By Daniel L. Bishop, AIA, Project Architect, Hoffmann Architects

Among Hoffmann Architects' current building façade work is a curtain wall replacement project at Stony Brook University Medical Center, in Stony Brook, N.Y.

HOFFMANN ARCHITECTS

GLAZED CURTAIN WALL ASSEMBLIES: RESTORATION AND REPLACEMENT STRATEGIES

LEARNING OBJECTIVES

After reading this article, you should be able to:

+ **DIAGNOSE** common deficiencies in glazed curtain wall assemblies, including poor thermal performance and water intrusion.
+ **COMPARE** rehabilitation and replacement options using criteria such as disruption to occupants, weight, and maintenance demands.
+ **CONSIDER** bird safety when designing curtain walls.
+ **EVALUATE** options for energy efficiency, noise resistance, light transmission, fire protection, and other design criteria.

ANNOUNCING THE ONENYC 2050 initiative on Earth Day 2019, New York City Mayor Bill DeBlasio touted the sweeping climate legislation recently passed by the City Council, then went on to suggest that new restrictions were forthcoming. "We are going to introduce legislation," he announced, "to ban the glass and steel skyscrapers that have contributed so much to global warming. They have no place in our city or on our Earth anymore."

With this bold condemnation, the mayor gave voice to an apprehension harbored by many: as concerns about climate change mount, what should cities do about their stock of inefficient buildings?

Buildings with large areas of glass are often seen as emblematic of the wanton energy waste of the mid- to late 20th century. However, given recent advancements in high-performance building technology, singling out one particular type of building is a misguided, if well-intentioned, approach to improving the efficiency of the entire built environment. A building with a low percentage of glass but egregious thermal shorts may be far less energy-efficient than a well-designed glass-clad structure that incorporates low-e insulating glazing and high-performance detailing.

GLAZED CURTAIN WALL DISTRESS

HOFFMANN ARCHITECTS

Broken glass

Failed gaskets and seals

Leaks and drafts

Condensation

Frame displacement

As glass curtain walls age, they succumb to the same forces of time and weather that afflict any other building type. While it is true that many older curtain walls were constructed with poorly performing glass and framing assemblies, there are retrofit and rehabilitation solutions that can address thermal inefficiency, along with water intrusion, noise infiltration, and structural distress, while upgrading the appearance of the building to align with contemporary aesthetics.

Eliminating glazed curtain walls from city skylines may seem, at first, like the kind of forward-thinking solution we need to combat climate change. Glazed façades, however, are an important part of the architectural lexicon, and shunning them means turning our backs on buildings, from Lever House in New York to Willis Tower in Chicago, that have made our cities what they are. Large areas of glass offer unimpeded views, natural daylight, and a clean, modern look. With new technologies, meeting energy performance goals need not be at odds with preserving what we love about glazed curtain walls.

CURTAIN WALL DEFICIENCIES

Since curtain walls can make up a large area of a building's façade, when issues arise the ramifications can have a major impact not only on the energy consumption and maintenance demands of the building, but on the comfort of building occupants.

Poor Thermal Performance

Curtain walls with minimal or uneven insulating properties can lead to temperature gradients and undesired air movement within a space. Typical causes include:

- **Gaps in curtain wall glazing gaskets and frame joinery seals,** which allow air infiltration;
- **Absence of thermal breaks** between exterior and interior curtain wall framing components, which permits direct transfer of thermal energy through conductive metal framing;
- **Low-performing glazing,** such as single-ply glass, that has poor resistance to the transfer of heat energy; and
- **Absent or deficient cavity insulation,** located at opaque areas of the wall assembly, which creates cold points in the curtain wall.

Water Intrusion

At the perimeter of the curtain wall, missing, poorly installed, or deteriorated flashings may allow water to penetrate the assembly and leak into the building. Water may be observed directly in line with the site of flashing failure, or moisture may be initially concealed as it travels undetected through interior cavities, only to reveal itself at seemingly unrelated locations.

