CURTAINWALL FAILURES – DESIGN OR PRODUCTS

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ABSTRACT

This presentation will examine recent window and curtainwall assembly failures and performance issues for insulated glazing units (IGUs). With the advent of the globalization of the construction industry, façade glazing systems are beginning to experience new types of failure in their assembled components, resulting in performance issues with high-rise projects. The speaker will present forensic study results from a dozen high-rise buildings with curtain and window wall assembly failures.

SPEAKER

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CURTAINWALL FAILURES – DESIGN OR PRODUCTS

This paper will focus on the causes of the increasing number of window and curtainwall assembly failures we are seeing in high-rise buildings. Over the last 20 years, many developments have been made in the construction of building skins that impact the performance and life expectancy of curtainwall and window assemblies. These developments include advancements in energy efficiency, recyclable content in materials, global manufacturing, and more prominent air barrier, LEED, and International Code Council (ICC) requirements. While developments are necessary to improve energy efficiency, cost efficiency, and sustainability, they can result in unexpected consequences. We will examine how these developments impact curtainwall and glazing assemblies and contribute to unexpected air and water intrusion stemming from coating, seals, sealant, and insulating glass unit (IGU) failures.

CURTAINWALL DEFINITION

According to the *Whole Building Design Guide*, curtainwalls are walls that do not carry floor or roof loads. Wind loads and the curtainwall's dead loads are transferred back to the structure at the slab edge. Curtainwalls are typically thin and aluminum framed, with glass panels or thin stone panels that "hang" like a curtain from the building's structure. The glazed curtainwall system is often a metal frame (usually aluminum) that frames glass, brick veneer, metal panels, thin stone or precast concrete. The inclusion of infill panels within the curtainwall provides different challenges. Challenges include maintaining internal building temperatures, inhibiting wind and water intrusion, and sustaining the long-term performance of the building. Remember, the main function of a curtainwall is to keep the outside out.

The advent of glazed curtainwalls was a marvel when first introduced, and many American architects embraced them. Glazed curtainwalls provide more interior space than traditional bearing walls, they are less expensive, quicker to construct, and provide clean lines and greater sightlines. Over 100 years ago (circa 1909), one of the first examples of a curtainwall was built in Kansas City, Missouri. Architect Louis Curtiss combined the new technology with established period design elements to design a structure that is still used today. The six-story Boley Clothing Company Building features glazed curtainwalls framed by traditional cast iron and terra cotta ornamentation.

Over the course of time, cast iron has given way to aluminum. Aluminum is lighter, can be extruded, and can be coated with a variety of high-performance coatings. Glazing systems have improved over the decades. Modern curtainwalls use double or triple panes of glass, coated with silver to provide low emissivity and improve thermal efficiency. Gas filling with compounds such as argon and krypton is often used to improve an IGU's "U" value. Air- or gas-filled double/triple pane units have desiccants to absorb moisture from within the glass and prevent "fogging" or interior condensation.

TYPICAL CURTAINWALL SYSTEMS

Curtainwalls are comprised of two primary components: the frame and the infill panels. The components are commonly connected to the building slab edge by means of embeds and typically bypass one or more floor slab edges. Curtainwall assemblies are typically "unitized" or "panelized," allowing complete factory assembly of the curtainwall components. They are engineered to carry their own weight and to resist lateral wind pressures and both thermal and seismic movement.

THE FRAME

A typical curtainwall frame is composed of steel, aluminum, multi-laminate glass, or other resilient materials. The frame is the support grid that holds the glass in place. Common framing systems include in following:

- **Stick systems** are the most basic type of curtainwall, with individual mullions or framing elements assembled in the field.
- **Unitized systems** apply the same design principles as stick systems, but sections of the curtainwall are assembled (unitized) in the shop and installed as a unit.
- **Unit mullion systems** combine the preassembled panels of unitized systems with the multi-story vertical mullions of stick systems. Upright mullions are installed first, with horizontal mullions and glazing installed as a unit.
- **Column cover and spandrel systems** articulate the building frame by aligning mullions to structural columns. Preassembled or field-assembled infill units of glass or opaque panels are fitted between the column covers.
- **Point-loaded structural glazing systems** eliminate the visible metal framework by incorporating tension cables, trusses, glass mullions, or other custom support structures behind the glass panels. Glazing is anchored by brackets or by proprietary hardware embedded in the glass.

