall with reduced airtightness. The leakage process involved water droplets entrained by air flows through the joint. Increasing the leg height had little effect, but adding a kick-out or bird's beak end increased the leakage onset pressures by 1.5 and 2 times respectively. Another way of improving the weathertightness of a loose-fitting flashing was to fit it tightly against the top of the cladding and with the leg protruding out from the cladding. This effectively rainscreened the joint at the same time as controlling air and water entry at a relatively dry location.

Dynamic water leakage properties. The leakage characteristics of tight and loose-fitting downturned flashings were measured with air pressure fluctuations in the range 0.1–0.7 Hz. The tight-fitting joint behaved as though there is little inertia or storage in the leakage path, leading to leakage onset pressures that could be calculated from the steady pressure leakage function for the joint. For the loose-fitting joint, there was a tendency for the peak pressures to exceed the steady state onset leakage pressure. This indicated that the joint acted as a reservoir that drained out at low pressures in the cycle.

6. FURTHER WORK

This experimental study is a small part of the work needed to put junction design on a scientific footing. For a start, the junction leakage characteristics will have to be combined with wind pressures, rain loads and surface run-off rates to calculate leakage rates. This step of the process is illustrated in Figure 15 using a head flashing as an example. It shows the steps that would have to be taken to apply a modified detail to a building falling outside the scope of E2/AS1. Secondly, there will be additional consideration due to the junctions between panels having to cope with deflections from wind and seismic loads. In fact, the facing covers required to cope with deflections may exceed the cover required for weathertight performance.

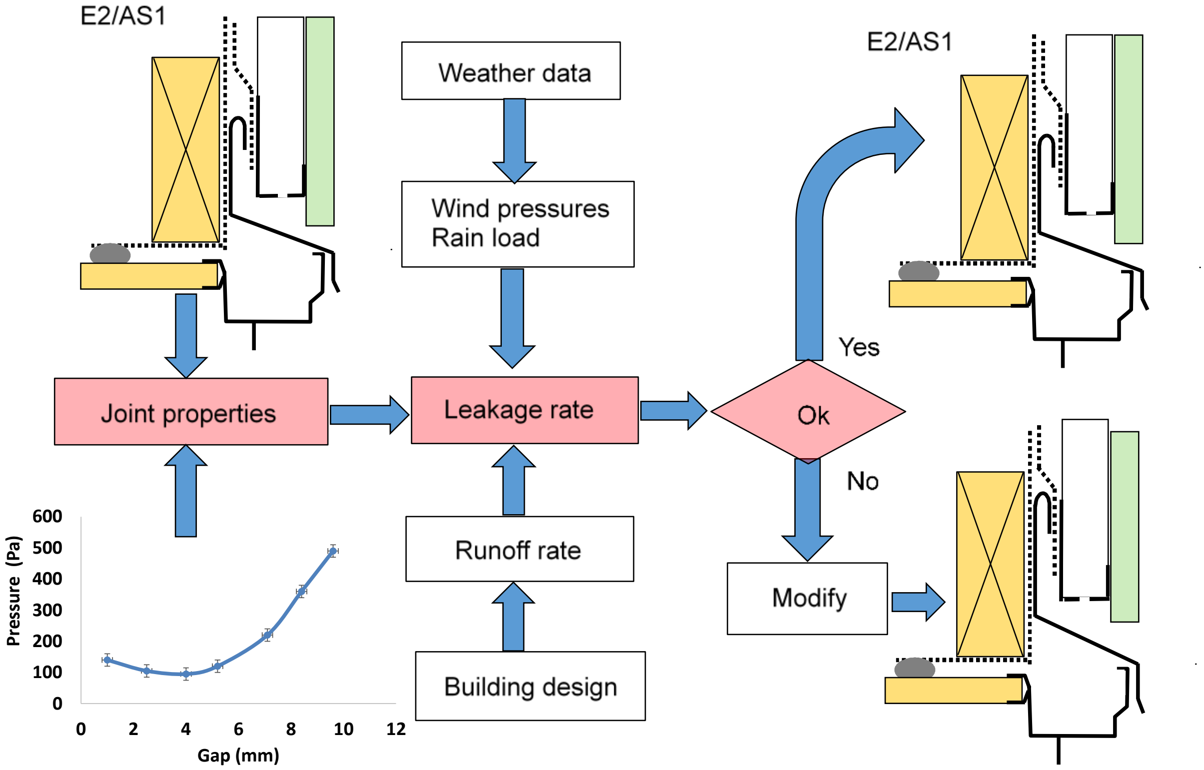


Figure 15. Schematic of the process for modifying a junction detail to take account of high wind and rain loads on a façade.

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