Curtain wall systems are typically designed with integral weep systems to collect and channel incidental water infiltration to the exterior. However, as gaskets are exposed over time to UV radiation and weather, they become brittle and shrink. Deterioration of the gasket creates voids that admit more water than the system was designed to handle, inundating the integral weep system during a rain event. As water builds up, it can overflow into the interior components of the curtain wall.

Condensation

Condensation is especially worrisome for cool climates. When indoor air is heated and outdoor temperatures are cold, insufficiently insulated exterior walls develop an interior surface that is cool enough to condense ambient moisture. Condensation may be directly observed as 'sweat' on visible surfaces, or it may be hidden from occupant view within concealed spaces, such as spandrel locations.

Compromised Glass

Damaged glass can be both unsightly and a safety hazard. Cracks in glass may be caused by incidental impact, extreme temperatures, or applied forces caused by thermal movement or displacement of structural elements. Contaminants incorporated into the glass during manufacturing, notably nickel sulfide inclusion, may also lead to what appear to be spontaneous cracks, as the contaminant expands differently than the surrounding glass.

Fogging of insulating glazing can render a unit nearly opaque. When glazing components off-gas, often due to extreme temperatures, the gaseous compounds can cloud the space between panes. Fogging may also be due to condensation, which may occur when perimeter seals are compromised, and water vapor is admitted into the insulating glass airspace.

Metal Framing Deterioration

Aluminum curtain wall systems are typically finished with an anodized or fluoropolymer coating. While durable, these finishes deteriorate over time and expose the aluminum substrate. Aluminum may not rust like steel, but the chemical process of ***oxidation*** still occurs as the metal reacts with oxygen. Aluminum oxide forms a thin, white layer, which protects the underlying metal from further reaction. Although it does serve to halt the oxidation, the surface deposit may be unsightly and is a sign that the coating has begun to fail. Corrosive damage to aluminum framing is most often observed at ground level, where the curtain wall finish and protective oxidation layer are continuously eaten away by chlorides in deicing salts, such as those applied to sidewalks.

Curtain wall frames may be damaged through the process of ***galvanic action***, in which electron transfer between electrochemically dissimilar metals leads to deterioration. For instance, if steel screws or copper flashings are used on an aluminum frame, the aluminum, lower on the galvanic index, would be sacrificial and succumb to deterioration. Galvanic action can be identified by discoloration and erosion of the metal substrate.

Displacement

Curtain walls consist of framing members that are supported by anchors secured to the building structure. Should these anchors be insufficient, or deteriorate, the curtain wall can become displaced. The resulting misalignment of materials will open seams and apply stress that may deform or break curtain wall components.

Noise

Surroundings change over time, and the sound environment of the building may not be the same as the one considered during the original construction. Increased street traffic or altered airplane routes may produce noise levels that exceed those for which a curtain wall was designed.

The acoustical performance of exterior fenestration, including curtain wall assemblies, is quantified by the ***Outdoor/Indoor Transmission Class (OITC)*** rating system, which measures the loss of decibels through an assembly. A higher rating is indicative of better sound transfer resistance.

REHABILITATE OR REPLACE?

Once a design professional has identified curtain wall issues and evaluated their probable causes, multiple factors should be considered in the decision as to how best to address the observed problems.

Project Goals

Rehabilitation options are designed to improve the performance of existing systems but are not likely to match the efficiency of a new system. Performance expectations should be weighed against the returns that a restoration or replacement strategy can offer.

Disruption

The extent to which construction affects tenants and building services varies according to the scope of work. Complete removal and replacement of a curtain wall system generally has much greater impact on building usage than does rehabilitation of the existing assembly. Restoration may involve work undertaken solely from the exterior or occurring over a short period of time, with minimal impact on building operation.

Weight

Existing systems composed of single-ply glazing, and those designed to accommodate only the lower wind pressures mandated by previous building codes, will be significantly lighter than new systems. To meet current building code requirements for insulating glazing and wind load resistance, structural analysis is likely necessary, to determine whether the existing building structure has the capacity for the new loads. If not, augmenting the structural system will be required.