THE GLASS

Alastair Pilkington developed float glass in the 1950s, which enabled production of the large glass sheets that characterize curtainwall construction. Plate glass production begins when molten glass is fed onto a bath of tin where it flows along the tin surface and forms smooth glass with even thickness. The glass is then further fabricated, including cutting to size, heat-treating, and application of low-emissivity (low-E) coatings. Curtainwall glazing ranges in price, durability, impact resistance, and safety, depending upon the manufacturing process of the glass. Common glass types include these:

- **Annealed glass** undergoes a controlled heating and cooling process that improves its fracture resistance. Despite its improved durability, annealed glass can break into sharp pieces, and many building codes limit its use in construction.

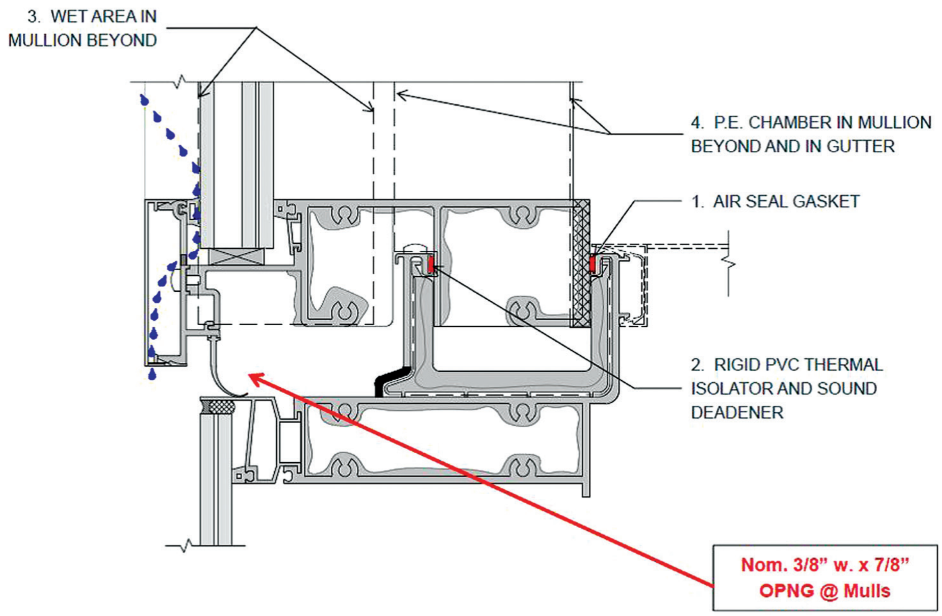

Figure 1 – Detail of a unitized rainscreen curtainwall.

- **Tempered glass** is either chemically or thermally treated to provide improved strength and shatter resistance. On impact, tempered glass shatters into tiny pieces that are less likely to cause injury than larger shards.
- **Heat-strengthened glass** and chemically strengthened glass fall between annealed and tempered glass in terms of strength. Unlike tempered glass, strengthened glass can be sharp when shattered, so it is best suited to areas with limited access. Scratches in strengthened glass have also been shown to compromise its strength.
- **Laminated glass** bonds two or more sheets of glass to an interlayer of plastic, generally polyvinyl butyral (PVB), which holds the glass in place if broken. Laminated glass is often specified for curtainwalls in hurricane-prone regions or in areas requiring blast protection.
- **IGUs** improve thermal performance with double or triple panes of glass separated by a space filled with air or an inert gas.
- **Spandrel glass**, which is darkened or opaque, may be used between the head of one window and the sill of the next. To create the illusion of depth at spandrel areas, transparent glass may be used in a "shadow box," with a metal sheet at some distance behind the glass.

SYSTEM MANAGEMENT: WATER PENETRATION AND AIR INFILTRATION

All types of assemblies have to manage water and air infiltration under wind-driven pressure. Wind-driven pressure increases with building height and allows for floor deflection, seismic forces, and wind pressure. High-rise buildings are subject to higher winds, which create a positive pressure on the windward side of the skin and negative pressure on the leeward side. The pressure differential can have the effect of forcing air and water through or around the skin assembly and into the building.

