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TESTING

Dimension Stone Testing and Evaluation: The What, Why, When, and Where

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20

Table of contents

DEPARTMENTS

FEATURES

Frustration with Fenestrations

By Karl A. Schaack, PE, RRC

CURTAINWALL, STOREFRONT, AND other window systems are installed as building enclosures comprised of glass and some type of metal frame (most commonly aluminum) or wood and vinyl intended to protect the building interior from the elements. Curtainwall and storefront systems are typically designed to carry only their own weight. The exterior wall transfers wind loads to the main building structure, also known as the main wind-force-resisting system, at connection points at floors or columns of the building. This type of system is designed to resist air and water infiltration, movement created by wind and seismic forces, its own weight, and thermal expansion and contraction.

Approaches to the installation of curtainwall systems and storefront systems in strip, ribbon, multispan, and/or punched-opening situations vary significantly, as installation teams must cope with changes to the building code (such as requirements for continuous insulation on the exterior face of walls), the introduction of various and new building cladding systems, and designers' efforts to create commercial buildings with distinctive aesthetics. The ever-evolving design expectations have contributed to frequently observed technical issues related to window systems installed on small- and large-scale commercial, institutional, multifamily, and similar residential-style construction projects. Even traditional installations may encounter problems.

I have been performing quality assurance observations, water-spray testing, and chamber testing of window systems for the past 15-plus years and have taken part in subsequent "forensic" investigations to determine the source(s) of water infiltration during testing. Repetitive conditions have been observed that have been found to be primary sources of leakage and substandard performance of the subject systems. While there are multiple and varied systems and conditions, there are "top 10" conditions that continue to be observed and documented even in today's construction, which might be perceived as a more knowledgeable and technically advanced industry trade. The conditions described in this article are considered to be common and pervasive in this industry. These conditions are highlighted with the desire to identify obvious and potential issues and options for corrective and/or preventative action(s).

SEALANT CONTINUITY

Maintaining continuity of primary sealant at perimeters of "traditional" curtainwall frames is a common issue. Curtainwall frames are typically secured to the structure with either F-shaped or T-shaped anchors where the flange or base plate of the anchor is secured to the structure at sill and head conditions. The primary sealant joint is created by the installation of backer rod and elastomeric joint sealant applied in a conventional hourglass joint profile between the window frame and substrate. Horizontal flanges/plates of anchors commonly extend into this joint (**Fig. 1**).

Plates of anchors can impede the insertion of backer rod and affect the continuity of the hourglass configuration of the primary sealant joint and the bond area of the curtainwall frame at ends of vertical mullions. Consequently, to continue and maintain the primary sealant joint, the profile has to be altered to more resemble a fillet-shaped profile that is applied along the edge of the anchor plate. Note that in this type of application, a bond breaker tape should be applied over the edge of the anchor plate to prevent three-sided adhesion of the sealant. Traditionally, there are two anchors located at each edge of the opening or vertical mullion and any intermediate vertical mullions. The profile of the sealant can change multiple times depending on the size of the opening and therefore can become tricky to maintain a weathertight seal. During chamber testing of these systems, leakage has been commonly observed at voids in the sealant that occurs at interfaces of the different sealant profiles.

RANGE OF EXPECTED MOVEMENT

As with all types of fenestrations, wind load is an important structural consideration for curtainwall

Figure 1. *Base plate of anchor extending into joint between frame and substrate.*

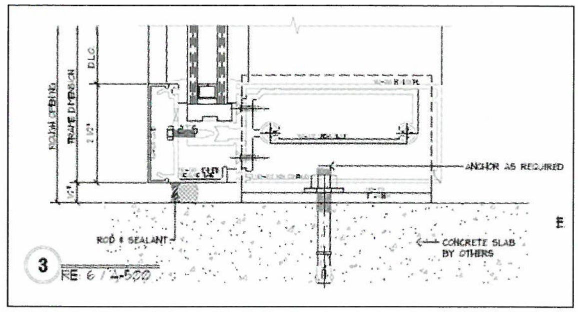


Figure 2. *Curtainwall sill detail.*

systems. The more deflection occurring in the frames due to the induced wind loads, the more stress is placed on the assembly and greater likelihood of system failure and/or glass breakage. There are multiple factors to consider when designing a curtainwall system to accommodate expected movement, including thermal expansion and contraction, movement due to wind load and gravitational forces, and movement caused by deformation or displacement of the building. Movement must be accommodated to limit stress on glass, framing, and anchors, and without excessively reducing the frame's "bite" or capture of the glass.

