AN UNCONVENTIONAL APPROACH TO CURTAIN WALL REPAIR

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Many buildings built in the late 20th Century and early 21st Century included glass and metal curtain walls. Some of these buildings are approaching the age when deterioration of glazing gaskets and internal curtain wall seals can result in leaks. In other buildings, fading of exterior components, failure of insulated glass units and/or the need for improved energy efficiency is necessitating major rehabilitation of these curtain walls.

While many SWR Institute members routinely perform sealant repairs on such curtain wall systems, few have developed the expertise to perform complicated repairs that involve dismantlement or modifications to the system. To date, sealant repairs have provided an adequate short-term remedy to curtain wall issues. However, given the aging curtain wall systems in North America, more complicated repairs and modifications will be demanded by building owners.

This article will be presented in two parts with

the second installment being published in the Spring Issue of the *Applicator*. This first part will summarize the typical failure mechanisms in curtain wall systems, the conventional repair approaches, and a discussion of advantages and disadvantages of each repair approach. For a more detailed discussion of deterioration mechanisms in curtain wall systems, refer to SWR Institute's "A Practical Guide to Waterproofing Exterior Walls."

The second installment will be a case history involving unconventional repairs to a large commercial building curtain wall system. These unconventional repairs include retrofitting the curtain wall system with new custom-extruded external pressure bars and caps to address several issues, correcting displaced mullions and replacing mechanical louvers integrated into the curtain wall system. The repairs also included over-cladding the decorative metal cladding panels between curtain wall sections with a new system that incorporated an air and water-resistive barrier and a drainage plane.

DETERIORATION MECHANISMS IN GLAZED SYSTEMS

Typical deterioration mechanisms of curtain wall and window systems can be divided into the following four categories:

AESTHETICS DEGRADATION

The aesthetics of a curtain wall system can be adversely affected by long-term exposure to elements. Such degradation can consist of fading or peeling of metal frame finishes and staining of glass and metal components due to sealant plasticizer migration or etching of the glass and metal due to alkalinity of adjacent cementitious materials.

Fading of metal frame systems is directly related to the quality of finishes and exposure to UV. Peeling of metal finishes can be due to improper surface preparation during the original coating process or exposure to salts in service (such as areas of curtain walls in coastal environments, or those adjacent to walks where deicing salts are used).

Glass staining is sometimes referred to as "picture framing". This phenomenon has been well documented and is typically due to migration of plasticizers from older silicone sealants that may have been used as glazing, used in repairs, or used in adjacent joints. This phenomenon can also impact the metal framing components.

WATER AND AIR INFILTRATION ISSUES

Air and water infiltration issues are some of the most common problems with curtain wall systems. When manifested in recently installed curtain wall systems, they are typically indicative of installation or design issues. However, as properly designed and installed curtain wall systems approach twenty or more years in service, many of their internal seals and exterior weather seals deteriorate, resulting in air and/or water infiltration issues. Other factors such as deterioration of expansion joints can also lead to air and/or water infiltration problems.

GLAZING GASKETS

One of the most common deterioration mechanisms in curtain wall systems is the degradation of glazing gaskets. (Photo 1) Most curtain wall systems rely on pre-formed gaskets for a watertight seal between the glass or spandrel panels and metal components. These gaskets serve as

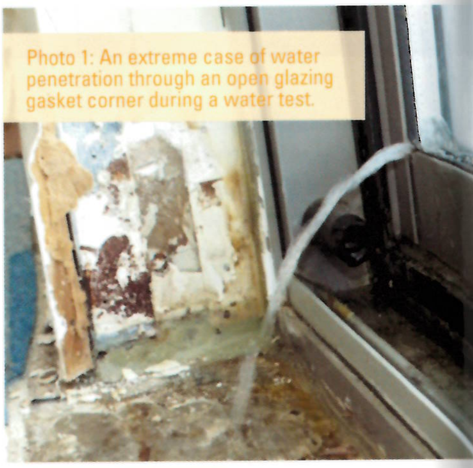


Photo 1: An extreme case of water penetration through an open glazing gasket corner during a water test.

