

Results on Assessing the Effectiveness of Wall-Window Interface Details to Manage Rainwater

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ABSTRACT

Inadequate detailing practice and defective installation of windows has accounted for a significant number of premature failures of the building envelope. This has spurred the development of alternative construction details to manage water intrusion at the wall-window interface. Laboratory investigations focused on assessing the effectiveness of wall-window interface details to manage rainwater intrusion in the wall assembly have provided an effective way to obtain useful information on the varying performance of different interface details. Previous studies undertaken to investigate the effectiveness of details typically used in wood frame low-rise wall assemblies have shown the degree to which different details manage rainwater intrusion and the extent of fault tolerance of these systems. This paper offers a report on more selected results obtained from evaluating the watertightness of a series of four wall-window interface details representative of construction practice across Canada. A brief overview of four sets of wall-window interface details and variations on their implementation are described in general and details for a set, comprised of two specific wall-window interface details evaluated in the study are provided. The set of two variations of interface details described were configured for a fixed PVC window incorporating mounting flanges and installed in a rainscreen wall. The results of water penetration tests are provided in terms of water entry through deficiencies in the cladding, water collection within the assembly and the severity of the simulated wind-driven rain loads. The effectiveness of the two approaches to window installation in managing rainwater entry is discussed.

INTRODUCTION

A key design element for exterior walls is the control of rain penetration. Lack of attention to design principles or failure to implement them in the detailing of wall components may lead to premature deterioration of wall elements. Inadequate detailing and defective installation of windows has accounted for a significant number of premature failures of the building envelope as has been evident across Canada in past years [1, 2, 3, 4]. For example, a survey of building envelope failures in the coastal region of British Columbia indicated that 25% of the moisture problems associated with water ingress into wall assemblies were directly attributable to penetration through the windows or the window-wall interface [3]. However, the issue of building envelope failure is not one that is limited to coastal climates, although it is likely that assemblies are more vulnerable in such climates, but one that has found interest throughout North America, and abroad in regions where wood frame housing is also in use, such as New Zealand.

For example, the BRANZ undertook research studies [5] into the weathertightness performance of the installation of windows in cladding for low-rise residential construction in New Zealand,

focusing on assessing the performance limitations in weathertightness of the Window Association of New Zealand's Window Installation System for direct-fixed cladding in low-rise residential construction.

More recently, the issue of premature failure of the building envelope has been apparent in Minnesota [6], where it is reported by the building inspection division of the town of Woodbury that homes built since 1990 were experiencing major durability problems. Specifically, 276 of 670 stucco homes built in Woodbury in 1999 have failed (ca. 41%); the primary cause for failure were window leaks, lack of kickout flashing, and improper deck flashing above the wood framing [6]. Clearly the problem of water penetration at window openings persists and not only in coastal areas for which the perception is that climate loads are very severe. Although coastal climates may indeed be severe, details that promote the entrapment of water and that are not fault tolerant are likewise susceptible to premature deterioration, even in areas of apparently reduced "climate loads".

The state of California has taken interest in understanding the level of risk afforded by different window installation methods and has recently reported on a test program to evaluate the performance of difference window installation details [7]. The overall goal was to perform a systematic laboratory evaluation of specifically identified conventional and innovative residential building materials, assemblies, and construction practices. The laboratory evaluations were designed to provide experimental evidence of moisture loading, propensity for mold formation, and potential performance improvements associated with innovative building assemblies and construction practices.

In North America, this more recent interest has spurred a review of existing ASTM standards [8] and in the Canadian context, standards of the CSA for assessing the performance of windows [9]. Two studies focused on assessing the watertightness of windows and the wall-window interface were completed by Ricketts [10, 11] on behalf of CMHC. Results indicated that although a wide range of causal factors was found to contribute to leakage activity, the principal paths for water leakage are those associated with the wall-window interface. These could occur either through the window assembly to the adjacent wall assembly or through the window to wall interface with the adjacent wall assembly. A review of the CSA A440 B rating performance [9] indicated that the criteria for water penetration control do not identify leakage associated with these leakage paths, nor is there a requirement for testing of the installed window assembly. Additionally, it was found that the selection of windows and the design of the wall-window interface do not consider local exposure conditions as may be provided by the local topography or other building features such as overhang protection.

Some recommendations that followed from these reports included [10, 11]:

- Assessment of in-service and micro-exposure (at window proximity) conditions
- Provision for redundancy in water penetration control through the installation of sub-sill drainage.
- Consideration of the durability of water penetration control performance
- Development of a water penetration testing protocol for the window to wall interface

Hence there is widespread interest in obtaining a better understanding of the comportment of different window installation methods for a range of climate loads. Laboratory investigations can provide an effective way to obtain useful information regarding the effectiveness of specific wall-window interface details to manage rainwater intrusion in the wall assembly [12, 13]. Although laboratory studies are short-term tests that do not directly relate to expected long-term performance, these can be used to determine the response of wall assemblies to specific rain events for which the recurrence period can be ascertained. Establishing the response of wall

assemblies to simulated events is an indirect means of determining the likely risk of water entry over a given period for a specific climate region. These may also provide some measure of the expected risk to water entry and the fault tolerance of different installations methods in extreme conditions.

The current test program, previously reported in [14], has sought to evaluate different interface details and their ability to manage rainwater entry and as well, provide a means of assessing the robustness of specified design by, for example, considering what occurs when jointing products fail or construction has reduced airtightness. In addition, a test program having a specified test protocol nominally permits benchmarking “performance” of proposed interface design details. As well, the development of a “standards” approach in a laboratory setting offers potential as a precursor to a field certification protocol that is currently lacking.

In this paper, the results of water entry are provided for a set of two variations of wall-window interface details configured for a fixed PVC window incorporating mounting flanges and installed in a rainscreen wall. Interface details of the two approaches to window installation are given and the effectiveness of different details in managing rainwater entry is discussed.