Curtainwall installations commonly do not take into account the thickness (typically ¼ in. [6 mm]) of the base plates of F or T anchors. Because the base of the anchor extends beyond the end of the horizontal mullion, when the frame experiences anticipated vertical movement, it can come in contact with the anchor plate, consequently restricting full movement at wind-load anchors at the head of the opening. Joints between frames and substrates presented on shop drawings for curtainwall systems typically do not depict or accommodate the thickness of anchor plates in the cross-section profile, and total allowable movement often can be missed. As depicted in **Fig. 2**, a ½ in. (13 mm) wide joint is noted between frame and concrete slab. Assuming a ¼ in. thick anchor plate and any variations in the substrate, ¼ in. or less is available to allow movement.

When curtainwalls span multiple floors, they are anchored at floor lines, typically with some type of "clip" (such as a steel angle or bent plate). This anchorage can happen at a concrete slab edge or at a structural member such as a steel I-beam. To accommodate expansion of the curtainwall frame, the attachment points at these clips used to resist wind loads typically include vertically oriented slotted holes. If the holes with the clips are slotted, a through-bolt is allowed to experience vertical movement in either direction while still resisting wind loads (**Fig. 3**). Additionally, the floors/structure can move independently of the window system.

During installation, bolts have sometimes been observed to be positioned either at the top or bottom of the slotted holes (**Fig. 4**), consequently

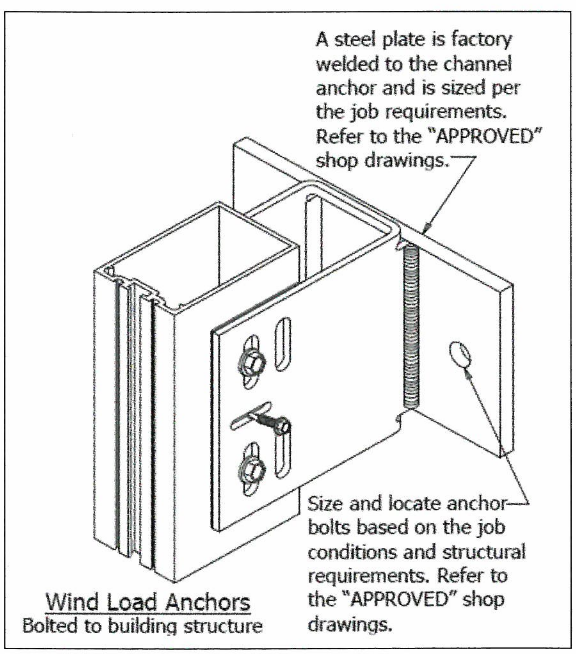


Figure 3. *Diagram of wind load anchor with slotted holes. Diagram adapted from reference 1.*

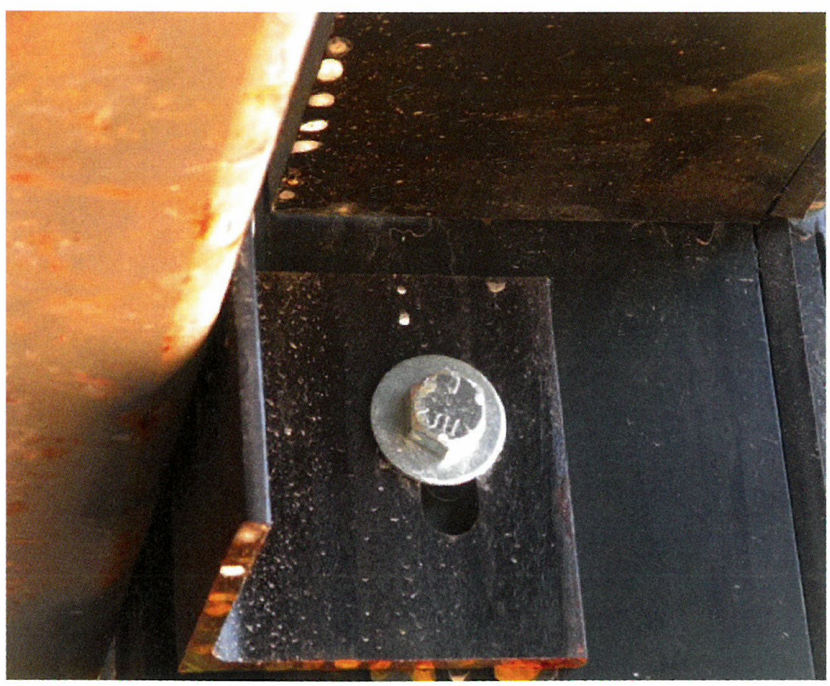
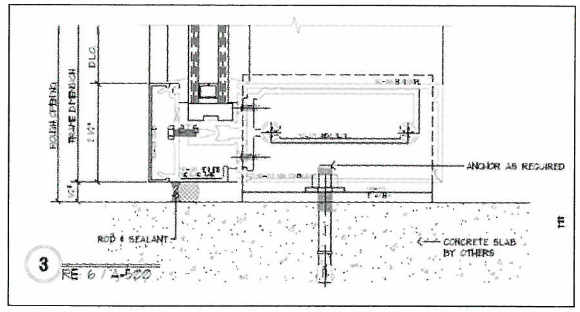