Photo 2: Extensive shrinkage and deterioration of glazing gaskets.

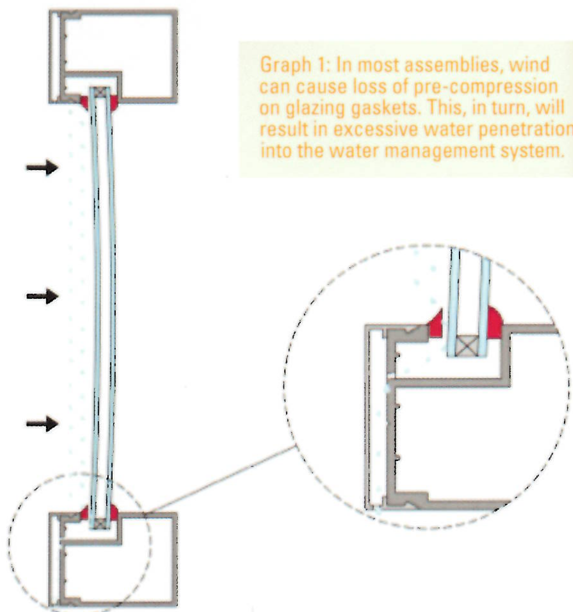
the primary seal against air and water infiltration. Glazing gaskets are made of various materials including neoprene, EPDM, silicone and other elastomeric materials. Gaskets are either molded or extruded. Extruded gaskets must be cut to length and jointed with adhesive at the mitered corners. In some cases, the corners are simply miter cut at the appropriate angle and not adhered. In other cases, the gaskets may be cut at ninety degree angles and simply butted against the gasket on the adjacent side of the glazing. Molded gaskets have integrated mitered corners with no seams and typically provide a better seal at the corners.

Inside set glass curtain wall systems typically incorporate a combination of a preset "bedding" gasket on the exterior and a "drive-in" wedge gasket on the interior. Outside set glass systems would have a "bedding" gasket on the interior and a "drive-in" wedge gasket on the exterior. Preset gaskets can typically not be removed and replaced easily, while drive-in wedge gaskets can.

Depending on gasket type, prolonged exposure to UV can result in hardening, shrinkage and crazing (cracking) of the gasket material. Gasket shrinkage can lead to loss of pre-compression. When combined with wind forces, the loss of pre-compression of gaskets can result in sufficient openings to form between the glass and the glazing gasket that allow water infiltration. (Graph 1) In some cases, gasket shrinkage is significant enough that the gaskets shrink away from glass corners resulting in loss of water tightness. Molded gaskets can pull out of their retaining grooves due to shrinkage and extruded gaskets can simply shrink away from the corners leaving the corners with no waterproofing protection (Photos 2 and 3). Although most curtain wall systems incorporate internal weep systems, their weep system typically cannot accommodate significant water infiltration due to gasket deterioration and shrinkage.

EXTERIOR SEALANTS AND EXPANSION JOINTS

Curtain walls systems also depend on exterior sealants and expansion joints to prevent air and water infiltration. In fact, many building facades are comprised of curtain wall sections adjoining other types of cladding systems. In such systems, the exterior sealant joints between the curtain wall system and the adjacent cladding materials are critical in maintain-



Graph 1: In most assemblies, wind can cause loss of pre-compression on glazing gaskets. This, in turn, will result in excessive water penetration into the water management system.

Photo 3: Typical shrinkage of glazing gaskets at butted corners can result in excessive water penetration into the glazing pocket.


Photo 4: Removal of the glazing reveals lack of zone dam at the corner of a glazing pocket.

ing the watertight integrity of the facade. Sealants are also used to form expansion joints within the curtain walls systems.