Generally, a curtainwall manages water as a rainscreen design principal. Rainscreens carefully manage the water and air infiltration by allowing water to partially enter the "wet" areas of the skin where it can be managed and effectively expelled. A rainscreen system (*Figure 1*) attempts to maintain the same pressure in the wet zone as the exterior face by unitizing an air barrier between the interior and exterior face of the building skin. The air barrier prevents or reduces the differential pressure gradient. Since the pressure differential is responsible for driving the water inside, the rainscreen system reduces the likelihood of water intrusion. In addition to the air barrier, seals and sealants are used to further prevent air and water infiltration through curtainwall skins.

Other more traditional systems of water management include dry-gasket glaze and wet-sealed barrier-type approaches. Dry-gasket type systems assume that water will bypass the exterior gasket. Once inside the glazing rabbit or pocket, a series of internal weeps or drainage holes is used to channel or manage the infiltrated water back to the building exterior. By contrast, the wet-sealed or barrier-type systems aim to completely eliminate water infiltration and are often used as repairs for previously failed glazing systems.

SYSTEM MANAGEMENT: THERMAL PERFORMANCE

A curtainwall's thermal performance can be divided between the framing and the glass. While aluminum curtainwall frames have many advantages, one disadvantage is that they are inefficient at disrupting thermal transfer. Aluminum frames quickly heat up in warm temperatures and quickly cool down in cold temperatures. This creates a thermal bridge between the less conductive materials, which allows for easy heat and cool flow. The primary method for discouraging thermal transfer is by creating thermal breaks. The goal of a thermal break is to separate the internal aluminum from the exterior aluminum, preventing heat and cold transfers. Polyamide is a typical material used in thermal breaks and is an efficient isolator between exterior and interior environments.

Glass is often the largest single component of a curtainwall system and plays a large role in determining "U" and solar heat gain coefficient (SHGC) values. To reduce heat transfer through the glass, a low-E coating is added to the glass. Emissivity is a measure of the ability of a surface to radiate energy. In warm temperatures, low-E coatings reflect a larger percentage of solar radiation which, if left untreated, passes through the glass as heat. During cool temperatures, low-E coatings reduce convection at the interior window surface and aid in maintaining ambient interior temperatures.

Modern high-performance, low-E coatings are comprised of multiple metallic layers coupled with either one, two, or three layers of silver. Many of the additional metallic layers are utilized to reduce the inherent reflectivity of the silver layer. Silver is highly reflective and creates a mirror effect if not otherwise dampened.

Building skins, especially those constructed like curtainwalls, need to handle many forces such as wind, rain, seismic movement, and temperature differentials. In order to properly ensure an effective

Figure 2 – ASTM E1105 water testing of a curtainwall.

curtainwall design, laboratory and field mock-ups are necessary based on ASTM standards and American Architectural Manufacturers Association (AAMA) tests: AAMA 501.1 (water resistance), AAMA 501.2 (field testing), ASTM E330 (structural), ASTM E331 (water resistance), ASTM E283 (air resistance), and ASTM E1105 (field testing). See *Figure 2*.

In theory, if the building skins are designed, fabricated, and installed correctly, in accordance with good industry practices, they can stand for many decades and perform as designed without major issues. The Empire State Building, which is over 80 years old, was retrofitted with dual, energy-efficient glazing in the existing curtainwall skin, which is still performing. However, our forensic studies have shown that even the best designs are subject to failure. Failure can occur for a number of reasons, including substandard materials and components, improper application of coatings, cutting corners in fabrication or erection, and poor design of assemblies. These failures can result in air or water intrusion, interior condensation, aluminum coating failures, insulating glass failure, glass breakage, and other deficiencies.

COMMON MODES OF FAILURE

Repairs to fix building skins are often very expensive, sometimes exceeding four times the cost of the original construction. Knowing what to look for, how to extend the serviceable life, and when it is time to retain a glazing expert are all critical in avoiding costly and disruptive failures.

Like all building elements, curtainwalls have weak points. Although issues vary with frame material, construction methods, and glazing type, there are some common concerns that design professionals look for when evaluating the condition of a curtainwall system.

GASKET AND SEAL DEGRADATION

A common cause of curtainwall complications is failure of the gaskets and seals that secure the glazing. Gaskets are strips of synthetic rubber (e.g., EPDM or silicone) or similar types of tapes compressed between the glazing and the frame, forming a water-resistant seal. Gaskets also serve to cushion the glass and accommodate movement from wind, thermal, or seismic loads.

As gaskets age, they begin to dry out, shrink, and crack. The elastic material degrades when subjected to ultraviolet radiation and freeze-thaw cycles, much like an old rubber band. At first, air spaces are created by the shrinking, dried gaskets, which admit air and moisture into the system

Figure 3 – Example of gasketing failure.