Figure 4. *Anchor at top of slotted hole in wind load anchor.*

Figure 1. *Base plate of anchor extending into joint between frame and substrate.*



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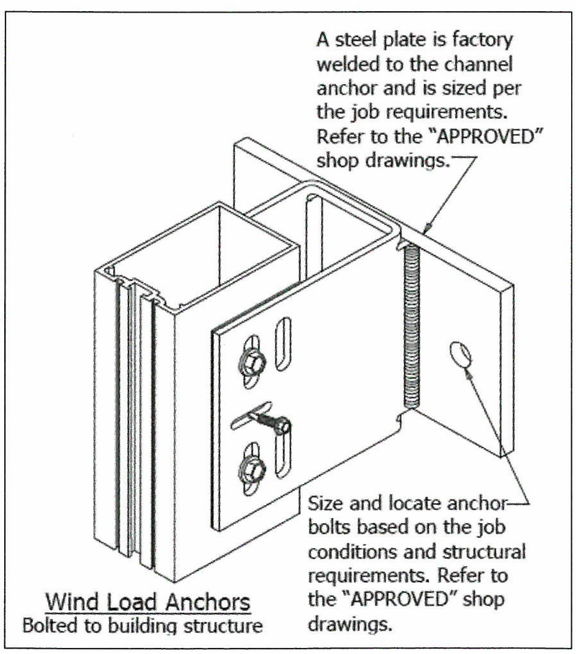

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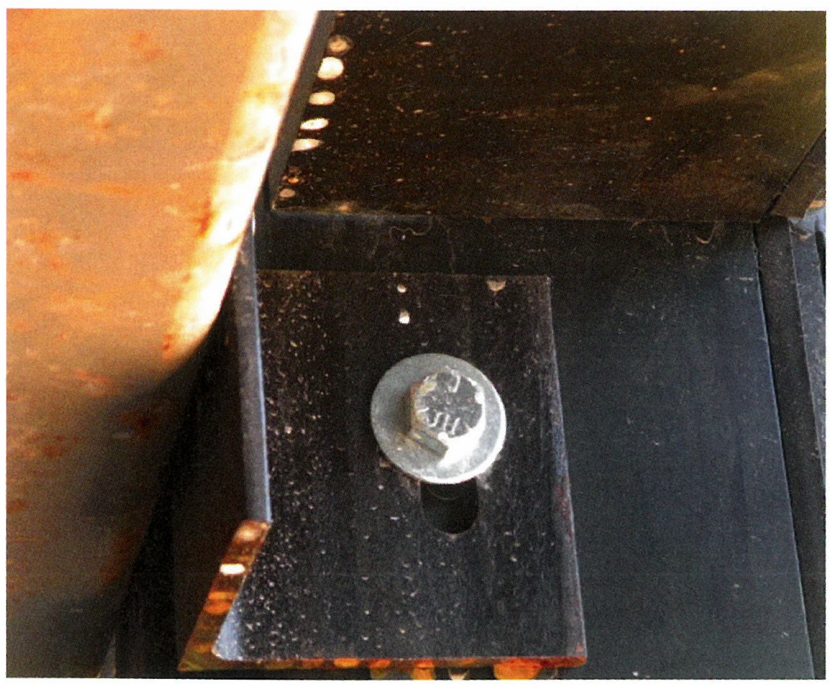

Figure 4. *Anchor at top of slotted hole in wind load anchor.*

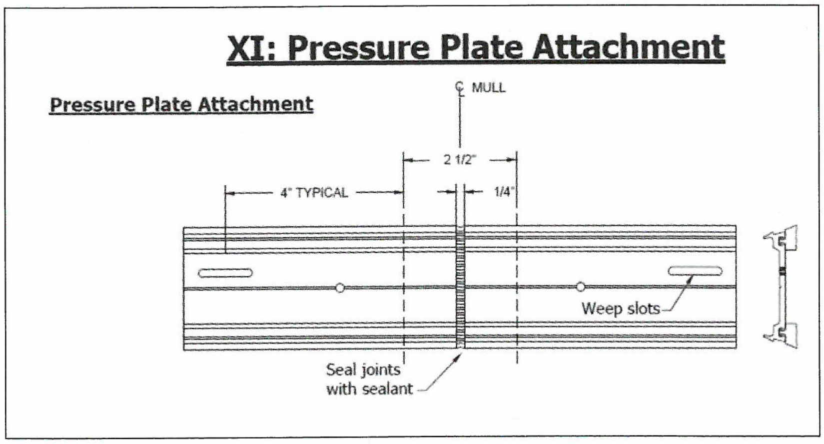

Figure 5. *Diagram of typical curtainwall pressure plate. Diagram adapted from reference 1.*

