

Aluminum Windowsill Anchorage and Supplemental Waterproof Flashing Design Practices

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Sill flashing designs are among the most challenging aspects of aluminum window system design and installation on both new installations and replacement projects. While the aluminum window system components and window performance criteria are often well illustrated and presented by the manufacturer, providing a waterproof transition of the windowsill to the supporting substrate can be challenging and is not a part of the manufacturer's standard window design.

Inadequate attention to sill flashing details can result in water leakage into the building interior. Water intrusion into the exterior walls below windows may go undetected for some time, resulting in substantial damage to wall components and interior finishes. Proper flashing repairs on installed window systems can require complete window system removal.

When designing windowsill flashing systems, supplemental waterproofing systems (in addition to the manufacturer's standard or high-performance sill design) can be considered to provide longer-term waterproof performance. This approach involves utilizing anchorage systems that do not penetrate the horizontal portion of the manufacturer's sill, and the use of a flexible

waterproof system as the secondary flashing system. Designs should include systems that shed water and, most importantly, adapt to existing conditions. During construction, mock-ups can be used to set the standard for aesthetic quality and to allow for water infiltration testing to verify the performance of the design and installation.

BACKGROUND

The use of flashings is a concept that has developed out of the need to allow water that enters a building's cladding and fenestration system to drain to the exterior of the wall system. Historically, wood window systems incorporated solid-wood sills and subsills that were often sloped to the exterior to promote drainage of the exterior surfaces exposed to weather. Depending on climatic conditions, wood sills and subsills can require extensive maintenance, including periodic painting, to help prevent wood decay. Shrinkage and expansion of wood components caused by moisture create gaps in corners between the sash and sill components, which are areas of potential water penetration through the window, as are gaps between the window frame and the substrate. Perimeter sealants are used to prevent moisture penetration at these locations.

The development of aluminum window systems has provided the industry and property owners the advantages of increased water penetration resistance and increased energy efficiency, while providing an inorganic exterior material that does not require frequent painting to protect it from weather and deterioration. In addition, the aluminum sill receiver and subsill extrusions are fabricated to form a reservoir that can collect water that enters the window system and drain it to the exterior through weeps in the exterior surface of the component.

In contemporary aluminum window design, the corners of the aluminum frame are mitered or butt-joined together. In this type of system, an attempt is made to seal the inside corners with gasket-type components and/or applied sealant. Based on water leakage performance requirements of the window system design, an additional subsill component can be used immediately below the standard sill or receiver component of the window frame to increase its resistance to water penetration. Window manufacturers offer this subsill component as an optional component of their window system. In window repair or replacement projects, the subsill component may be necessary to adapt the window for installation into the existing substrate.



Figure 1 – Water leakage paths indicated by pink paper strips at interior after removal of wood stool.



Figure 2 – Debonded vinyl base-of-wall molding.

Windowsill Leakage Investigation

Inadequate windowsill design and installation can result in water penetration into the exterior wall system. In many cases, long-term infiltration may continue undiscovered, as the water is absorbed by wood and gypsum wallboard components. In addition, casework, mechanical systems, or furnishings at the exterior wall can often hide water damage to interior wall finishes.

Water leakage at windowsills is often initially observed in the form of water damage to interior wood stools that are adjacent to the windowsill. Wood stools are typically not primed and painted at the underside surface and thus can expand as water is absorbed. Removal of the wood stool can help reveal the areas where water is penetrating the windowsill (*Figure 1*). Water that enters the exterior wall cavity can result in wetted floor finishes. Water can cause the vinyl base that is adhered to the gypsum wall board to become debond-

ed and lead to organic growth on the gypsum wall board and on the adhesives beneath the vinyl base (*Figure 2*). Water that becomes trapped within the exterior wall stud cavity leads to accelerated deterioration of wall components, including corrosion

of steel studs and fasteners, and organic growth on wood and paper-faced gypsum board. In exterior wall constructions where paper-faced gypsum sheathing was used, inspection openings below leak areas can reveal eroded sheathing or areas where the



Figure 3 – Cavity side of exterior gypsum sheathing displays organic growth and rippling (debonding) of the paper facing.

paper facing has debonded (Figure 3), which may affect the fire rating of the sheathing. Removal of interior finishes can also help reveal water leakage paths, such as at screw fasteners that penetrate window flashings and exhibit corrosion (Figure 4).