Figure 4 – Path of water intrusion over IGU glass edge.

Figure 5 – Example of glass fogging in conjunction with low-E corrosion.

(*Figure 3*). This can lead to condensation, drafts, and leaks. As the gaskets further disintegrate, they may loosen and pull away from the frame. Without the support of flexible gaskets, the glass loses stability and may shatter or blow out. For this reason, it is important to maintain and routinely replace gaskets to keep the curtainwall system operational and safe.

Shrinking of exterior gaskets is a common concern and is not always easy to fix. Although some systems, such as those incorporating pressure bars, allow for gasket replacement without removal of the glazing, it is difficult or impossible to replace gaskets in most curtainwall systems without removing the glass. Wet sealing may be an option. It involves cutting out worn gaskets and adding perimeter sealant. However, wet sealing does not generally result in a reliable water barrier. It also creates a demand for ongoing maintenance. In many cases, the required ¼-in. minimum dimension for the wet sealing is not present. Where possible, it is best to maintain the original glazing system and start with sustainable gaskets capable of long-term performance like silicone.

In addition to what one would normally expect as failure-causing situations, the advent of new sealants, gaskets, and the associated chemicals has proven that designers need to be conscientious of the quality and durability of the gaskets incorporated into these highly energy-efficient curtainwall assemblies.

We have found that using a high-grade rubber is not the only criteria for window gaskets. While incorporating recycled materials into new products is ecologically conscious and commendable for many projects, it can lead to additional gasket shrinkage and inadvertent failure. Lastly, competition and profit goals may drive manufacturers to reduce polymers, ultraviolet (UV) protection, anti-oxidation protection, and to add more fillers.

In lieu of compression gaskets, some curtainwall systems use structural sealant—usually a high-strength silicone product—to secure the glass to the frame. Like gaskets, sealants have a finite service life and require proper engineering to have the necessary bond strength and waterproofing characteristics. Signs that perimeter sealants need replacement include shrinking or pulling away from the surface, gaps or holes, discoloration, and brittleness.

Sealants are known to break away because of poor adhesion or improper application. With thermal expansion, the difference of aluminum expansion is 2.5 times greater than that of glass, enabling large relative displacements to cause many sealants and seals to separate.

A perfectly watertight designed curtainwall cannot be maintained by sealants alone. Redundancy in water protection that incorporates an in-wall drainage system and carefully considered sealant, is the best way to avoid water infiltration and to mitigate water damage.

IGU COATING AND SEALANT FAILURE

All IGU manufacturers require their units to be glazed within a framing system that weeps water away from the insulating glass perimeter seals. According to the Glass Association of North America, "Failure to properly glaze insulating glass units may result in premature seal failure and will void insulating glass warranties. IGU sealants are also degraded by prolonged exposure to water or excessive moisture vapor."

In the case in *Figure 4*, seals were ineffectively executed or they degraded, allowing water to enter the glazing system and literally sit on top of the glass. As a result, water or water vapor permeated the silicone secondary seal and attacked the low-E coating (located on the inside surface of the exterior lite), causing glass corrosion.

High-performance, low-E coatings are the most commonly used and have two or three layers of silver in addition to other metallic compounds. The black spots on a mirror are analogous to the corrosion seen in *Figure 5*.

Glazing seals typically incorporate a combination of polyisobutylene (PIB) and silicone sealants to hermetically seal the inert air or gas between the dual or triple glazing. Interior glazing seal failures can occur due to a number of causes, including: improper application of sealants, excessive or prolonged exposure to moisture, and changes in elevation and/or pressure between the inboard and outboard glass. See *Figure 6*.

In order to achieve the required bonding between the PIB and the glass substrate, insulating glass manufacturers remove the low-E coating approximately ½ to ¾ of an inch on the entire perimeter of a lite of glass. This edge deletion allows the PIB and secondary seals, such as silicone, to bond properly to the glass. Failure of seals to properly bond can result in PIB migration.

PIB migration (*Figure 7*) leads to both a visually unappealing condition and a potentially serious reduction in the insulating glass unit longevity. There is no known remediation method, and the condition is, as far as we know, progressive. Over time, the migration will worsen, leading to a reduction in the service life of the IGU seal,

Figure 7 – Example of PIB migration.