A discussion of failure mechanisms in sealant joints is beyond the scope of this article; however, it should be noted that due to their low thermal mass and the high coefficient of thermal expansion for aluminum, curtain wall systems are subject to frequent thermal movements. If sealant joints within the system or around the perimeter of the system are not designed properly, failures can occur. Proper design of the joint, proper selection of the sealant materials and proper installation are key in ensuring long-term performance of the joints. Industry standards such as ASTM C1472, ASTM C1193, and SWR Institute's "Sealants: The Professional's Guide" provide good information on these topics.

Building expansion joint accessories are often incorporated into the building facade to accommodate building movements. If not properly integrated with the curtain wall system, or if not able to accommodate in-service movements, expansion joints can also be a source of water or air infiltration.

INTERNAL SEALS

Most curtain wall systems rely on their internal drainage system to accommodate incidental water that can bypass the primary seals. The internal drainage system typically consists of horizontal troughs formed by various framing members (typically referred to as "glazing pocket"), end dams or zone dams to control flow of water in those troughs and sealants to ensure watertight integrity at various joints. (Photo 4) In most cases, original deficiencies in the application of the internal seals may not manifest until the primary seals deteriorate sufficiently to allow a significant amount of water to enter the system. In other cases, material

Photo 5: Deteriorated internal seals can only be observed by removing various system components.

Photo 7

deterioration or movement at the connection can cause failure of the internal seals. (Photo 5) Once internal seals fail, the drainage system will not be able to control incidental water, resulting in water infiltration.

Another issue with internal seals is the shrinkage of thermal breaks. Thermal breaks are incorporated in the same members that form the drainage troughs in the system. Once thermal breaks shrink, they either result in separation from the end dams, or separation from the shoulders of the thermal break. In either case, water leakage can result.

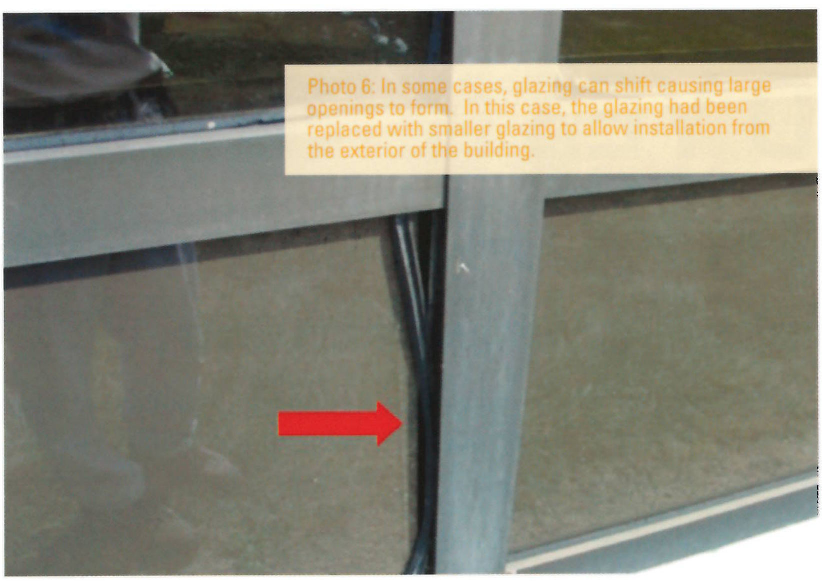


Photo 6: In some cases, glazing can shift causing large openings to form. In this case, the glazing had been replaced with smaller glazing to allow installation from the exterior of the building.

THERMAL PERFORMANCE ISSUES

Curtain wall systems can also suffer from thermal performance issues. These issues can result in excessive energy usage, condensation and thermal discomfort for building occupants.

In most cases, thermal performance deficiencies are due to original design and construction of the system and not related to ongoing deterioration or aging. However, some in-service deterioration or damage can cause thermal performance issues. As examples, IGU seal failures can be considered a thermal performance issue that is a result of ongoing deterioration. Additionally, in-service damage to interior vapor retarders of spandrel panel insulation can also cause localized condensation.