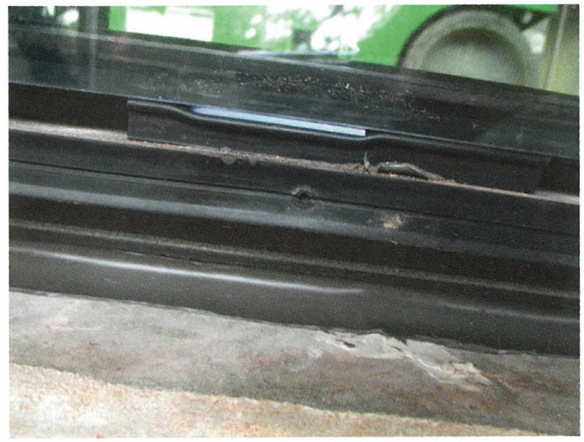

Figure 6. *Plastic shim between setting block and glass lite.*

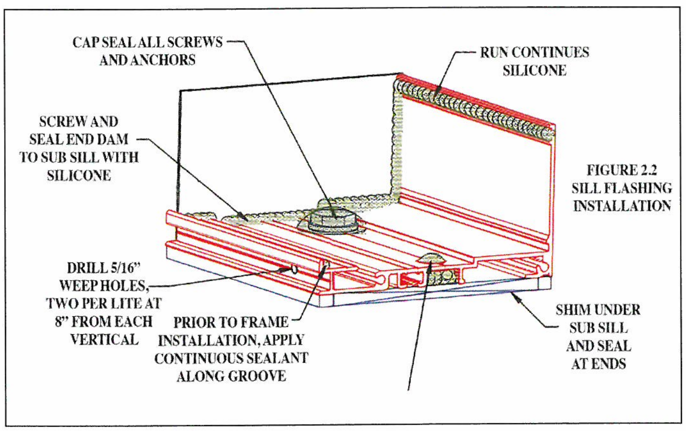

Figure 7. *Diagram of typical sealant application on sill receiver. Diagram adapted from reference 3.*

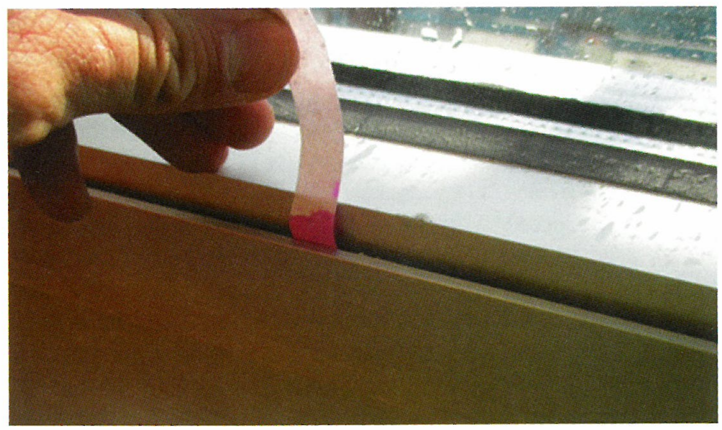

Figure 8. *Moisture detected at back leg of sill receiver during field spray leakage test.*

not allowing full range of movement, which could result in excessive stresses on the system. In most cases, the bolts should be positioned near the middle of the slot to accommodate future movement.

PRESSURE BARS

A traditional curtainwall system uses pressure bars/plates to secure glass lites to frames. Pressure bars are secured with screws installed through predrilled holes. To provide suitable compression of the glass to the gaskets and against the frame, the screws should be installed at the manufacturer's recommended torque (typically, 25 to 100 in.-lb [2.8 to 11.3 N-m]). During installation, technicians commonly use battery-powered drills to install these screws, and after continual use, battery power becomes diminished, and the screws most likely will not be installed with proper torque to achieve adequate compression. During installation, the installed screws should be checked periodically and monitored with an appropriate digital torque wrench. If the pressure bars are not secured appropriately, proper compression will not be achieved between gasket and frame/glass, and water leakage will likely be experienced, especially during chamber testing and in service.