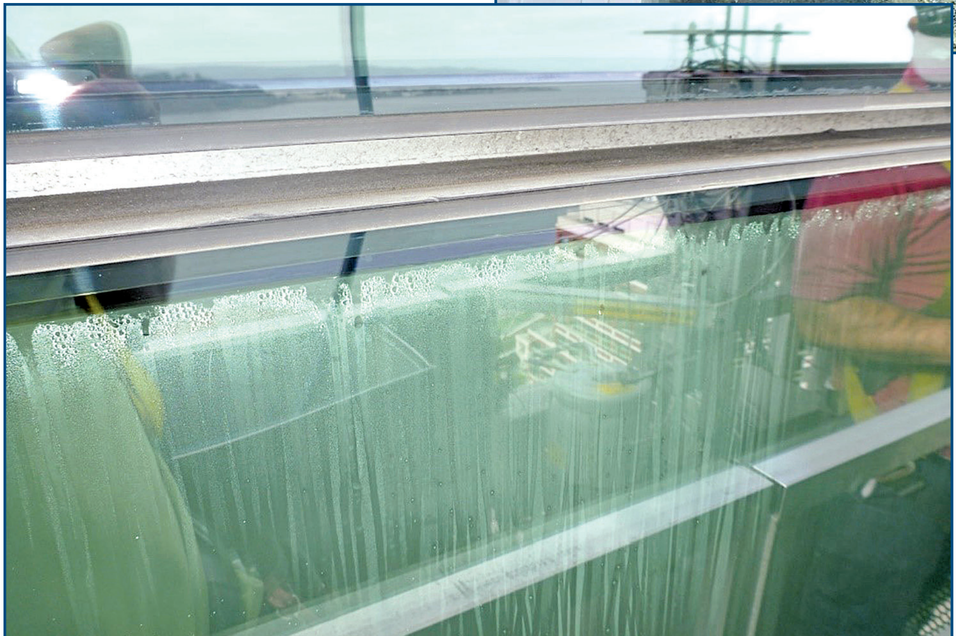

Figure 6 – Example of a total IGU seal failure.

Figure 8 – Example of condensation failure.

which in turn leads to premature fogging and condensation within the IGU.

The migration of the PIB typically takes place within the airspace of the IGU, and the author believes it is triggered or worsened by exposure to solar radiation (heat) and UV. Operable windows also seem to display more migration than adjacent fixed panels, which further reinforces the notion of the PIB as "thinning" as a result of direct solar exposure.

In the author's experience, this issue is limited to PIB by a particular manufacturer that is gray in color. In laboratory testing, it has been determined that the percentage of solids (polymer) within the gray-colored PIB is 64.8%, with plasticizers as low as 2.6%. This compares to control samples of PIB that have 97.5% polymer and about 30% plasticizer by weight.

GLASS FAILURES

Glass failures in curtainwalls can be split up into several different categories. Nickel sulfide (NiS) inclusions, thermal cracking, and damage from impact are the most common types of glass damage.

Nickel Sulfide Inclusions

NiS inclusions, also known as "glass cancer," are imperfections incorporated in glass when it is manufactured. All glass has microscopic inclusions resulting from the manufacturing process which, generally speaking, are of little concern. One exception is NiS inclusions in tempered glass, which has led to a number of dramatic glass failures.

As glass is heated during the tempering process, NiS converts to a compressed (alpha) phase. When the glass is cooled rapidly to temper it, the trapped NiS lacks sufficient time to return to a stable, low-temperature (beta) phase. The resulting pressure leads to micro-cracks in the glass, which can propagate until the glass structure is thoroughly compromised and the glass shatters in what seems to be a spontaneous breakage.

In an existing structure, ultrasound, laser imaging, or heat soak testing may be used to identify NiS inclusions; however, such test methods can be labor-intensive and expensive. Specifiers should consider not using tempered glass in these applications or specifying "heat soaking" of the glass, which virtually eliminates NiS inclusions.