HOFFMANN ARCHITECTS

Wet glazing an existing glazed curtain wall

Maintenance

Rehabilitation options that include the application of remedial materials, such as sealants and films, have finite lifespans and maintenance requirements that should be considered in comparison to the longevity of a new curtain wall system.

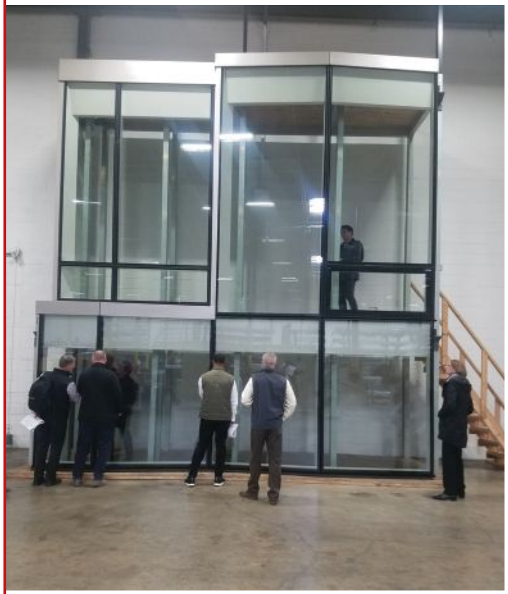
Payback Period

Replacement systems typically have a higher upfront cost than rehabilitation measures. However, over the lifespan of the system, energy savings from increased thermal performance and improved natural lighting may recoup the initial cost difference. While difficult to quantify, occupant comfort and productivity should also be weighed.

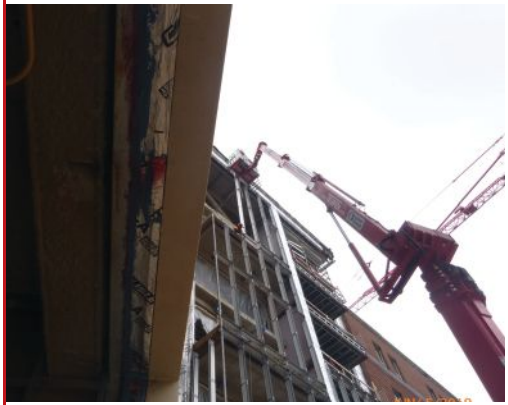
Code Requirements

Removal and replacement of curtain wall systems may trigger updated building code compliance. Rehabilitation measures not inclusive of major component

HOFFMANN ARCHITECTS



Mockups verify aesthetics and preformance



Installation of a new stick-built curtain wall

replacement are commonly considered building maintenance and so do not typically require conformance with more stringent codes.

REHABILITATION OPTIONS

Rehabilitation offers a lower-cost alternative to total replacement that can address specific deficiencies.

Gasket Replacement

Gaskets installed between the curtain wall frame and glass can be replaced. Gasket replacement can require intensive effort, however, as glazing, framing members, and adjacent elements may require temporary removal to allow access to gaskets. To ensure compatibility with the existing curtain wall frame, identification of gasket size and profile is required.

Wet Glazing

In lieu of gasket replacement, existing gaskets may be cut back and sealant applied at the glass-to-frame joint. While wet glazing spares the time and expense of removing glazing and framing elements to replace gaskets, the use of sealant requires attentive installation and ongoing maintenance. Understanding of adhesion and durability properties during the sealant selection process is critical, as incorrectly specified sealants can fail to bond properly or become weathered and brittle. Provision for expansion and movement is also essential.

Recoating

Field-applied, air-dried fluoropolymer coating systems are available for recoating of exterior aluminum curtain wall components. Recoating requires well-executed preparation to ensure success. Although fluoropolymer coatings offer durability and longevity, field-applied coatings are not expected to have the same longevity as the original, factory-applied finish.