GLASS DISPLACEMENT AND BREAKAGE

In some cases, glass units can be displaced within the glass pocket over time (Photo 6). This phenomenon is sometimes referred to as "walking" and is typically due to installation of glass units without anti-walk blocks. Glass anti-walk blocks are semi-elastomeric blocks that are placed within the vertical glazing pockets to prevent lateral movement of the glass. Unfortunately, some storefront and curtain wall designs allow glass installation by sliding the glass unit into the pocket from side to side. Such installation will not allow for proper placement of anti-walk blocks on both sides of the glass unit.

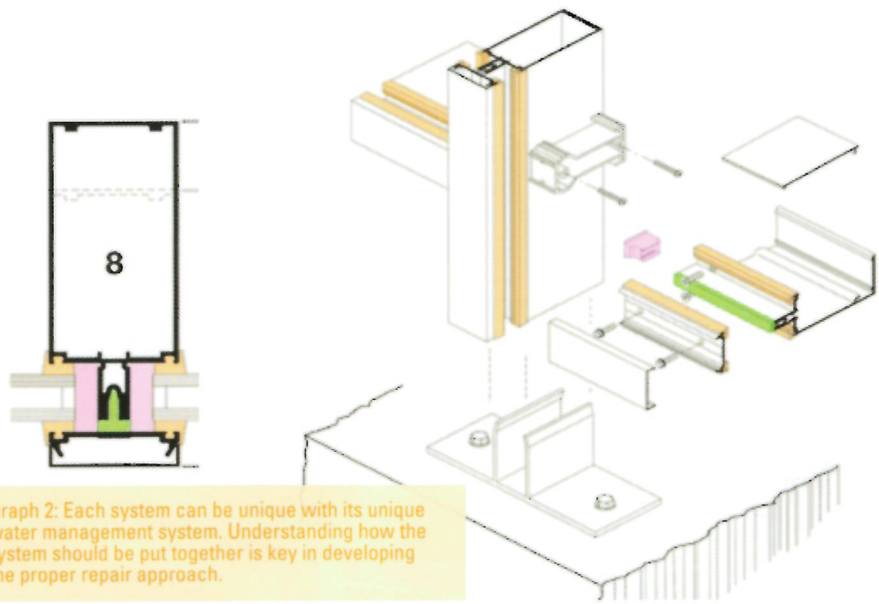
Glass units can also break due to many reasons including nickel sulfide inclusions, rough glass edges that result in stress concentrations, insufficient glass strength, excessive frame deflection, impact, or heat build-up (Photo 7). A discussion on glass breakage is beyond the scope of this article.

STRUCTURAL AND SAFETY ISSUES

Many other distress or deterioration mechanisms in curtain wall systems can pose structural or safety concerns. These include, but are not limited to: loose mullion caps, glass breakage, corroded or distressed connections.

Many curtain wall systems incorporate snapped-on, pre-finished aluminum extrusions that cover the mullions. Typically, these components only serve an aesthetic function and do not impact the performance of the system. However, in some thermally improved system, mullion caps can contribute to additional thermal performance for the system. The proper fit of these components is dependent on tight manufacturing tolerances. Temperature changes, frequent removal and re-installation or improper manufacturing tolerances can result in dislodgement of these covers. If dislodged, mullion covers can pose a serious fall hazard.

As previously discussed, curtain wall systems are subjected to extreme thermal fluctuations. Unlike other building envelope systems such as masonry, stone or concrete, curtain wall systems have a relatively small thermal mass. This characteristic, results in rapid thermal changes in the system components. During a hot summer day, a portion of a dark curtain frame exposed to sunlight can reach one hundred seventy degrees F or more. While a masonry wall may take several hours to reach such peak temperatures, a curtain wall can reach these temperatures after a short period of exposure to sunlight on a warm summer day. Conversely, a curtain wall system can also cool rapidly due to its small thermal mass.



Graph 2: Each system can be unique with its unique water management system. Understanding how the system should be put together is key in developing the proper repair approach.