EXPERIMENTAL APPROACH TO EVALUATING WATER MANAGEMENT OF WINDOW INTERFACE DETAILS

The objective of the experimental work was to compare the ability of different wall-window details to manage rainwater. Given the many different combinations of windows, wall cladding systems and related interface details that could be assessed, importance was placed on establishing specifications to which all test specimens would nominally be fabricated, including:

- Overall size of specimen (determined by maximum size permissible in test apparatus)
- Size and location of windows
- Type of windows and cladding
- Type of sheathing board, sheathing membrane and interior finish

Accordingly, the configuration of test specimens was established that nominally permitted comparisons among the different details when subjected to simulated wind-driven rain conditions. Wall specimens were designed to permit side-by-side comparison of two wall-window interfaces details (Figure 1). Hence, each 2440 mm by 2440 mm wall specimen included two large openings of 625-mm by 1250-mm, in each of which was placed a 600 mm by 1200 mm window together with a set of wall-window interface details. These details include those located at the window head, the jambs and the sill. Half the specimen included a “selected practice detail”, the other a “variation”, which typically could be an “upgrade” of the interface detail that may or may not be common but nonetheless presented a research interest. Entry of water around either window opening was collected in troughs located beneath the respective sills. Water was also collected at the window, just beneath the sill level, on the interior side of the specimen. Thereafter, a choice was made as to which window-wall combinations to evaluate based on regional considerations of current practice and variations thereof. Additional details regarding the test specimen configuration specific to the results reported are provided below.

The Dynamic Wind and Wall Test Facility (DWTF), previously used to subject similar specimens to simulated wind-driven rain conditions, has been shown to offer a reproducible method for subjecting specimens to simulated wind-driven rain [12]. A test protocol was developed based on

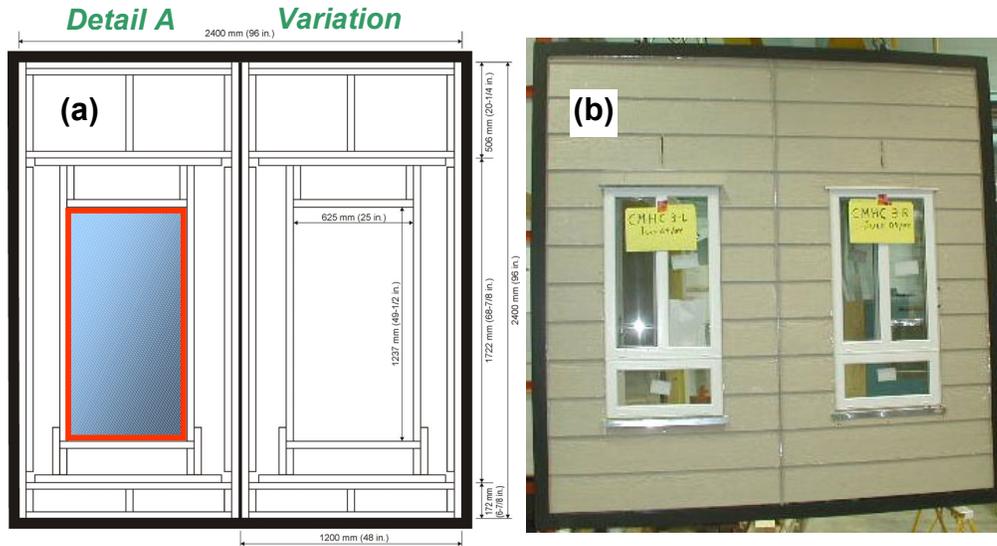


Figure 1 – (a) schematic of front elevation of 2.44-m by 2.44-m specimen showing location of 600 mm by 1200 mm windows and adjacent wood framing studs. Detail “A” might be representative of installation details used in current practice whereas detail “V” a variation on that practice; (b) photo of the completed specimen clad with hardboard siding.

previous work [15], and also took into consideration existing North American water penetration test standards such as ASTM E331 [8] and CSA A440.4 [16]. The protocol established parameters for spray rate (water deposition rate) on the cladding and pressure difference across the assembly [15]. Specimens were thus subjected to simulated wind-driven rain conditions for specified periods of time; these conditions replicated the main features of rain events. Rates of water entry at the subsill and behind the cladding were determined by measuring the rate of water collected from these locations as well as that portion that entered the window at the interface between the window lite and frame. The use of the facility together with the test protocol permitted comparisons of water entry results among the different wall-window interface details. Both the apparatus and protocol are briefly described in the sections that follow.

DESCRIPTION OF TEST APPARATUS - DYNAMIC WIND AND WALL TEST FACILITY (DWTF)

Water penetration tests were conducted using the Dynamic Wind and Wall Test Facility (DWTF) a more detailed description of which can be found in [14]. The facility is capable of subjecting full-scale test specimens (nominal size 2.44 by 2.44-m) to either static or dynamic pressure fluctuations of over 2 kPa and water spray rates ranging between 0.8 and 8 L/min-m². An air blower generates a steady-state component of air pressure when testing under static pressure conditions as was used in this study. Additionally, it provides a means to assess the air leakage characteristics of the specimens. The apparatus also contains a pressure regulated water spray system that simulates the action of rain deposition on the cladding surface. Water can be applied to the front face of the specimen in either full-spray format in which water is deposited evenly across the front of the specimen through an array of spray nozzles, or by cascading water from the top of the specimen in a continuous sheet of water.

SUMMARY OF TEST PROTOCOL

The test protocol was adapted from the MEWS protocol, described in Lacasse et al. [14], and a review of wind-driven rain loads as might be experienced across Canada [15]. The test protocol is completed in three stages as described below:

Stage	Description
1.	Characterization of air leakage and pressure equalization potential of the wall assembly
2.	Water penetration without deficiency in static mode at specified spray rates of 0.8, 1.6 and 3.4 L/min.-m ² with pressure variations from 0 to 700 Pa and nominal air barrier system (ABS) leakage of 0.3 and 0.8 L/s-m ² at 75 Pa
3.	Water entry with deficiency in static mode at spray rates varying from 0.8 to 3.4 L/min.-m ² and pressure variations from 0 to 300 Pa and nominal ABS leakage of 0.3 and 0.8 L/s-m ² at 75 Pa

The intent of the initial test sequence (Stage 1) was to determine the air leakage characteristics of the specimen installed in the test apparatus such that subsequent tests on different specimens could nominally be conducted at or near the same air leakage rate. Gathering information on pressure distribution across the wall at or near water collection points was also useful. Air barrier system (ABS) leakage was regulated by introducing a series of openings at the interface between the window frame and the ABS. The desired nominal leakage through the ABS was achieved by providing openings along the wall-window interface at the specimen's interior surface as was necessary to obtain two nominal leakage levels of 0.3 and 0.8 L/s-m². The nominal values for air leakage are those achieved at 75 Pa and derived from air leakage tests over which pressure differences across the specimens ranged from 50 to 700 Pa.