Visual inspection of window systems from the building exterior can reveal deficiencies in the window system design and installation. Inspection of the window perimeter sealant joint can reveal gaps at the extruded ends of window components (Figure 5). The lack of properly designed and installed terminations of exposed ends of aluminum extrusions often results in sealant being pumped into the open end in the field

during the window installation (Figure 6), which typically fails to bond to or separates from the extrusion. These conditions can contribute to water leakage to the building interior.



Figure 4 – Removal of finishes at metal stud track directly below windowsill revealed water staining and corrosion of fasteners.

Metal Sill Pans

Metal sill pans are frequently used as part of the windowsill flashing system. In continuous ribbon- or strip-type aluminum



Figure 6 – Sealant pumped into open end of sill component extrusion.



Figure 5 – Gap in perimeter sealant at head-to-jamb intersection of window frame components.

Figure 8 – No sealant installed in flashing lap.

Figure 7 – Hemmed drip edge not properly integrated with adjacent flashing component at lap.



window systems, deficiencies are often observed in laps where the hemmed drip edge results in a buildup of material, causing a gap at the lap (Figure 7). If the lap is not properly sealed (Figure 8), water leakage can occur.

Structural columns that are integrated in the exterior wall construction between the windows can result in an obstruct-

pan flashing system, resulting in a flashing that is cut or modified in the field by the installer to fit around the column. This approach can result in a poorly installed flashing that is not watertight and leads to water infiltration into the wall system (Figure 9).

In order to direct water to the exterior, metal sill pans should have properly sealed metal end and back dams. Sealant that is applied in an attempt to create an end dam in the field can debond from its substrate (Figure 10) or can be damaged during the subsequent windowsill component installation.

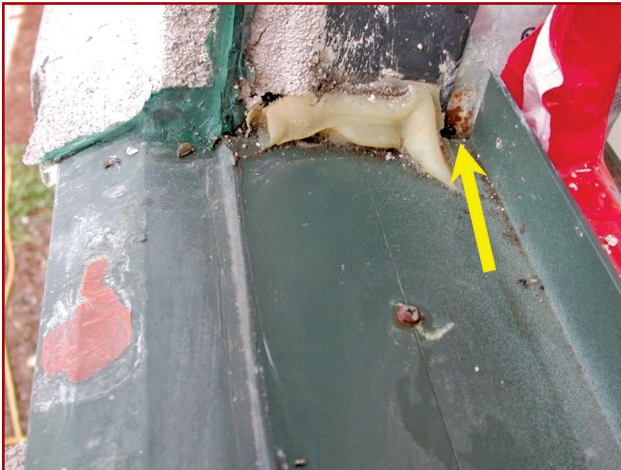


Figure 10 – Debonded sealant end dam. Note sealant does not continue to the back dam interface (arrow).

Sill Flashing Penetrations

Whether the flashing located directly beneath the windowsill component is a sheet metal pan, a window manufacturer's standard sill, or a high-performance extruded aluminum sill, fasteners are frequently used by the window installer to fasten the sill flashing to the substrate. These sill fasteners are located in the horizontal leg of the flashing, where they can be exposed to water that collects on the flashing. While the heads of the sill fasteners can be sealed over or encapsulated with sealant, the penetration may still remain susceptible to leakage.

In sheet metal pan installations, screw-type fasteners typically compress the flashing at the fastener head, resulting in a depression in the flashing at the penetration. The dab of sealant that is often used to encapsulate the fastener head may not fully seal the fastener penetration watertight, especially if the sealant does not adequately bond to the surface of the metal pan (Figure

Figure 9 – Deficiencies in pan flashing at tube steel column obstruction.