Proper positioning/placement of the pressure bars in relation to the location of the weep holes in the bar is also important (**Fig. 5**). Pressure bars can be mistakenly installed "upside down," which makes weep holes improperly located below the centerline of the pressure bar, resulting in excessive accumulation of water and subsequent leakage into the interior.

SETTING BLOCKS

Setting blocks are installed under glass lites when the glass lites are placed within frames. Proper size, hardness, and placement of setting blocks within glazing pocket are essential to any quality glazing installation. This ensures full bearing of the glass while allowing water passage to the weep system. Common criteria for setting blocks are as follows:[2]

- Setting blocks should be made of neoprene, ethylene propylene diene terpolymer (EPDM), silicone, or another compatible elastomeric material, and they should have a Shore A Scale hardness of 85 ± 5.
- A minimum of two identical setting blocks should be used with each glass lite installation. The location of these setting blocks depends on the size of the lite, with the preferred location being equidistant from the centerline of the glass at the quarter points of the sill, but not less than 6 in. (150 mm) from the corner edge.
- The width of the setting block should be at least ⅛ in. (3 mm) wider than the glass thickness and 1⁄16 in. (1.5 mm) less than the full glazing channel width to allow for the passage of water.
- The length of each block should be sized to provide 0.1 in. (2.5 mm) of coverage per square foot of glass area, with a minimum length of 4 in. (100 mm).
- The height of the setting block should be adequate to provide the recommended glass bite and minimum glass-edge clearance.

Figure 9. *Photos of F and T anchors.*

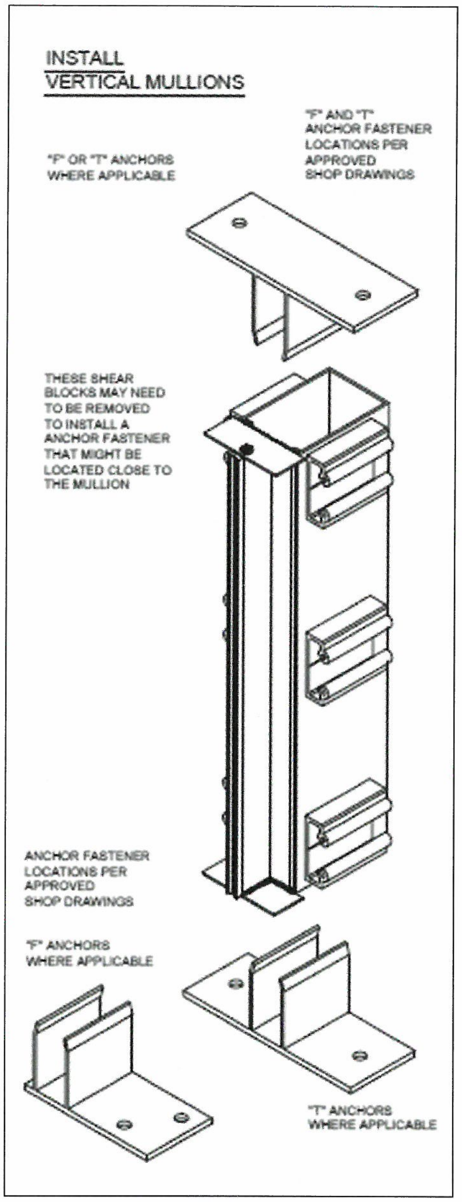

Figure 10. *Diagram of F and T anchors. Diagram adapted from reference 4.*

- Adequate edge and face clearances are essential to allow cushioning of an insulated glass unit (IGU) within the framing system and to provide pressure to support the edge of an IGU under deflection. If adequate clearances are not present, glass breakage may result from glass-to-frame contact. Improper materials are sometimes used for setting blocks (improper material and size), such as sections of hard plastic shims, which have been frequently observed to be used to support glass (**Fig. 6**). The typical plastic horseshoe-shaped shim has a Shore A Scale hardness greater than 100, which exceeds industry recommendations.

STOREFRONT SILL PANS OR RECEIVERS

Typical storefront systems are composed of a sill receiver that is secured to the substrate. The common profile of the sill receiver is L-shaped, with a horizontal leg and a vertical back leg. After the sill receiver is secured in place, the frame is set into the sill receiver. In addition to fastener heads and end dams, a bead of sealant is to be applied between the vertical back leg and storefront frame to achieve watertight performance (**Fig. 7**).

This sealant creates a seal to prevent water intrusion into the assembly when the assembly is subjected to rainwater with a pressure differential. This sealant has been observed to be omitted or improperly applied on a regular basis and can readily result in water penetration during water-spray testing (**Fig. 8**).

F AND T ANCHORS

F and T anchors are used to secure frames of curtainwall systems to the structure at heads and sills. F and T anchors are shaped like the letters they represent (**Fig. 9**).