The next test stage (Stage 2) permitted testing the proposed wall-window interface details to extreme wind-driven rain conditions where specimens were assumed to be in unflawed condition and to function as intended (i.e. tested as built in the laboratory and assumed without deficiencies). Water penetration through small unintentional openings, consistent with specimens built of unflawed conditions, tends to be more sensitive to variations in pressure. Consequently the focus in this stage is on the variation of pressure (0 to 700 Pa) with high rates of water spray (0.8, 1.6 and 3.4 L/min.-m²).

The ability of the wall-window interface details to manage water given a deficiency along one of the interfaces was assessed in Stage 3. Deficiencies, purposely introduced in the specimens consisted, for example, of openings such as missing lengths of caulking (sealant); such deficiencies might simulate the loss in bond or rupture of the seal brought about by the effects of aging. In this situation, the sensitivity of water penetration through relatively large deficiencies to the rate of water impinging on the façade can be evaluated. Water entry through larger openings appeared to be more sensitive to variations in spray rate than pressure differential. Hence, pressure differentials across the assembly were in this stage restricted to 300 Pa. Deficiencies introduced in the first line of defence against water entry necessarily provide a path for water entry behind the siding that permits evaluating the ability of the wall-window interface detail, and adjoining elements of the wall, to collect and evacuate water to the exterior of the assembly. Such an approach may also permit replicating inadequate construction installation and helps determine the fault tolerance of the detail in respect to water management.

DESCRIPTION OF TEST SPECIMENS

The wall assemblies were intended to be representative of low-rise residential construction with the exception of two changes to the structural assembly, both of these implemented with the intent of enhancing the visual field of view directly behind the sheathing board in proximity to the window opening. In the first instance the king studs, typically adjacent to the jack studs used to support the window header and the sill, were removed to provide a broader view of the sheathing membrane outside the perimeter of the window opening. It was considered that the expected loss in rigidity of the frame in the plane of the wall would be offset by the fact that the overall assembly is enclosed by a steel frame and that the unsupported lengths are small in comparison to what might be expected in a typical wood frame construction. The second component that differed from typical wood frame construction was the sheathing board; in this instance, acrylic sheets, having a

comparable flexural modulus to that of OSB, were installed with a 3-mm gap at mid-height of the specimen on the exterior of the wood frame. The use of acrylic sheathing provided a means to trace water entry on the interior side of the sheathing membrane. The expectation was that the location and timing of water ingress could readily be observed using this technique. As such, the specimen consisted of: 38 by 138 mm (nominal 2" by 6") wood studs, transparent acrylic sheet on the inside as the principal element of the air barrier system (ABS), acrylic sheets as sheathing board, spun-bonded polyolefin membrane or asphalt impregnated paper serving as sheathing membrane and an exterior horizontal hardboard siding installed on vertical furring strips for one set of test runs and directly against the back-up wall for a second set.

Different types of PVC windows were used in the project all of which had overall dimensions of 600 mm (width) by 1200 mm (height) and were fabricated in Canada. These included a "box" window frame (non-flanged) and those incorporating a mounting (fixing) flange integral to the frame. As well, both fixed and operable sliding windows were used and where operable windows were utilized, these formed the upper part of a combination operable-fixed window.

Selection of Wall-Window Detailing

A team of Canadian building envelope specialists provided information for their respective geographical region of practice into current practice for detailing the wall-window interface of wood-frame buildings. Specific though not exhaustive information was obtained on regional practice of the West Coast, the Prairies (i.e. Alberta, Saskatchewan, Manitoba), Quebec and Atlantic Canada. This highlighted significant differences in regional practices across Canada for detailing the wall-window interface and wall assembly, additional details of which are provided in [14]. A summary of the different wall-window combinations including information on window frame and type, wall and siding types and variations of interface details is provided in Table 1.

Table 1 - Summary of window-wall cladding combinations selected for testing

Specimen	Window Frame	Window Type*	Wall Type / Siding Installation	Variation (determine effect of)
W1	Box (Non-flanged)	Fixed	Rainscreen wall – clear cavity behind siding	Extra seal at junction of jambs and head of window R.O.**
W2	Flanged	Fixed	Concealed barrier wall – no clear cavity	Changes in protection of R.O.; back dam at subsill
W3		Combination - Operable sliding (upper) / Fixed (lower)	Rainscreen wall – clear cavity behind siding	Two subsill drainage methods for flat sill
W4			Concealed barrier wall – no clear cavity	Sealing sheathing membrane to window flange

*All windows were fabricated of PVC; **R.O. : rough opening

Of the different details evaluated in this study, focus is made on the specifications for and test results derived from specimen W3. These details focus on the installation of windows that include integral mounting flanges and solutions for detailing such windows when incorporated in a rainscreen wall. The use of PVC windows having integral mounting flanges is typical of new construction but is increasingly being used when reconstruction of damaged facades is required. Given that for reconstruction there is also interest in the applying a rainscreen wall solution, focus was placed on evaluating different variations of such installation details. The intent was to determine if, between different approaches, significant differences would be observed in respect to the water management of the respective details. In particular, there was interest in knowing the degree to which the different approaches would permit adequate drainage of the subsill area, and whether the mounting flanges would restrict the rate of drainage from the subsill. It is noted that the approaches adopted for specimen W3 place the window further towards the exterior and hence out of plane with the thermal resistance of the wall. Although the

focus of this study was on management of rainwater at the wall-window interface, the viability of this approach in respect to the potential for condensation at the window frame would need to be verified for the different geographic locations in which it might be used.