The small thermal mass of curtain wall systems combined with extensive use of aluminum in curtain wall frames (aluminum has a relatively high coefficient of thermal expansion), make curtain wall systems particularly prone to thermal-induced deterioration. The thermal expansion of a twenty foot tall aluminum mullion subjected to a temperature range of minus twenty degrees F to one hundred seventy degrees F is over 5/8". While the curtain wall system can undergo such significant movements, the structural frame of the building, which is protected from temperature fluctuations, undergoes very little thermal movement. This results in differential thermal movements between the curtain wall system and the building frame. Building frame deformations such as creep and deflections also exacerbate such differential movement between the curtain wall system and the building frame. The connections of the curtain wall system to the building frame must be designed to accommodate such movements, while properly transferring curtain wall gravity and wind loads to the building frame.

Thermal cycles can result in loosening of bolted connections to the building frame or failure of the connections. If not designed or installed properly, curtain wall framing members are overstressed resulting in bowing or deformation to accommodate thermal movements.

In addition to thermal movements, attachment brackets can fail due to other causes, including corrosion and improper accommodation of movement in various directions.

REPAIR APPROACHES FOR CURTAIN WALL SYSTEMS

Repair methodologies to address curtain wall issues can range from simple cleaning or sealing to complete replacement. This section provides a brief summary of typical repair approaches used to address various curtain wall issues.

Before any repair program can be undertaken, the designer should understand how the system is intended to function (Graph 2) In addition, the scope of the project needs to be thoroughly defined through the investigative process. In many cases, repairs have been undertaken to address one known symptom, only to find later that the root cause has not been addressed and the original symptoms reappear. For this reason, it is important to understand the cause(s) of each encountered issue, so that an appropriate solution can be developed. It is also important to evaluate the effectiveness of each repair through mock-ups and verification testing.

Any repair design should consider costs, anticipated service life of the repairs, maintenance requirements for the repairs, reliability of the repairs in addressing the issues and inconvenience to the building occupants.

When developing repair alternatives, it is imperative to discuss the advantages and disadvantages of each repair approach with the building owner, so that the building owner can make an informed decision regarding the repairs.

This section focuses on addressing water infiltration issues. For more information on repair approaches for other issues, refer to SWR Institute's "A Practical Guide to Waterproofing Exterior Walls".

CONVENTIONAL WATER INFILTRATION REPAIRS

WEEP CLEANING AND BAFFLE REPLACEMENT

Where the system's weeps and baffles are accessible, they can be cleaned to ensure optimum performance of the drainage system. In some cases, such cleaning may be sufficient to relieve the system of excessive water that results in interior leaks. If accessible, cleaning of the weeps and replacement of baffles can be far less costly than other repairs. However, where baffles are installed within the system with no access from the exterior, their cleaning can pose a practical difficulty.