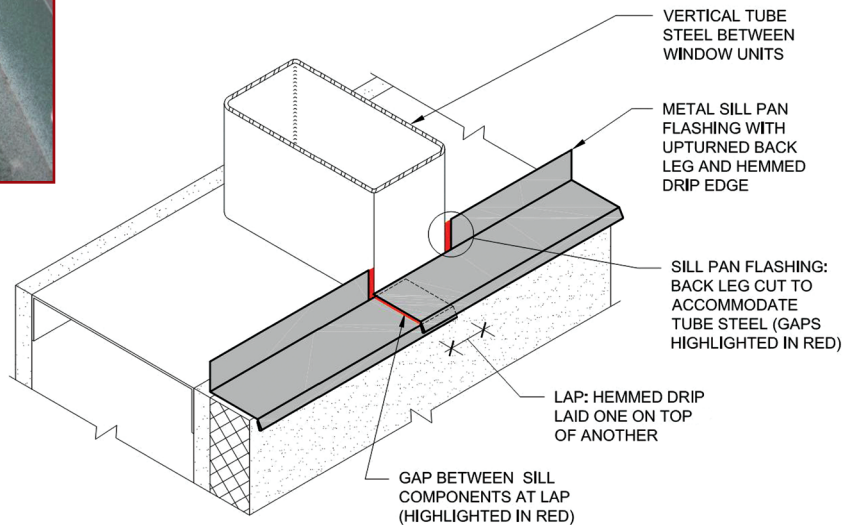




Figure 11 – Sealant debonded from fastener head at metal pan.

11) or if the sealant is damaged by the subsequent installation of the windowsill component. Inspection openings in the interior of the wall may reveal that water leakage occurs at these fastener penetrations.

After the sheet metal pan is installed, the extruded aluminum windowsill component is set on top of the sill pan flashing. In many applications, anchors are then drilled through both the extruded aluminum windowsill component and metal pan beneath. This type of installation can be problematic, as the penetration through the sill pan cannot be adequately sealed, if at all. Sometimes, in an attempt to seal the anchor penetration, a practice known as a “blind” sealant application is performed. In a blind sealant application, a hole is drilled

in the extruded aluminum sill component, sealant is pumped into the hole, and the anchor is installed. The head of the anchor is commonly located within the glazing pocket of the extruded aluminum windowsill component. While it can be encapsulated with sealant, the penetration in the pan is unlikely to be sealed watertight.

In a similar manner, extruded aluminum subsills fabricated by window manufacturers are generally detailed to be penetrated by windowsill component anchors installed through the horizontal portion of the subsill. Often these anchors are placed in the “wet” area of the subsill, which is the area where water that penetrates the window system can collect prior to being directed to the exterior. Again,

while the heads of the exposed anchors can be encapsulated in sealant, the penetration of a subsill component that is in the drainage area of the subsill can still lead to water leakage into the building interior (Figure 12).

End Dams

Extruded aluminum subsills fabricated by window manufacturers have various methods for attachment and sealing of metal end dams. While these methods can vary from manufacturer to manufacturer, they typically include either sealant or foam gaskets at the interface of the end dam and subsill termination. The sealant or gasket is generally installed in the field, and foam

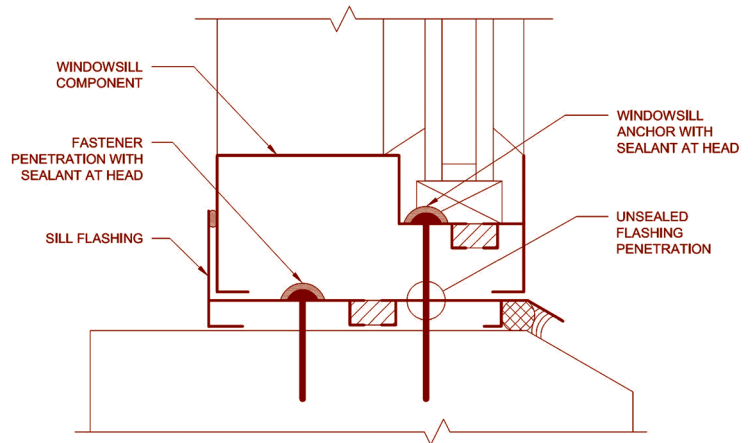


Figure 12 – Unsealed penetration at sill flashing.