WALL-WINDOW DETAILING FOR SPECIMEN W3

Specimen W3 included PVC combination windows (horizontal sliding upper portion of 800-mm height, CSA rating B3; fixed lower portion of 400-mm height, CSA rating B4; total assembly not rated), having integral mounting flanges that were installed in a rainscreen wall incorporating a 19-mm clear cavity behind the cladding. The hardboard siding was affixed to 19-mm pressure-treated furring strips, the strips fastened to 2-in. by 6-in. (38-mm by 138-mm) wood frame studs. The rough opening at the sill was protected with strips of bituminous-based self-adhered membrane: one membrane covered the rough sill, the bottom of the rough jambs, and extended 150-mm over the sheathing membrane below the subsill. A second strip of self-adhered membrane covered the bottom 150-mm of the rough jambs and a 150 mm wide band of sheathing board. A paper-based asphalt impregnated product used for the sheathing membrane, was also used to protect the remaining portions of the rough opening extending along the height of the jambs and across the head of the window. Of the two different installation methods, the specified practice (“B-side”) included installation of the window directly on the furring strips, as shown in Figure 2 (a). The variation of this detail (“V-side”), shown in Figure 2 (b), has the window flange mounted to the protected sheathing board on the backside of which were placed shims (shown in photograph) that provided a small space (2-3-mm) between the mounting flange and the board.

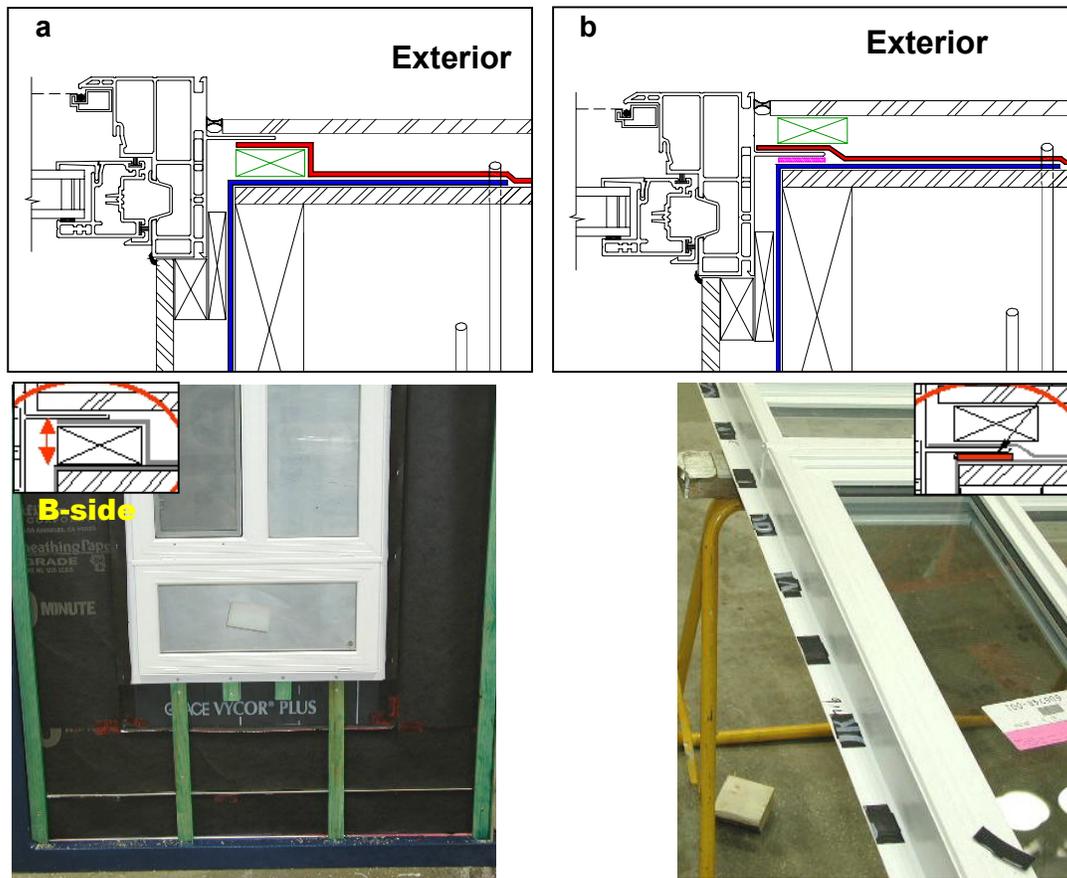


Figure 2 - Horizontal sections: (a) “B-side” window and photograph (below) showing installation on furring strips; (b) variation (“V-side”) window and photograph (below) showing membrane shims on backside of mounting flange.

The shims were made of small portions of bituminous-based self-adhered membrane that had been folded over and applied to the flange at fastener locations. Following window installation, sheathing membrane was loosely installed (no seal) over the window flange at the head and jambs and beneath the window flange at the windowsill. Drip cap flashing (rigid PVC), not incorporating end-dams, was installed at window heads whereas rigid metal flashing, serving as sill drip cap, was placed at the junction of the window and cladding. The 6-mm joint between cladding and window frame was sealed with a backer rod and sealant.

DEFICIENCIES INCORPORATED IN THE CLADDING

Three (3) sets of deficiencies were incorporated at the interface between the exterior cladding and the window frame and included: (1) 90-mm vertical slit (ca. 2-mm width) above window heads; (2) 90-mm missing length of sealant and backer rod located at the horizontal joint along the lower and outer corner of the window frame, at the junction of the window frame and the sill flashing, and; (3) a 90-mm long by 6 mm wide missing sealant and backer rod in a vertical joint at mid-height of the outer window jamb. Each of these locations is identified in Figure 3.