Glass Replacement

Replacement of single-ply glass with insulating glazing units (IGUs) can greatly increase the thermal performance and sound resistance of glazed areas of an existing curtain wall. Note, however, that glass replacement does not address thermal issues in metal curtain wall framing.

Since IGUs can be exponentially greater in weight and thickness than single-ply glazing, the structural capacity and size of the curtain wall frame's glazing pocket must be considered. The sectional width of an IGU requires a large glazing cavity that an existing curtain wall frame may not accommodate.

Glass Films

Glass films provide a less invasive, less costly alternative to glass replacement. Films adhere to the glass surface and improve thermal performance by reflecting radiant solar energy. They may also be used to augment strength and breakage resistance properties. Innovations in ***low-e (low emissivity) glass coatings***, which reflect ultraviolet and infrared energy, have significantly improved thermal performance in glazing assemblies. Low-e coatings may be incorporated into a laminated assembly or IGU, or low-e films may be applied as a retrofit measure.

Films may also be used to change the appearance of glass for aesthetics or bird safety, or they may be applied to alter the ***solar heat gain (SHG) coefficient*** of the existing glass, reducing glare and improving indoor comfort. Considerations include film life span, substrate preparation requirements, and potential reduction of ***visible light transmittance (VLT)***.

REPLACEMENT OPTIONS AND CONSIDERATIONS

When restoration options cannot adequately address an existing curtain wall system's deficiencies, replacement offers an opportunity to renew the appearance of the building and wholly address curtain wall issues. There are many options to consider when selecting a new curtain wall system.

Curtain Wall System Types

In a ***stick system***, individual curtain wall components are shipped to the jobsite for field assembly. Components can be supplied in stock lengths for field cutting, or in knock-down fashion, where components are custom machined and sized by the manufacturer. With a stick assembly, all connections and seals are installed in the field.

Unitized systems are factory-assembled into large modules. Once delivered to the site, the units are installed and mated together to form the curtain wall assembly. Unitized systems tend to be of superior quality than their stick-built counterparts, as a high percentage of seals are completed in a factory setting. Site installation time and labor is less than with a stick system, although the cost of fabrication may be higher.

In a ***water management system***, the exterior surface acts as a continuous barrier to exterior air and water. In contrast, a ***pressure-equalized (zone-glazed) system*** includes a series of gaskets in the curtain wall framing: an exterior gasket to resist air pressure and an interior gasket to create a water- and airtight barrier. Organization of multiple gaskets in this manner creates an interstitial, pressure-neutral space, which blocks wind-driven rain from impinging onto the water barrier gasket and prevents moisture from being sucked into the assembly by a pressure differential between the interior and exterior.

The side of the curtain wall frame from which the glazing or spandrel panels are installed is an important property of the assembly. Building size, location, and siting should be taken into consideration when determining the system type. ***Exterior glazing*** requires elevated access, such as scaffolds, to install, while ***interior glazing*** demands that glass units be able to pass through the interior of the building. If future glazing repairs are needed, access will be dictated by the type of system selected.

Thermal Performance

High-performing ***thermal breaks*** of adequate thickness can substantially improve the performance of an aluminum curtain wall frame. Since metal is highly conductive, a separator material of low conductivity placed between the inner and outer frames can reduce heat

▶ BIRD SAFETY: MILLIONS OF BIRDS DIE EVERY YEAR IN COLLISIONS WITH GLASS

AS THE IMPACT OF GLAZING on the migratory bird population is increasingly understood, local communities are advocating for and implementing building regulation. The federal Bird-Safe Building Act of 2019, the New York State Bird-Friendly Buildings Act and the New York City Bird Friendly Glass-Int. 1482 are examples of proposed regulation.