Figure 13 – Damaged foam gasket and gap between back dam and end dam.



Figure 14 – Gap between top of end dam and window jamb.

gaskets are often damaged during the end dam installation process. In addition, the back-dam-to-end-dam transition is often not fully sealed by the gasket, due to lack of compression at the top portion of the end dam (Figure 13). Typically, the end dams are held in place at their bottom edge only, by screw fasteners that engage raceways at select points in the underside of the subsill. These fasteners do not provide adequate compression of the foam gasket.

If the end dam is not sealed watertight to the subsill, water leakage can occur. At the inside surface of the subsill, a sealant fillet bead is often added to the end-dam-to-sub sill transition. This sealant has to carefully follow the profile of the extruded subsill, including the thermal break, and along the vertical edge of the back-dam-to-end-dam transition. The end dam should be constructed at the same height as the back dam, which is determined by the window system's water leakage design performance criteria. End dams that are too high can affect end dam constructability. The end dam may be too flexible and too easily bent, leaving gaps where it cannot be fitted tight against the jamb (Figure 14). This detail is detrimental to the constructability of the perimeter sealant joint installation between the window frame and substrate. End dams should be constructed so that they do not preclude proper perimeter sealant joint installation.

For a more robust installation, consideration can be given to shop-welding end dams onto the subsill ends. An advantage to this approach is that the subsill can be properly cleaned of aluminum filings and debris in a contractor's shop and the end dam installation performed under controlled shop conditions. This also allows the end dams and back dam to be welded watertight. If needed, sealant can also be applied at the end-dam-to-sub sill transition and, after the sealant is allowed to cure properly, the assembly can be water-tested. Although this construction method will cost more to fabricate, it provides a more robust end dam that is not easily damaged during window installation.

Subsill Anchorage Considerations

Depending on the type of curb or wall construction to which the window system is being anchored, windowsill anchorage options can be evaluated based on the substrate's susceptibility to water leakage and subsequent potential damage. For instance,

in wood- or metal-framed wall construction, horizontal anchor penetrations that allow water leakage to the substrate can result in deterioration and damage. Alternatively, sill anchorage into a sound concrete substrate under similar installation practices is less likely to result in uncontrolled water infiltration leading to damage to the substrate or other finish materials.

Where there is a high susceptibility of water damage to substrate materials, consideration should be given to installation of windowsill anchorage that does not pene-

trate through the sill pan and extruded subsill assembly. Consideration can be given to design and installation of metal angles, brackets, or clips that attach through the vertical surfaces of the window components. These fabrications should be of the same metal as the window system, or have a separator if the metals are not compatible to help prevent galvanic corrosion.

As an example, metal angles can be used, with the horizontal leg anchored to the structural substrate within the window opening, and the vertical leg fastened to the

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Figure 15 – Metal angle used to anchor through vertical surface of window frame.



Figure 16 – Brackets used to anchor window frame to substrate.

window frame (Figure 15). In some cases, where the frame of the window is flush with the interior of the framing of the wall or curb that supports the window, brackets can be used that anchor to the vertical surfaces of the window frame and the substrate (Figure 16). In all cases, it is important that the fasteners through the vertical leg of the subsill or metal pan are located $\frac{3}{4}$ to 1 in. above the horizontal sill components or higher, depending on the water-resistance rating of the window, and that the fastener heads are fully encapsulated with sealant. If these fasteners are placed too low, water leakage can occur at these penetrations while water builds up in the frame.