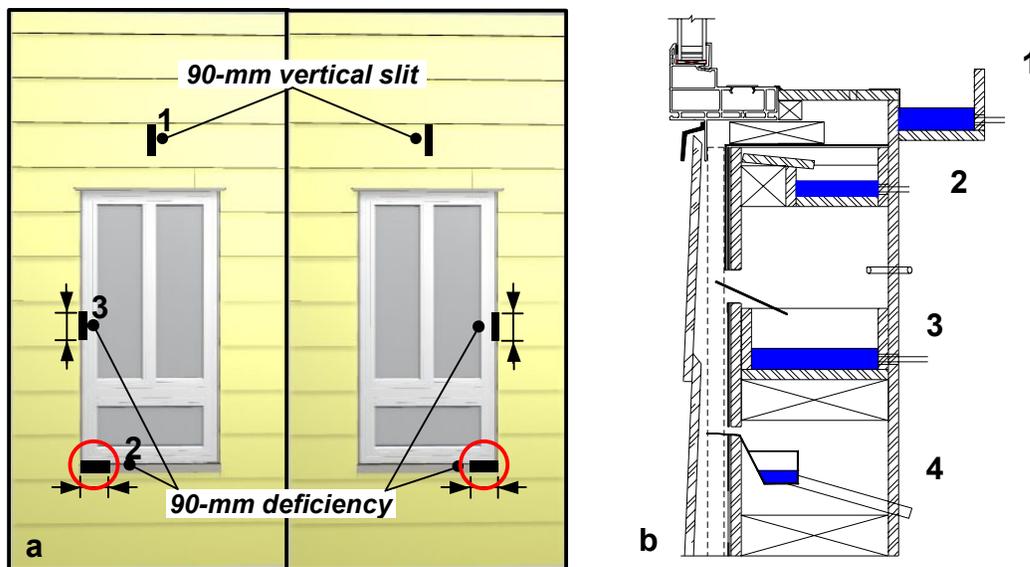


Figure 3 – Front elevation of 2.44-m by 2.44-m specimen (cladding exterior) showing location of 90-mm deficiencies (missing sealant, backer rod at specimen face); (b) Vertical wall section (inter.) showing location of water collection troughs at (1) window on interior side of test specimen, (2) beneath window in false subsill; (3) beneath subsill for collection of water drained from subsill (see Fig. 4) and, (4) lower most trough for collection behind siding [14].

WATER COLLECTION TROUGHS

Water penetration at the window proper, entering unintended openings in the cladding and interface, or entering through deficiencies, was collected in troughs located as shown in Figure 3 (b). A trough located at (1) in Figure 3 (b) permitted collecting water that would penetrate the window between the lite and window frame; water accumulating at the sill could be collected in a false sill trough at (2), or in a trough located beneath the sill at (3) which measured water drainage from the sill to the trough; water finding its way behind the cladding would be collected near the base of the wall in the trough at (4). Nominally, this permitted quantifying the amount and rate of water entry along different paths and differentiating the significance of these paths given different test conditions. For example, water entering the subsill area, as shown in Figure 4, would drain from the subsill down the front of the waterproof membrane and be directed into collection trough (2) beneath the subsill. As shown in the figure, water was redirected to this trough using a protruding metal plate that was placed in a horizontal opening, a narrow slit, located ca. 180-mm below the sill edge.

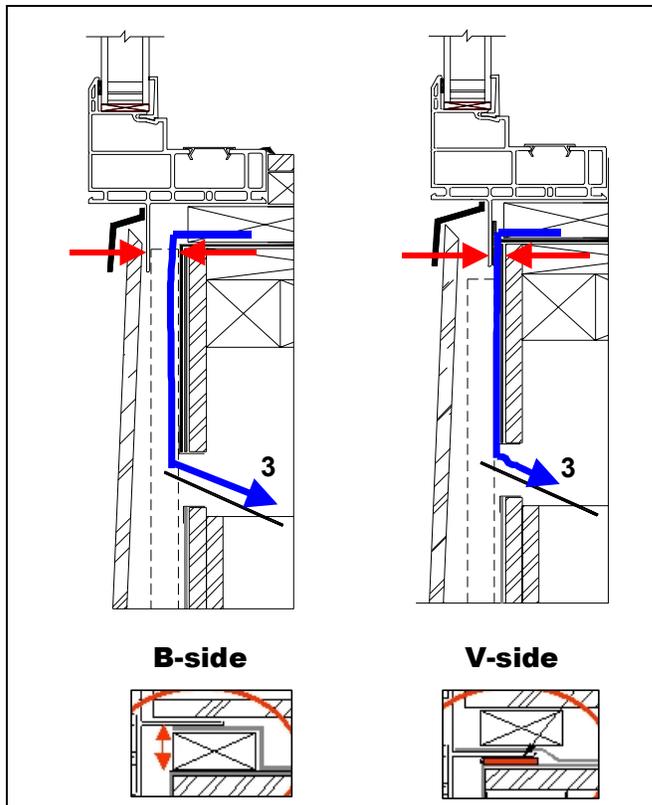


Figure 4 – Expected direction of water drainage from subsill to collection trough (3) for base-case (B side) and variation (V-side) portions of specimen W3

SELECTED RESULTS

The water penetration tests subject the specimens to the simultaneous application of a water cascade on and pressure difference across the wall assembly. The cascade of water originates at the top of the wall and flows over the wall cladding at three different rates: 0.8, 1.6 and 3.4 L/min-m², whereas pressure is applied to the exterior of the wall at seven different levels: 0, 75, 100, 200, 300, 500, and 700 Pa for each of these cascade rates. Specimens in a pristine condition are first tested and thereafter, deficiencies are introduced in the wall, as previously described, and the series of tests repeated for each deficiency and at two different levels of nominal air barrier system (ABS) leakage (“tight” – 0.3 L/s-m²; “leaky” 0.8 L/-m² at 75 Pa). Over the course of the test, rates of water entry (ml/min) to the respective collection troughs were recorded as were the water cascade rate and pressure differential across the test assembly.

Results for specimen tested without deficiencies

Results from tests in which no deficiencies were introduced on the specimen indicated very little or no water entry to the sub-sill area or behind the cladding for either the B- or V-side of the specimen. However, above a differential test pressure of 200 Pa, water entry at the windows increased substantially. This might have been expected given the sliding window used in the upper part of the combination window; the sliding window is rated as CSA B3 (i.e. 300 Pa). As shown in Figure 5, at the highest differential pressure and water cascade rate (i.e. 700 Pa and 3.4 L/min-m², respectively) water entry at the window of the B-side was roughly double that of the V-side up to a maximum of 484 ml/min on the B-side, and 237 ml/min on the V-side. As well, above these pressure levels, the rate of water entry for either side was dependent on both, increases in water cascade rate and increases in pressure differential. The difference in entry rates across windows that nominally have the same expected performance rating is perhaps due to the

difference in respective water loads at the face of the window proper. These loads are typically affected by any protrusions from the cladding plane be they the window profile or drip cap flashing placed at the head of the window. Both windows had head flashing however, the window on the B-side projected out from the cladding plane to a greater extent (~ 16-mm) than the window on the V-side; hence, the B-side window may have been exposed to a more substantial water load accounting for the increased entry rates on the B-side as compared to the V-side at the window.