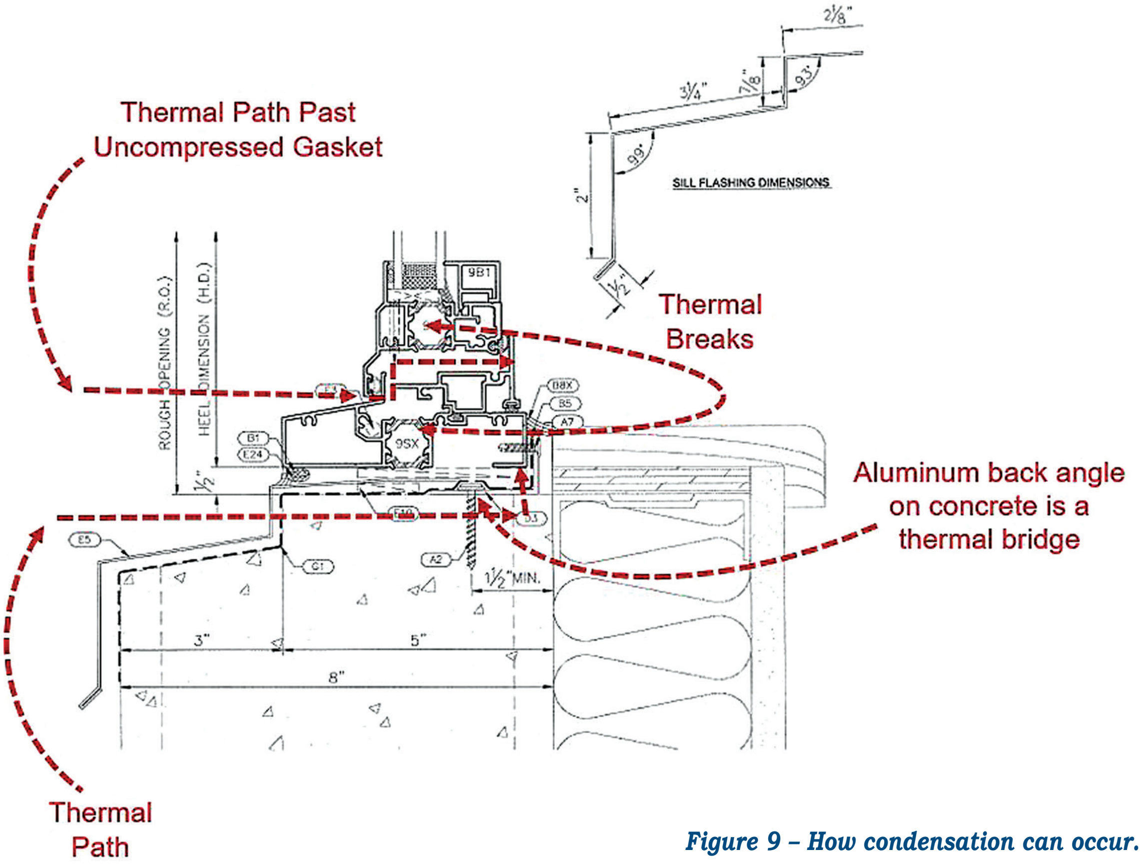

Figure 9 – How condensation can occur.

Thermal Cracking

Thermal cracking is a notable concern that engineers should consider when designing curtainwall assemblies. When the sun strikes the glass, it heats the exposed portion of the pane, causing it to expand. The unexposed edges remain cool, creating tensile stress that can lead to cracking, particularly in glass that has not been heat-strengthened or tempered. Thermal cracks are easy to detect, as they are usually perpendicular to the frame and typically expand through the entire window section.

Hairline cracks in glass may indicate excessive thermal loading, particularly if the glass has a coating, such as a low-E film or tint. Low-emissivity coatings are placed on the glass to reduce the building cooling load. They redirect solar radiation away from the glass while absorbing a fraction of that radiation within the glass. This absorbed solar radiation increases the temperature of the glass and can cause it to expand unevenly, resulting in thermal cracking. The more solar radiation absorbed, the more likely the glass will crack.

The likelihood of thermal cracking is reduced by heat-treating the glass within the IGU. Heat-strengthened glass can take higher thermal stresses and is the typical solution for heat absorption issues. In order to properly design for low-E coatings, a specifier should consider the stresses that will be induced in the substrate glass and see if the stresses will likely cause the glass to crack.

WATER INFILTRATION AND CONDENSATION

Moisture damage is the most common type of failure in curtainwall sections. Water infiltration can cause glass corrosion, damage interior finishes, lead to mold and mildew, and degrade indoor air quality. Moisture damage can be classified into two distinct parts: water infiltration and condensation. In the U.S. alone, water intrusion is responsible for 85% of all construction-related lawsuits.

Condensation on glass curtainwalls may be an indication that the relative humidity (RH) of the interior is too high, and an adjustment to heating and cooling equipment is necessary. However, condensation may also point to failure of the curtainwall system.