The stem of the "T" and the legs of the "F" extend up and slide into the open ends of the vertical mullions, and the remainder of the clip or plate is intended to bear completely on the substrate, with fasteners installed through pre-drilled holes in the plate and into the substrate. F anchors have only one anchoring leg and are installed at jambs, while T anchors have two anchoring legs and are installed at intermediate vertical mullions (**Fig. 10**).

During installation of window assemblies into rough openings, installers sometimes place plastic horseshoe-shaped shims under these anchors in an apparent attempt to make up tolerances in openings to achieve the desired installation. Common plastic horseshoe-shaped shims are often placed in stacked formation between elements and substrate to fill gaps/spaces (**Fig. 11**). However, the placement of shims between the base plates of these anchors/clips and the substrate can create improper load distribution, resulting in frame distortion and possible glass breakage.

GASKETS

EPDM rubber or silicone gaskets are installed between glass lites and aluminum frames to hold the glass in place and to function as a weather seal. The gaskets should typically be ⅛ to ¼ in. (3 to 6 mm) per foot (300 mm) of horizontal dimension longer than daylight opening of frame. For example, for a gasket for a 4 ft (1.2 m) long window opening, the length of the gasket would need to be ½ to 1 in. (13 to 25 mm) longer than the opening. Additionally, the ends of glazing gaskets should be cut on an angle to form a mitered corner and then properly cleaned, and silicone sealant applied between abutting ends of the gaskets (**Fig. 12**).

If the gaskets are not installed at the proper length or are stretched during installation, shrinkage of the rubber gaskets after installation would most likely result in gaps occurring between the ends of the gaskets located at the corners of the frames (**Fig. 13**). These gaps can result in excessive amounts of water entering

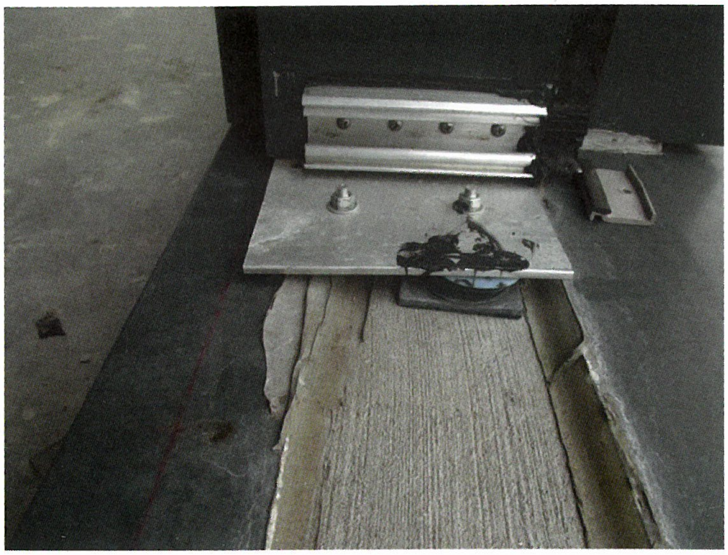

Figure 11. *Photo of plastic shims placed under F anchor.*

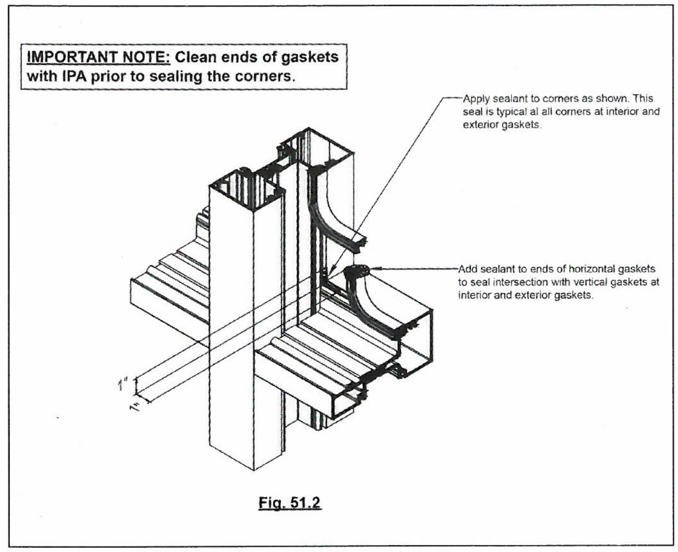

Figure 12. *Diagram of sealant application at ends of gaskets. Diagram adapted from reference 5.*

Figure 13. *Photo of gap between ends of abutting gaskets at interface of vertical and horizontal mullions.*