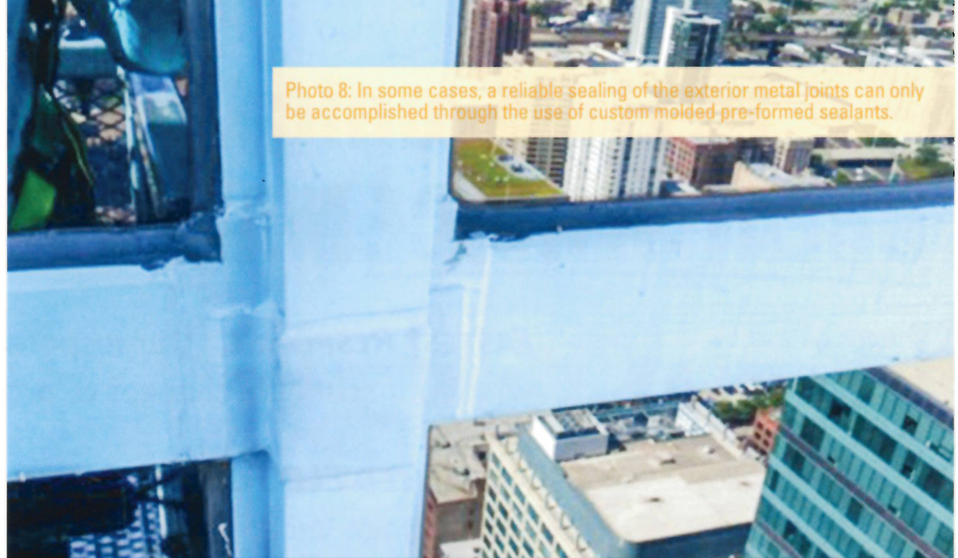
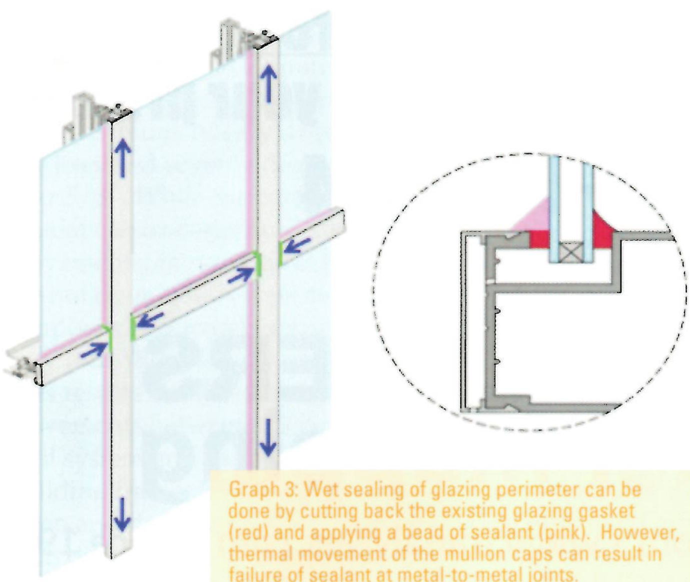


Photo 8: In some cases, a reliable sealing of the exterior metal joints can only be accomplished through the use of custom molded pre-formed sealants.

Photo 9: The use of custom molded pre-formed sealants at a curtain wall system. Note that not only the shape, but also the color have to be customized for a project. Such joints can become unsightly once they collect airborne dirt.

WET GLAZING

One of the most common and least expensive repair approaches to address curtain wall water infiltration issues is to seal all exposed glazing and frame joinery with sealant. This approach is typically referred to as "wet sealing". Wet sealing involves application of sealant over glazing gaskets and at all other locations where water infiltration into the system can occur. Although sealing of exposed frame joinery need not necessarily be included in a wet sealing project, it often is. Wet sealing of glazing typically consists of cutting and removing the exterior portion of the glazing gaskets and applying a cap bead of sealant around the glazing. (Graph 3) In addition, frame joinery can be sealed; however, in most cases, decorative mullion caps are not removed to seal frame joinery. Instead, sealant is applied at all mullion cap interfaces. Some wet sealing projects involve the use of silicone strips or pre-molded silicone shapes to seal mullion and frame joinery The wet sealing approach attempts to minimize the impact of internal seal issues by minimizing water penetrating into the system. Ideally, a wet sealing repair renders the curtain wall system a barrier system. However, the success of wet sealing is highly dependent upon workmanship and the geometry of sealant joints used for the wet sealing project. Rarely, adequate geometry can be accomplished at exposed frame or mullion cap joinery that can accommodate differential movements between those components. In such cases, the use of silicone strips or pre-molded custom silicone boots can help provide for a watertight condition (Photos 8 and 9).



Graph 3: Wet sealing of glazing perimeter can be done by cutting back the existing glazing gasket (red) and applying a bead of sealant (pink). However, thermal movement of the mullion caps can result in failure of sealant at metal-to-metal joints.