Condensation on cold interior window and curtainwall surfaces is caused when warm, moist air comes into contact with a window surface that is at or below the dew point temperature. Modern aluminum window and curtainwall design uses "thermal breaks" to limit the transfer of outside cold temperatures to the interior window or curtainwall where warmer humid air can cause condensation. As mentioned above, thermal breaks attempt to disrupt a thermal bridge between the exterior and the interior.

Condensation occurs when the temperature of the glass or aluminum frame in a curtainwall reaches the dew point temperature of the interior space conditions. Water forms on the surface of the glass or aluminum and can cause damage to the interior finishes. Basic design against condensation ensures that the condensation resistance factor (CRF) of a given curtainwall section meets the requirement of the space, which is based on the expected temperature and humidity of the space. Designers should be aware that the CRF is an average and cannot account for cold spaces in the facility that can cause localized condensation (*Figure 8*).

A proven method to prevent condensation in curtainwall frames is to use thermally broken aluminum. Thermal breaking is where one or more pieces of polyamide or other material are incorporated within the aluminum frame, which significantly decreases the temperature transfer from the aluminum exterior of the curtainwall to the interior surfaces.

For example, a reduction in the transfer of cool exterior temperatures decreases the possibility of condensation on the interior aluminum surfaces. Another proven method of limiting condensation is by incorporating thermal breaks within the design, providing a limited amount of non-thermally broken aluminum to be exposed to exterior conditions.

Condensation can be just as damaging to interior surfaces, such as drywall and wood trim, as water infiltration. In some cases, it appears that a window is leaking when, in fact, it is condensation. Design guidelines are particularly important for avoiding the creation of thermal bridges that will actually bypass the thermal breaks within a window system. As our detail in *Figure 9* shows, even with a thermally broken aluminum window frame, factors like the method of attachment to the rough opening and under-functioning window components such as gasketing can cause exterior temperatures to be transferred to interior surfaces.

The *Whole Building Design Guide (WBDG)* states that when designing a curtainwall glass unit in areas where high humidity is required within the space (such as hospitals) or where configurations are abnormal, software modeling is a must to ensure that condensation (*Figure 10*) does not occur. The *WBDG* also states laboratory tests simulating indoor and outdoor air temperatures and humidity of the space are good practice to see how a glass panel will perform. Specified tests are AAMA 1503.1 and National Fenestration Rating Council (NFRC) 500.

Figure 10 – Condensation on an interior window surface.

Figure 11 – Sample of trim cover failure.

DESIGN AND CONSTRUCTION DEFECTS

As with any type of construction, curtainwalls are subject to the shortcomings of manufacturing, installation, and human capability. Material failure and age-related deterioration may be common causes of curtainwall distress, but many premature and costly failures are attributable to avoidable errors.

Missing, incorrectly applied, or otherwise deficient sealants at frame corners and other intersections can lead to serious water infiltration issues. Failure on the part of the contractor to follow manufacturer's guidelines, and improperly manufactured sealants and gaskets can result in premature failure that is both difficult to access and expensive to repair.

Flashing detailing requires fastidious attention to prevent leaks at intersections between the curtainwall and other building elements. Without detailed contract documents that fully describe and illustrate perimeter flashing conditions, along with coordination between the curtainwall installer and construction manager during installation, flashings may not be adequately tied or terminated, permitting water to enter the wall system.

Poorly installed trim covers and accessories can also pose a danger to people and property below. Trim covers (*Figure 11*) and accessories can be snapped in place or adhered using structural glazing tape alone without mechanical attachments. However, poor quality control of the products during the manufacturing process can provide potential problems in the long term. Dies used for extruding covers can wear out, resulting in poor fit and holding strength. Checking for tolerances and proper preparation and adhesion can be critical to long-term performance.

We have found that corrosion of metal surfaces is accelerated if the proper preparation and coating requirements are not followed. When measured with an Elcometer, we have seen a 0.3-mil paint coating that was found to be 0.1 mil or less.

There are several architectural-grade paint finishes available on the market, but we typically recommend fluoropolymer paint finishes (like Kynar) that meet AAMA 2605 certification. But like all paint, even Kynar-based paint finishes need proper preparation and application to perform as intended (see *Figures 12* and *13*).