Concrete Substrates

When attaching window systems to concrete substrates, there is often more flexibility in the methods that can be used to create unique sill flashings for window systems. When replacing windows in a reinforced concrete exterior wall, a sill flashing system can be created in the field, starting with the installation of a metal angle that forms the back dam for the flashing system. The horizontal leg of the angle can be set in a butyl sealant and anchored to the concrete substrate. A fluid-applied waterproofing membrane can then be installed over the horizontal surface of the angle and fastener heads. The fluid-applied waterproofing membrane can also be used at the jamb locations of the concrete substrate to form a complete and watertight sill flashing system (Figures 17 and 18). Since the substrate is

reinforced concrete and the waterproofing application is a fully bonded system, the sill components of the window system can be penetrated with vertical fasteners as part of the bonded membrane application.

Another approach in either new or existing concrete construction is to create a raised back ledge in the sill of the concrete substrate. This approach utilizes the concrete substrate to create the back dam required for the window flashing system. The height of the back dam should conform to the required leakage performance criteria

of the window system. In this type of construction, the concrete substrate directly underneath the windowsill is made waterproof by utilizing a fluid-applied waterproofing membrane system.

CASE STUDIES

Two case studies are presented herein where retrofit sill flashing and supplemental anchorage design were integral parts of the window system replacement. These concepts can also be utilized on new construction projects, affording the design team

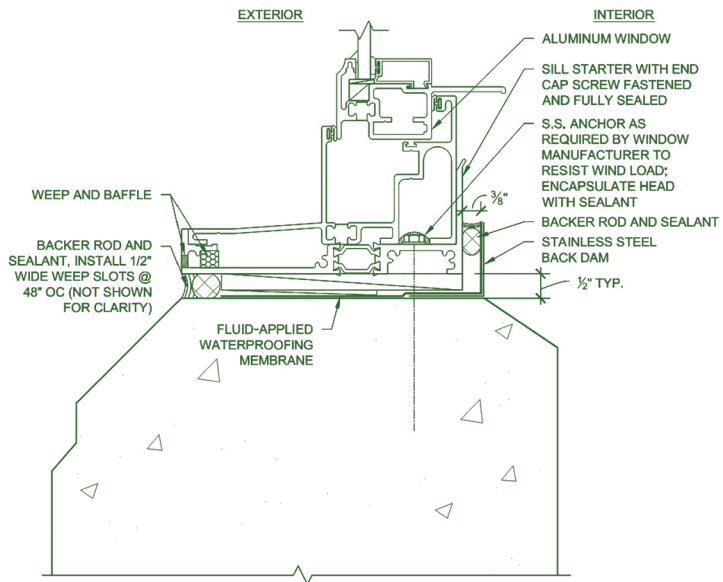


Figure 17 – Field-constructed sill flashing system on concrete substrate.

more flexibility in the design process, as substrates and window flashing design can be better coordinated for specific conditions. These case studies presented include the Public Safety Building in Eugene, Oregon, and the Sitka Sound Science Center in Sitka, Alaska.

Public Safety Building

The Public Safety Building is a 1970s reinforced concrete-framed two-story municipal building located in downtown Eugene, Oregon. After several attempts to address ongoing water leakage originating at the second-floor balconies, a balcony waterproofing and window replacement project was undertaken in 2012. As part of the project, the original single-pane wood-framed window system was replaced with a new aluminum-framed, thermally broken window system with insulating glass units. The new waterproofing system consisted of a reinforced hot-applied rubberized membrane system applied to the top of the structural concrete slab, protection layer, drainage mat, insulation, and pedestal paver system. The balcony was separated from the building interior by the original wood window system that sat on top of a wood curb.

As with many retrofit projects, existing conditions created unique transitions. In this case, stepped concrete exterior walls that supported the new window system required integration with the new waterproofing and paver system. A specialized window flashing design was developed that could be integrated into the waterproofing

19). The existing wood curb that separated the balcony from the building interior was decayed and, due to the construction schedule, had to be replaced with a new wood-framed curb in lieu of concrete. Anchoring the windowsill vertically into the wood blocking was not an option, as potential water leakage could result in long-term decay to the wood blocking. Therefore, using a metal angle as a back dam installed on the wood curb, the waterproofing membrane

membrane system.