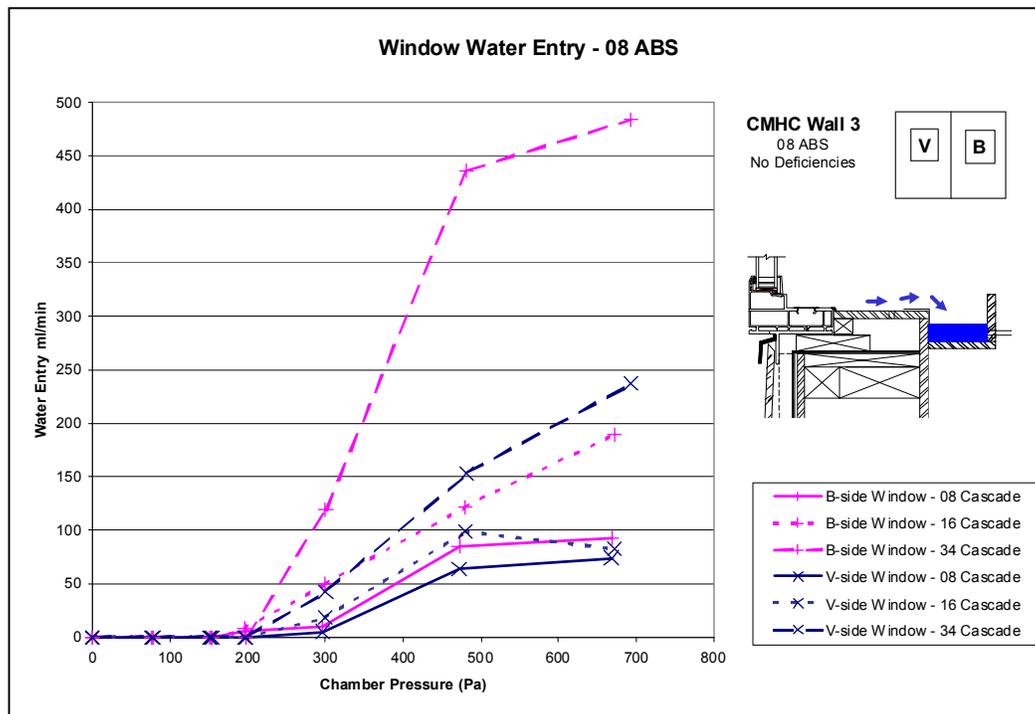


Figure 5 – Water collection rates to trough located at window of specimen W3 (Figure 3 (c) – trough (1)); collection rates (ml/min) are shown in relation to pressure differential (“chamber pressure”) across test specimen (Pa) for both B- and V-side of specimen at different water cascade rates for which, for example, “08 Cascade” refers to nominal cascade rate of 0.8 L/min·m². The test was conducted for a specimen having an ABS leakage of 0.8 L/s·m² at 75 Pa.

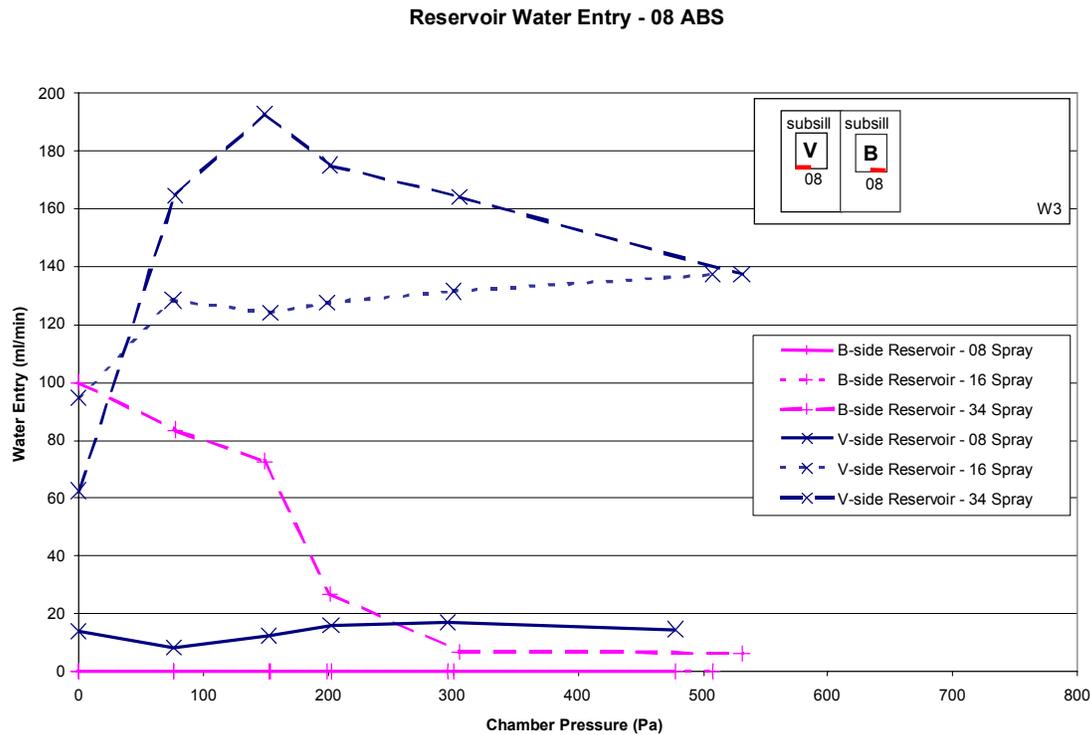
Results for specimen tested with deficiencies

Of the three deficiencies incorporated in the test specimen and subjected to tests conditions, the only deficiency that resulted in any substantial increase in water entry to any of the respective troughs as compared to results from tests with no deficiencies, was a 90-mm missing length of sealant and backer rod located along the horizontal joint at the lower and outer corner of the window frame (vz. circle, Figure 3 (a)). The vertical openings introduced in this specimen at two locations, one above the window head in the cladding (i.e. narrow slit), the other at the cladding-window frame interface, mid-height along the jamb, are deficiencies that characteristically appear not to have provided substantial opportunity for water entry. One of the reasons for this is related to the quantity of water available for entry through a narrow vertical opening over which water may flow. In principle, for a given rate of water flow over the cladding, a uniform film of water forms thus providing a water load in proportion to the width over which it is applied. Hence, narrow vertical openings, such as those that may appear at the juncture of two cladding panels, necessarily have smaller potential for water entry as compared to wider horizontal openings, assuming the width of the horizontal openings are comparatively greater than that of a narrow slit. In practice, one must also consider protrusions up-stream of the flow of water that potentially affects the load downstream. Certainly, head flashing affects water flow and flow over surfaces

is not always uniform which may also lead to variations in load at openings, vertical or otherwise. Hence the degree of local wetting of surfaces may vary from the average projected flow.