Paint finishes are either "wet," like the typical Kynar application, or "dry," like powder-based paint finishes. Both are applied electrostatically, so application is limited to factory environments.

Paint failures are relatively infrequent when compared to some of the other failure modes in window-wall and curtainwall systems, but remediation of failures is particularly difficult. Often, the failure is related to lack of or inadequate pretreatment or where primers are part of the application but were improperly applied to the base metal being painted.

There are firms that specialize in field recoating of failed paint finishes. Most of these firms use a water-based paint due to concerns about volatile organic compounds (VOCs) and toxic-smelling aftereffects of painting. While warranty periods of 10-15 years are available from the recoating applicators, the original warranty on AAMA 2605-compliant paint finishes ranges from 10-30 years with accelerated aging studies, indicating that a properly applied paint finish has a life expectancy exceeding 40 years.

CONCLUSIONS AND LESSONS LEARNED

Curtainwall systems, particularly in high-rise buildings, can fail for a variety of reasons. They require specification, inspection, testing, and verification to avoid premature failure. Typical failure modes include water infiltration, glazing failure, and gasket and seal degradation.

While the IGU industry has made great strides in the last 30 years to reduce failure, we have seen new IGU failures over the last five to ten years. The new failures include flowing PIB sealants, as well as a lack of edge deletion of the low-E coating from the glass perimeter, leading to poor sealant adhesion and corrosion of the low-E coatings themselves.

IMPORTANCE OF CONSCIENTIOUS DESIGN

From the descriptions of failures faced in curtainwalls and the examples discussed in this report and the presentation, several different conclusions can be deduced. First and foremost, an engineer or curtainwall design professional should be involved in all aspects of curtainwall design.

These professionals should be aware of the proper techniques to prevent failures, such as new performance issues plaguing the industry. A thorough understanding of waterproofing issues, glass failure issues, installation issues, poor visual performance, and poor thermal performance is necessary during the design phase.

Design professionals should also be aware of and consider the strengths and weaknesses of various materials during material selection. From our earlier discussion about gaskets and seals, we have learned that seals with excessive fillers or recycled materials break down much quicker than virgin material, possibly because the recycled portion has lived its useful life already and there is no longer the resiliency or sealing capacity that there once was.

Unforeseen structural interactions among building elements may lead to failure if the curtainwall has not been properly engineered. Inadequate provision for differential movement, as well as incorrect deflection calculations, may be responsible for cracked or broken glass, seal failure, or water intrusion. Glass and framing must be evaluated not only independently, but also as a system, with consideration given to the impact of proximal building elements.

EVALUATION AND TESTING

If leaks, deflection, etched glass, or other issues have become a concern, an architect or engineer should conduct a systematic evaluation of the curtainwall system, beginning with close visual inspection. ASTM and AAMA provide test standards for the evaluation of air and water penetration, as well as structural performance of glass in curtainwall applications. Field tests for water penetration, such as ASTM E1105, use a calibrated spray rack system with a positive air pressure differential to simulate wind-driven rain. ASTM E783 specifies test procedures for determining field air leakage at specific pressures.

Laboratory and field tests on project-specific mock-ups should also be specified to ensure proper performance according to the manufacturer's standards and guidelines. These tests ensure that mistakes caught early on in the project can be corrected or rectified while changes to design are at a less costly stage of construction. Curtainwall failures can be prevented by proper consideration of potential failures and ensuring proper installation and maintenance of curtainwall sections.

Glazing that displays systemic issues or other defects after installation may need to be evaluated for structural integrity. In such cases, a representative sample of glass units may be removed and tested under laboratory conditions. ASTM E997 is one test method for determining the probability of breakage for a given design load.

MAINTENANCE CONSIDERATIONS

Anodized and painted aluminum frames should be cleaned as part of a routine maintenance program to restore an even finish. For powder coats, fading and wear can be addressed with field-applied fluoropolymer products, although these tend to be less durable than the original factory-applied thermosetting coatings. Other coatings on the market aim to improve durability, but their track records and maintenance requirements should be considered prior to application.

With changes in building codes requiring more energy efficiency, curtainwalls have become more complex with new modes of failures such as low-E coating failure, condensation, air infiltration, etc. Global manufacturing has resulted in its own set of issues such as substandard gaskets, coating, and seals, as well as fit and finish problems. Design professionals and contractors need to be vigilant and learn from these new types of failures.

Figure 12 – Example of paint failure.

Figure 13 – Example of paint failure.