While wet sealing can yield adequate results, it is often considered a shorter-term repair because it is highly dependent on performance of the sealant joints. Although the sealant materials used for the repairs can last more than twenty years, joint failures can occur due to improper geometry and/or workmanship issues. As such, wet sealing is not considered a long-term solution to water infiltration issues. Nonetheless, this approach can provide some building owners with an economically viable repair with a reasonable level of service.

GLAZING GASKET REPLACEMENT

Where severely deteriorated glazing gaskets cause excessive water infiltration into the system, they can be replaced. Glazing gasket replacement poses some challenges. These include the difficulty in removal and replacement of preset gaskets. In such cases, de-glazing (removal of IGU) may be necessary to accommodate gasket replacement.

Removal and replacement of glazing gaskets only on the exterior side of the system may not necessarily be

Photo 10: Repair of internal seals after removal of glass units.

Photo 11: The thermal break at the glazing pocket to the left has been repaired through application of sealant. The glazing pocket to the right has not been repaired yet. These repairs require removal of glass units, and thorough cleaning of the glazing pocket.

sufficient. The interior gaskets provide for an air seal and are a part of the pressure equalization system. In some curtain wall designs, the interior glazing gaskets serve to provide water penetration resistance as well as air sealing. If interior gaskets have shrunk causing large openings, they too have to be removed and replaced. In many cases, due to interior finishes concealing spandrel panels, some interior gaskets cannot be easily accessed for removal and replacement.

INTERNAL SEAL AND THERMAL BREAK REPAIRS

Repair of internal seals is not performed on a routine basis. Such replacement will necessarily require de-glazing to expose the internal seals. In some cases, repair of internal seals may be possible by removing exterior pressure bars to expose glazing pockets. (Photo 10) However, such repairs are difficult and not as reliable as those made where glazing is removed from the system.

De-glazing and internal seal repairs are very costly when performed on the entire curtain walls system. However, performing such repairs on a localized basis to address certain water leakage issues is commonly performed. If complete de-glazing is performed, it provides an opportunity to replace the glazing units with more energy efficient units.

Addressing thermal break issues will also require deglazing to expose the thermal breaks. Once the thermal breaks are exposed, they can be cleaned and sealed. (Photo 10)

An important consideration for internal seal and thermal break repairs is ensuring proper surface preparation and removal of old deteriorated sealant. Due to complex geometry of glazing pockets and such joints, complete removal of existing sealant may not be practical.

COMPLETE REPLACEMENT

Complete replacement of the entire system is always an option. This approach can help resolve all performance issues including aesthetic degradation, air and water penetration, thermal performance and failed or inadequate connections. Although typically the most costly option and most disruptive to building operations, complete replacement of the system may be a good option for some building owners who demand energy efficiency, water tightness and updated aesthetics.

UNCONVENTIONAL WATER INFILTRATION REPAIRS

The original design and construction of each curtain wall system can be unique. As such, it may be possible to develop specific repair schemes to address each curtain wall system.

One such unconventional repair scheme is the use of custom extruded pressure bars and mullion caps to retrofit existing systems. This approach can be used to modify the size of the glazing pocket to accommodate IGUs, provide a thermal break in the mullions and/or to provide improved geometry for wet glazing. In most cases, such repairs can cost a fraction of replacement and can be performed from the building exterior to minimize disruption to the building operations. The cost effectiveness of unconventional repairs will likely improve as more sealant, waterproofing and restoration contractors develop expertise in such repairs.

Development of unconventional repairs poses a risk to the designer, contractor and building owner since they are not "tried and true". For that reason, careful consideration should be given to the repair objectives. In many cases, 3D modeling of custom extrusions and their intersections may be needed to properly design a profile that can accommodate complex joinery. Design of snapped-on components also requires careful consideration to avoid parts are would be too difficult to fit onto each other, or too loose to maintain mechanical interlock.

The author has designed unconventional repairs to many curtain wall and window systems. In all those cases, custom-extruded components have been used to improve the performance of the system. The case history that will be presented the Spring issue of the *Applicator* discusses an example project where unconventional repairs were designed and implemented.

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