Water collection in the trough beneath the subsill (see Figure 4, trough (3)) indicated substantial amounts of water entry for the V-as compared to the B-side of the specimen. As shown in Figure 6, at the lowest rate at which water was deposited on the cladding (i.e. 0.8 L/min.-m²) there was no water collected on the B- as compared to the V-side, the rate of collection in trough (3) over the applied differential pressure across the specimen not exceeding ca. 20 ml/min. At a water deposition rate of 1.6 L/min.-m² only the V-side registered water entry, comparatively substantial amounts ranging from ca. 100 to 140 ml/min being collected. At 3.4 L/min.-m², the highest cascade rate tested, water entry was recorded for both sides of the test specimen and ranged from ca. 60 to 190 ml/min, the peak occurring on the V-side, at 150 Pa pressure difference. Notably, water was collected when no pressure was applied across the assembly at substantial rates, upwards of 100 ml/min for the B-side. The entry rates were not dependent on changes in pressure; however, changes in water cascade rate did bring about increases in rates of entry to the collection troughs.

Figure 6 - Water collection rates to trough located beneath subsill (Figure 4 – trough 3) for both B- and V-side of



specimen W3. Collection rates (ml/min) are shown in relation to pressure differential (“chamber pressure”) across test specimen (Pa) at different water cascade rates for which, for example, “08 Cascade” refers to nominal cascade rate of 0.8 L/min.-m². The test was conducted for a specimen having a nominal ABS leakage of 0.8 L/s-m² at 75 Pa.

Subsequent testing with a false sill beneath the window (Figure 3 – trough (1)) indicated that the amounts collected in trough (3) could not be attributed to water drainage from the sill itself. Small amounts were collected in the false sill that was in the same order as quantities collected when no deficiencies were present in the wall. Nonetheless, there remained water entry to collection trough (3) that accounted for the increase in water collection rates of the V as compared to the B-side.

Hence, to better understand the path of water entry for deficiencies located at the outer and lower corner of the wall-window interface it is useful to first determine the likelihood of water penetrating the up-leg of the rigid metal flashing used beneath the window of both specimens. The intent of this flashing is to help drain water, collected from the window above the flashing, away from the cladding surface directly below the flashing. Additionally, it should also to prevent or retard water entry at its juncture with the window.

Figure 7 (a) shows the lower corner details at the cladding-window interface and (b), the 4-mm flashing up-leg. Water ran down the window face and, given the shallow slope of the sill flashing, pooled on the protruding flashing. Access to the back of the flashing was possible since the sealant and backer rod were removed at this location. Hence, the “pooled” water accumulated at this location and readily surmounted the ~ 4-mm flashing up-leg.

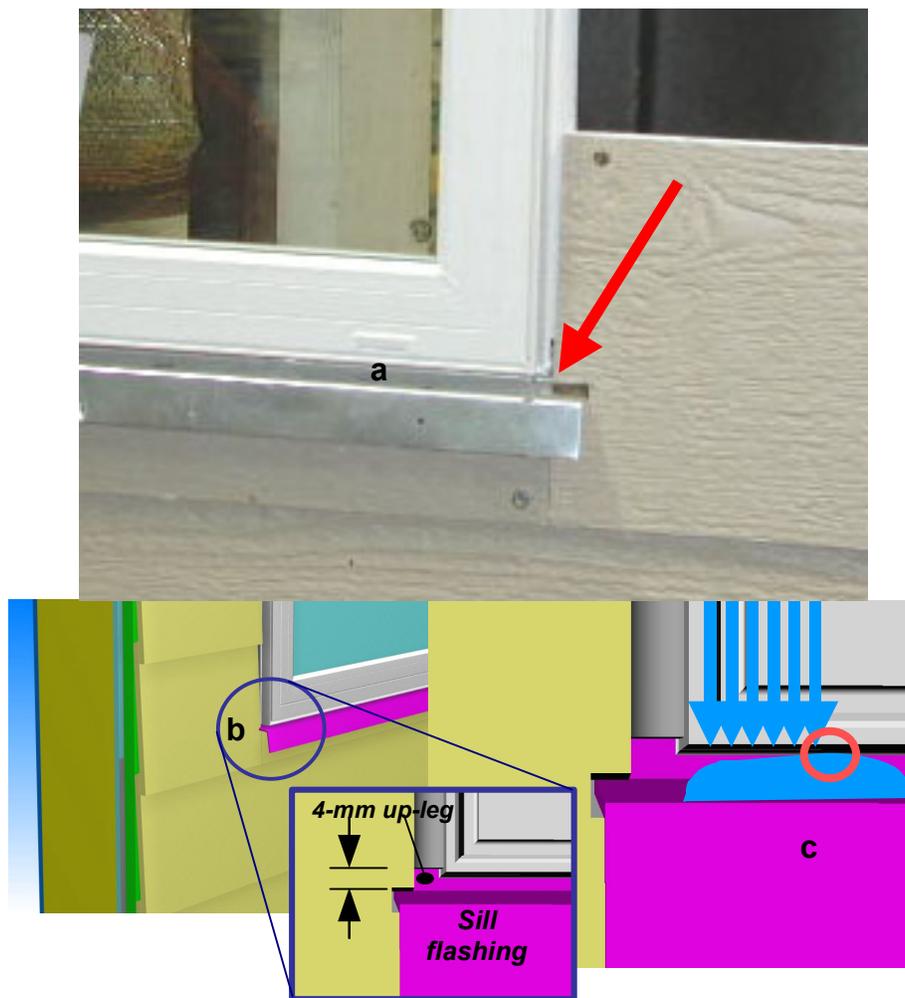


Figure 7 – Variation-side of specimen W3 and details of deficiency at (a) lower corner of window-cladding interface; (b) details of sill flashing showing 4-mm up-leg and; (c) water accumulation at sill flashing.