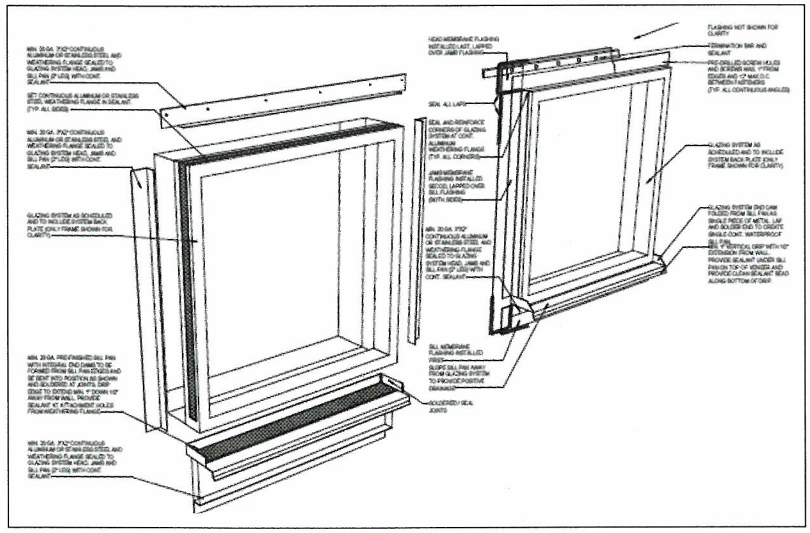

Figure 14. *Diagram of sheet metal weathering flange at window opening.*

the frame and overcoming the weep system or allowing an introduction and accumulation of dirt within the frame that can possibly impact proper weeping, causing water infiltration into the building interior.

PERIMETER TRIM EXTENSIONS

Current enclosure designs often depict window frames projecting out from openings in a wall to integrate with the selected cladding system/finish. This practice results in the primary sealant joint being located beyond or "out-board" of the opening in the wall. In this detail, a sheet metal L-shaped angle or weathering flange is commonly installed around the perimeter of the opening to provide a substrate beyond the opening to receive the sealant (**Fig. 14**). The sheet metal angle is typically installed on top of the weather-resistant barrier (WRB) that is applied around the opening and secured to the framing or substrate around the opening. Then the flanges are stripped into the WRB, typically with a self-adhering transition membrane.

One concern with this type of detail is achieving a proper watertight seal at laps and corners of the sheet metal angles. The use of pop rivets and sealant sandwiched in laps of sheet metal may not provide an adequate seal when the subject area is tested with a spray wand or when the window system is tested in a pressure test chamber (**Fig. 15**). Using stainless steel sheet metal for the weathering flange, securing laps with pop rivets, and soldering the joints can result in watertight joints. However, experience has revealed that highly skilled technicians are required to properly achieve an effective end result.

An additional area of concern is the proper attachment of the flange. The use of flat-/wafer-head and/or pancake-head screws is essential because it is quite difficult to adhere a self-adhering membrane over fasteners with protruding-style heads such as hex-head or bugle-head styles of screws. Bridging, loose areas, and/or fish mouths in the self-adhering membrane can result when the membrane is placed over large-head screws (**Fig. 16**). When nails are used to secure a flanged item to a wood substrate, the head should be driven flush to the

Figure 15. *Photo of sheet metal weathering flange corner lap.*

Figure 16. *Photo of fishmouth and loose area of self-adhering flashing applied over fastener head.*

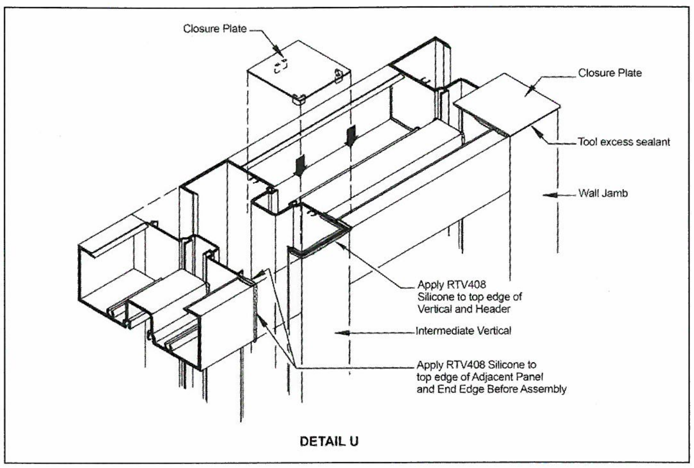

Figure 17. *Diagram of closure plate at end of vertical mullion. Diagram adapted from reference 6.*