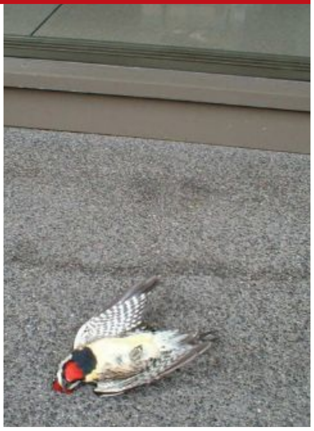
Dangers to birds, who do not perceive glass, include the reflection of sky and plant life on the glass surface, glass that allows a clear sight line through the building, and illuminated glass areas at night, all of which may attract or disorient birds. The most dangerous zones of a building are the first few floor levels, as well as areas immediately above elevated green terraces or roofs.

Free publications, such as "Bird-Safe Building Guidelines," by the New York City Audubon Society, and "Bird-Friendly Building Design," by the American Bird Conservancy, provide guidance to building owners and designers regarding potential hazards and design solutions.

As bird-safe design has become recognized as part of sustainable design, the Leadership in Energy and Environmental Design (LEED) rating system offers a pilot credit for "Bird Collision Deterrence" and provides specific steps for calculating—and improving—a facade's Bird Collision Threat Rating (BCTR).

There are many strategies available to help decrease the danger of glazing to bird safety, and the options are not limited to new construction. Bird-safe design approaches include: glass with lower reflectivity, patterning of the glazing surface, exterior shading devices to create "visual noise," and lighting timers that dim or turn off lights at night.

With increased public awareness of bird collisions and advocacy for new ordinances protecting birds, incorporating bird-friendly materials into glazed curtain wall assemblies is a design consideration that shouldn't be overlooked.



Strategies for minimizing the danger of glazing to birds include specifying glass with lower reflectivity and using lighting timers that dim or turn off lights at night.

HOFFMANN ARCHITECTS

A field water penetration test is used to investigate leaks within an existing glazed curtain wall assembly.

transfer. Modern curtain wall systems are either “thermally improved” or “thermally broken,” the latter requiring a minimum of ¼-inch-thick thermal breaks.

A system’s resistance to thermal transfer is directly related to protection against condensation, since ambient moisture tends to condense on a curtain wall frame that is losing heat. ***Condensation Resistance Factor (CRF)*** quantifies a curtain wall’s tendency to develop condensation; higher CRF values indicate better performance. Calculated using mean interior and exterior frame temperatures, CRF is a measure of average resistance and so falls short of identifying specific cold spots in the assembly that pose the greatest threat of condensation.

Glass Types

The three types of glass commonly used in current-day glazing are ***annealed, heat strengthened***, and ***tempered***. Heat-strengthened glass falls between annealed and tempered glass in terms of strength. Tempered glass, the strongest of the three, is chemically or thermally treated to provide improved strength and shatter resistance.

Building codes often have specific requirements for ***safety glass*** in hazardous locations. To meet the breakage and strength thresholds of safety standards, such as CPSC 16 CFR Part 1201 and ANSI Z97.1, safety glass is often tempered and/or laminated. Manufacturer markings, typically found in the corner of glass products, include information about safety standards with which the glass complies.

Laminated glass incorporates plastic films, such as polyvinyl butyral (PVB), between plies of glass. The laminate increases the glass’ strength and allows it to remain intact once broken. Often specified for curtain walls in hurricane-prone regions, laminated glass is also used in areas requiring blast protection or increased security.

Insulating glazing units (IGUs) incorporate multiple plies of glass separated by sealed perimeter spacers. The gap between glass plies may be filled with a noble gas, such as argon or krypton, to improve thermal performance. Perimeter spacer materials, in order of least to greatest thermal resistance, include aluminum, stainless steel, and plastic hybrid. To absorb excess moisture, the spacers may incorporate desiccant, which can increase the life expectancy of the IGU.

Electrochromic glass, also called smart glass or dynamic glass, changes tint with an applied current. Controls to manage light levels, glare, and color rendering may be operated by building users or integrated into automated systems. An alternative to blinds and shading, electrochromic glass can reduce energy demands and improve indoor comfort.