Adjacent to waterproofing membrane system applications, storefront-type window systems can be installed on curbs, and the window-sill flashing can be integrated with the waterproofing membrane system. The approach on this project was to create a monolithic waterproofing membrane installation integrated with the aluminum-framed window system (Figure

system was applied onto the vertical and horizontal surfaces of the wood curb (Figure 20). The metal back dam also functioned as a termination point for the waterproofing membrane, which was located underneath the window system. This assembly allowed for a monolithic waterproofing installation that is integrated with the window system and also functions as a watertight sill flashing.

A mock-up performed in the field helped determine the proper coordination of the various waterproofing, sheet metal, and window installation subcontractors' work sequence. To anchor the new window system and manufacturer's high-performance sill system, metal brackets were designed to anchor the sill component of the window system to the wood curb (Figure 20). New wood trim was used at the interior to cover over the metal brackets. The new design was successfully installed and resulted in a watertight installation, as the waterproofing membrane system was applied in a monolithic application and also formed a watertight sill flashing directly beneath the new window system.

Sitka Sound Science Center

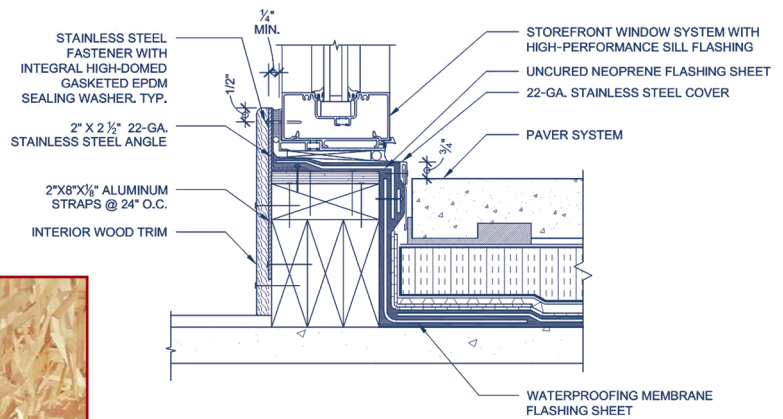
Constructed in 1929, the Sage Memorial Building is located on the waterfront of Crescent Bay within the National Historic Landmark district of the former Sheldon



Figure 18 – Field-constructed, fully bonded waterproofing membrane sill flashing system on concrete substrate.

Figure 19 – Fully bonded waterproofing membrane used to form the sill flashing system.

Figure 20 – Fully bonded waterproofing membrane application at window curb. Arrows indicate metal bracket back dam. Note: protection layer is present on top of waterproofing membrane.



Jackson College campus in Sitka, Alaska. Today, the nonprofit Sitka Sound Science Center owns and operates the Sage Memorial Building. The center is dedicated to increasing understanding and awareness of terrestrial and aquatic ecosystems of Alaska through education and research. The building houses a working fish hatchery and aquarium.

The building is two stories in height, and the façade is constructed of cast-in-place reinforced concrete with punched window openings. As part of the façade restoration, the existing but nonoriginal window systems were replaced. Due to the varying levels of concrete deterioration of the sills, concrete sill repair options included localized patching as well as complete sill removal and reconstruction. The sills were redesigned to better accommodate the new windows and manage water, while still matching the historical exterior profile and appearance. A raised horizontal ledge was created at the back of the existing windowsills by cutting and chipping out a portion of the existing

photographs were used to help select new windows that would aesthetically replicate the historical character of the original windows. The new thermally broken, aluminum-framed windows incorporated insulating glass units, and the window manufacturer's sill flashing components were included in the design.

The concrete windowsill was flashed using a fluid-applied waterproofing membrane system prior to window installation

concrete. Where new concrete windowsills were cast, the recessed ledge was part of the reconstruction, including slope for drainage of the exterior exposed portion of the concrete sill.

(Figure 21). Several mock-ups were performed to establish best practices for the fluid-applied membrane installation. Initial mock-ups revealed areas where the membrane was applied too thinly, not applied over the full height of the back dam, and had voids at the inside corners (Figure 22).