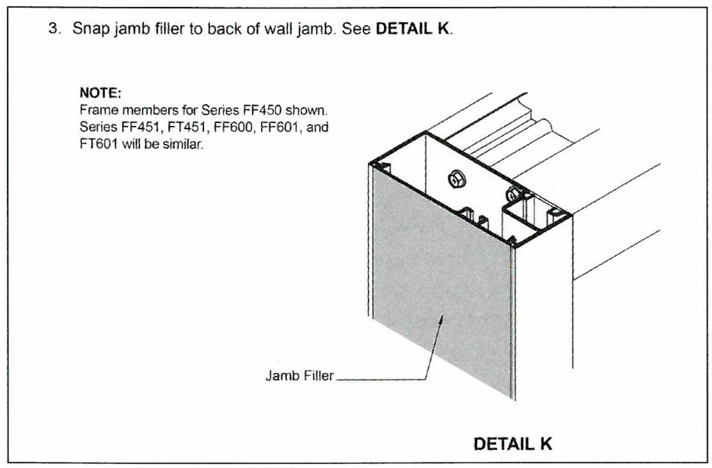

Figure 18. *Diagram of backer plate on vertical mullion. Diagram adapted from reference 6.*

frame to allow proper installation and adhesion of strip-in membrane.

FRAME CLOSURES/BACKER PLATES

Aluminum extrusions used to construct frames of window systems have open ends and backs when assembled to form a complete frame for a new window. The ends of vertical mullions that terminate at heads of sills are "open" and do not provide a suitable substrate dimension to receive backer rod and sealant. Consequently, a sheet metal cap/cover should be set in sealant on the ends of the frames to create a substrate to bond the sealant along the perimeter of the frame. (**Fig. 17**).

The profile of common aluminum extruded frames have open "backs." When placed within an opening in a wall, a proper sealant joint must be applied between the frame and substrate to achieve the desired weather-resistive performance. Because a framing member has an open back, an adequate substrate is not present to receive the backer rod and sealant. The width of the outer back leg is typically ¼ to ⅜ in. (6 to 9 mm), which does not provide ample surface area for receiving backer rod to achieve compression and provide backup for the sealant. Additionally, the surface area is not sufficient to obtain adequate surface "bite" area for the sealant. Backer plates should be installed on the extrusions to provide this important substrate (**Fig. 18**).

SEALANT INTERFACES

Although they are not an actual part of a curtainwall, storefront, or other type of window system, sealants installed in joints that occur between window frames and adjacent cladding are critical in maintaining watertight systems. Proper preparation of substrates before sealants are installed is important to achieve proper adhesion. Adjacent substrate materials vary significantly, with types including metal panels, brick masonry, exterior insulation and finish systems, precast concrete, and cut natural or cast stone, among many other materials. Many sealants are promoted as "primerless" or "may require primer," and the sealant manufacturer may not require application of primer on substrates for proper sealant adhesion. Not only is primer recommended on substrates to achieve the optimum performance, but proper cleaning of the joint substates is also important. Utilizing a two-cloth cleaning method is the best process to achieve a clean joint due to amount of dirt, dust, etc. that can accumulate on substrates on a construction site. The two-cloth cleaning method consists of an initial wipe with solvent on one cloth, followed by a second wipe with a dry cloth to lift and remove solvent and contaminants that may be suspended in the solvent.

Another issue can be obtaining and achieving joint dimensions between frames and adjoining substrate materials that allow for the proper sealant joint size and profile. Window systems and other materials are installed by multiple trades, and they are typically field measured and fabricated/installed within certain tolerances. However, improper joint sizing is commonly encountered.

In conjunction with achieving proper joint sizes, maintaining sealant compatibility is also critical. On many projects, the glazing contractor is given the responsibility for installing sealants around perimeters of frames, and silicone sealant is commonly used in this application. Sealants to be installed in joints in precast concrete and other similar claddings are often specified to be polyurethane. When the joints in the cladding intersect with the joints at the perimeters of windows, the sealants in these joints need to be compatible (**Fig. 19**). Silicone sealant is therefore recommended for each of these joints.

Figure 19. *Photo of sealant joints in wall panels intersecting joint around window frame.*

CONCLUSION

Although installation of window systems is considered to be somewhat of a high-tech industry with trained technicians and detailed installation manuals, we continue to encounter common issues associated with water infiltration that can be traced back to installation problems. Quality assurance implemented by the installation crew, or third-party reviewers, can be instrumental in achieving the optimum performance of the system.

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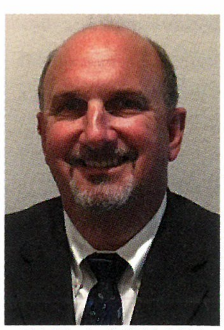

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