Fire Protection

The open design of a suspended curtain wall makes it susceptible to the spread of fire. For this reason, perimeter joint systems designed to resist the passage of flame and smoke are required at the void between curtain walls and fire-rated floor assemblies.

Joint systems include non-combustible ***safing insulation*** installed into the void and a sealant topping applied to bridge the void and lap over the adjacent floor and wall assemblies.

Perimeter joint systems are designated with an F-rating to indicate fire resistance time period, determined in accordance with ASTM E2307. Where field conditions differ from the tested conditions, a qualified professional should evaluate the assembly and render an engineering judgement for the joint system's F-rating.

QUALITY ASSURANCE

Whether rehabilitation or replacement is ultimately selected, quality assurance measures, including field testing for air and water infiltration, are an opportunity to evaluate expected performance. ASTM International and the American Architectural Manufacturers Association (AAMA) develop voluntary standards for the testing of materials and products. Field testing of installed assemblies may be mandated by code, required to meet voluntary accreditation standards, or used to confirm installation quality and performance.

Air and water infiltration field testing standards include:

- **ASTM E783:** Standard Test Method for Field Measurement of Air Leakage Through Installed Exterior Windows and Doors
- **ASTM E1105:** Standard Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Skylights, Doors, and Curtain Walls, by Uniform or Cyclic Static Air Pressure Difference
- **AAMA 501.1-17** Standard Test Method for Water Penetration of Windows, Curtain Walls and Doors Using Dynamic Pressure (references test chamber and water spray system per ASTM E1105)
- **AAMA 501.2-15** Quality Assurance and Diagnostic Water Leakage Field Check of Installed Storefronts, Curtain Walls and Sloped Glazing Systems (not used for operable components)
- **AAMA 503** Field Testing of Newly Installed Storefronts, Curtain Walls, and Sloped Glazing Systems (references ASTM E1105 for water infiltration and ASTM E783 for air infiltration)

To plan the extent, location, and timing of testing, the design team and building representatives should discuss quality assurance during the contract documents development phase. Independent testing agencies may be retained directly by the building owner or through the contractor as a requirement established in the contract documents.

THE FUTURE OF GLASS

It's true that many people associate glass-clad towers with an era that—literally—let energy fly out the window, but glazed curtain walls need not go the way of lead paint and asbestos. In response to the oil crisis of the 1970s, building codes were quickly and radically changed to address energy performance, but these efforts led to "sick building syndrome," in which reduced ventilation, increased propensity for condensation, and chemical additives made the "improved" buildings practically uninhabitable.

Rather than rush headlong into a prohibition on glazed curtain walls, legislators and building owners should look to design strategies that improve performance without sacrificing well-being. From patterned glass that averts bird collisions to insulating glazing and thermal breaks that minimize heat loss, curtain wall assemblies have advanced sophisticated solutions to building enclosure challenges.

As regulations tighten and manufacturers step up to meet performance demands, options will continue to evolve. That's good news for owners of glass buildings, who are understandably troubled by headline-grabbing sound bites that take aim at an easy target: the much-maligned glazed curtain wall. Fortunately, with so many rehabilitation and replacement options already available and more on the horizon, we need not eliminate glass curtain walls in our efforts to combat climate change—we need only improve them.

HOFFMANN ARCHITECTS

The TIAA Financial Services building in New York City received a curtain wall assessment and repairs.

CityCenterDC in Washington, D.C., received a façade condition assessment.

ABOUT THE AUTHOR: Daniel L. Bishop, AIA, is a Project Architect with Hoffmann Architects, Inc. (hoffarch.com), an architecture and engineering firm specializing in the rehabilitation of building exteriors. He develops building enclosure solutions, including glazed curtain wall designs, that address energy performance, longevity, waterproofing, indoor comfort, and aesthetics, while considering the logistical, structural, and practical demands of existing buildings.

+EDITOR'S NOTE

This completes the reading for this course. To earn 1.0 AIA CES HSW learning units, take the course exam posted at **BDCnetwork.com/CurtainWallCourse**