The recess in the concrete sill provided the necessary back and end dams for the sill waterproofing system. Since the waterproofing membrane was fully bonded to the concrete, the new window could be anchored through the horizontal portion of the windowsill component, penetrating through the fluid-applied waterproofing. Although not necessarily completely self-healing, the fluid-applied waterproofing is fully



Figure 22 – Voids found in waterproofing mock-up at inside corners (arrow).

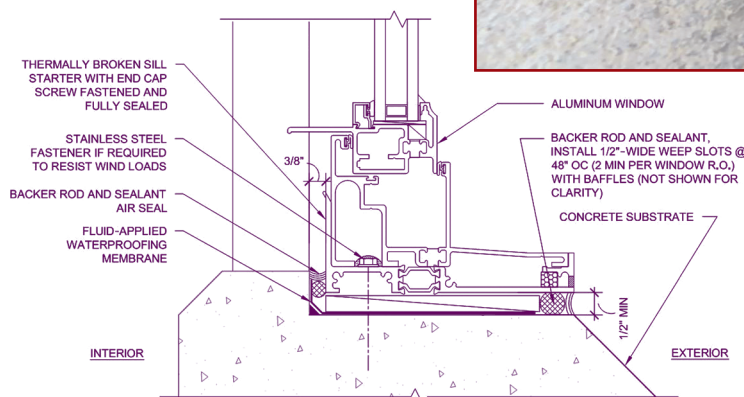


Figure 21 – Fully bonded waterproofing membrane flashing system.

bonded and prevents water from migrating outward from the fastener penetration. Two new windows were installed as a mock-up and water tested in order to verify window and flashing performance, prior to installation throughout the project.


CONCLUSIONS

The successful performance of a window system is the result of proper window selection as required for building use, performance, and local weather conditions, as well as successful watertight flashing design, installation of components, and coordination with the work of other building trades.

Mock-ups are an integral and important part of setting the standard for acceptable window and flashing installation on a project. It is recommended that mock-ups be performed on site, in actual construction conditions and wall openings. It is recommended that mock-ups be performed prior to materials being ordered for the entire project, since the purpose of the mock-up is to confirm the constructability of the systems as designed using the specified materials, and to verify that the right materials and sizes are ordered and delivered. Air and water infiltration testing can be performed on the completed mock-up to verify the performance of the entire assembly. To evaluate the expertise of the installers, it is recommended that the mock-ups be performed by the same installers that will be performing the work on the project. Mock-ups also provide an opportunity for manufacturers to verify compatibility of component materials, confirm the warranty, and provide additional recommendations. The mock-up

period also allows time for the project team to refine details as needed prior to the start of work.

Design of flashings can be a unique and challenging aspect of window design. Windowsill anchorage through wood or light-gauge metal-framed curbs and walls should be avoided, as water leakage can cause structural decay and deterioration of wall materials. For these substrates, supplemental fastening systems should be studied. When concrete substrates provide support for window systems, there are more

flashing options available, and anchoring through the horizontal leg of the sill component and flashing may not be detrimental to the water infiltration resistance of the window assembly. The publication ASTM E2112, *Standard Practice for Installation of Exterior Windows, Doors and Skylights*, is a resource for additional window flashing information. 

This paper was previously presented at the RCI Building Envelope Technology Symposium in Houston, TX, in October 2016.



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Inventor of Hard Hat Inducted Into National Inventors' Hall of Fame

Edward W. Bullard, inventor of the hard hat, will be inducted (posthumously) into the 2020 class of the National Inventors' Hall of Fame. Originally designed for miners, hard hats are now used by millions of people in an array of industries.

Originally named the hard-boiled hat because of the steam used in its manufacture, Bullard's hat was first made from steamed canvas, glue, leather, and black paint and was first produced a century ago, in 1919. Construction sites in the 1930s started requiring workers to wear head protection. In the 1970s, the Occupational Safety and Health Administration (OSHA) first required the use of hard hats on worksites where there is a potential for injury to the head from falling objects.