Figure 8 shows a vertical section at the wall-window interface for both the V- and B-sides of specimen W3. On the V-side (Figure 8 (a)), water surmounts the up-leg and passes behind the rigid sill flashing, running down the window mounting flange. However, the proximity of the mounting flange to the backup wall allows water to bridge the 3-mm gap created by the shims at the back of the window flange. As shown in Figure 8 (b) for the B-side, water follows similar path as on the V-side although the 19-mm gap created by the furring placed behind the cladding

proves difficult, but not impossible to bridge. In both cases, a portion of water attains the backup wall and is collected by trough, with the remainder running down the interior of cladding and is collected at the base of the wall. However, given the smaller gap of the V-side as compared to the B-side (3-mm / 19-mm) and the relative ease for water to bridge the smaller gap, implies that the V-side contributed to a greater amount of collection on this side of the specimen.

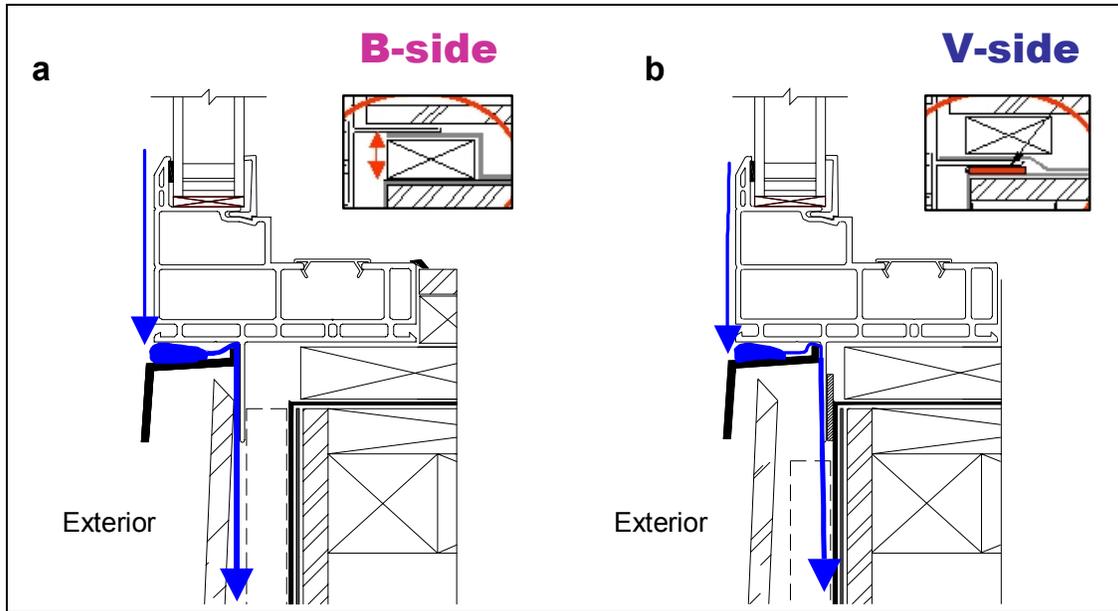


Figure 8 – Vertical section at wall-window interface of (a) selected practice B-side and; (b) Variation, V-side of specimen W3 showing path of water entry from exterior towards the interior and behind cladding.

In respect to determining which interface detailing practice is preferable, both sides were shown to provide adequate protection when no deficiencies were present as in either case, little or no water entry was observed to the windowsill. When deficiencies were introduced in the cladding-wall interface, water entry was clearly more prevalent, however given the rainscreen wall, most of this water would not find its way to the sill and would be drained to the base of the wall. The consequence of a deficiency such as the missing length of sealant and backer rod along the horizontal joint between the window sill flashing and the window frame would be added water entry behind the cladding that would in any case drain to the base. The V-side detail, for which the mounting flange is but 3-mm from the backup wall, would necessarily have a greater proportion of this entry collect and flow down the backup wall. This might be considered as an increased risk to water entry for elements below the entry location in the event that these have been improperly installed.

One important aspect of this detailed review of water migration over the window, the pooling on the flashing and the subsequent entry through unperceived openings behind the sill flashing is that such details often dictate whether water will or will not enter. Consider for example the flashing details as shown in Figures 4, 7 and 8. The flashing is shown to have a downward slope as expected, to promote drainage from this surface; in reality, the flashing was installed with little or no slope thus providing for the possibility of pooling along its edge to the point where the 4-mm up-leg could readily be breached. Had the flashing been sloped, pooling would most likely not have occurred, although water may have momentarily been pressed to the opening of a sloped flashing when gusts of high wind occur. This nonetheless clearly demonstrates the vulnerability of selected points in the assembly.

SUMMARY

A report is presented on selected results obtained from evaluating the watertightness of a series of two wall-window interface details representative of construction practice across Canada. The set of two variations of interface details were configured for a fixed PVC window incorporating mounting flanges and installed in a rainscreen wall. The windows were mounted either directly on 19-mm furring strips, or indirectly to the sheathing board with the use of shims consisting of portions of membrane placed on the backside and along the periphery of the flange at fastener locations. The results of water penetration tests are provided in terms of water entry through three sets of deficiencies in the cladding, including vertical openings in the cladding above the window head, missing lengths of sealant and backer rod along the window jamb and window sill and cladding interface respectively. Little water entry was observed when no deficiencies were present in the specimen and limited amounts were collected for deficiencies along a vertical line. Water entry through the combination sliding-fixed window assembly was observed at pressures below the rated performance and rates of entry were substantial at higher test pressures. The consequence of the deficiency along the horizontal joint between the sill flashing and the window frame was added water entry behind the cladding that would in any case drain to the base of the wall. Although the nature of the entry through the deficiency was similar for both details, a greater proportion of entry was evident for that detail having a smaller gap for water to breach as compared to the window installed on 19-mm furring strips. Hence for a given set of test conditions, a greater amount of water is expected to flow down the backup wall for the detail having the smaller 3-mm gap. This might be considered as an increased risk to water entry for elements below the entry location in the event that these have been improperly installed. Nonetheless, either approach appears to be satisfactory from the point of view of management of water entry. As well, aspects related to the potential for the formation of condensation at the window frame should also be considered. The risk to the formation of condensation for these window installation approaches would necessarily depend on the geographic locations where such solutions might be implemented.

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