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Journal

Curtain Walls: Not Just Another Pretty Façade

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Curtain walls may be rehabilitated for aesthetic reasons or to improve energy efficiency, in addition to the need to resolve deterioration associated with weathering, age and materials or installation failures.

They're unique, they're aesthetically pleasing and they serve as a barrier to the elements. And with today's demand for energy efficiency and alternative power sources, a curtain wall provides a solution. During the last two decades, curtain wall systems have not only evolved, they've grown incrementally popular in building construction. In fact, the curtain wall is considered one of the most influential developments in the history of modern architecture.

What is a Curtain Wall?

The curtain wall is one of the most recognizable components of today's building. Modern structures feature creative and extremely efficient curtain wall systems comprising lightweight glass, stone, aluminum, marble, metal or composite materials. These systems minimize air and water infiltration by equalizing the substantial wind pressures on high-rise buildings. When designed properly, they are beautiful and highly functional in keeping the elements out and the temperate environment in.

In a nutshell, a curtain wall literally hangs from a structure like curtains hang in a home. A curtain wall system is any exterior wall that is attached to the building structure, but is not load-bearing. A true curtain wall is the façade element that forms the weather barrier for the building, but it doesn't support the structure. It can have many different appearances, but its characteristic makeup features narrowly spaced vertical and horizontal mullions with glass, stone, metal or composite panels.

A Brief History of Curtain Walls

The development of curtain walls has added another dimension to the building industry. Today, buildings faced with curtain walls are associated with modern, commercial architecture. Their streamlined look is a result of the marriage of metal framing with gleaming glass.

Curtain walls first appeared on the scene in 1918. While designing the Hallidie Building in San Francisco, Architect Willis Polk came up with the notion that a contiguous, non-load-bearing, exterior glass wall could be constructed at the face of the entire building.

By the mid-1930s, newly created technology in sheet metal and aesthetics associated with the mass-production of airplanes and automobiles paved the

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way for new developments in building construction, most notably in metal curtain wall panels. After World War II, metal and glass curtain wall systems started appearing on commercial and institutional buildings. Large areas of glass became possible in the 1950s with the newly invented float process. Insulated glazing, air conditioning and insulation technology helped solve heating and cooling issues that accompanied large areas of vision glass. The United Nations headquarters, built in 1949-1950, featured the first complete glass curtain wall.

What's In Your Curtain Wall?

A wide variety of materials and designs are available to meet different requirements in curtain wall construction. But it's not just what's in your curtain wall; curtain walls are classified by how they are built.

While there are many variations of curtain wall construction, there are five systems implemented most frequently: stick system; unit panel system; unit mullion system; column cover and spandrel systems; and point-loaded structural glazing systems.

The oldest type of curtain wall is the stick system. (Figures 1a and 1b below) It features a cladding and exterior wall system that is hung on the building structure from floor to floor. The stick system is assembled in the field using various components, including anchors, mullions, rails, vision glass, spandrel glass, insulation and metal back pans. In addition, there are various hardware components, including connectors, setting blocks, corner blocks, pressure plates, caps, gaskets and sealants. Not only is the stick system airtight and resistant to water penetration, it's cheap, and quick and easy to install, making it one of the most commonly used types of curtain walls.

The unit panel (unitized) system is a curtain wall fabricated and installed as a panel system. It contains the same ingredients as a stick-built curtain wall system, but most of the system components are factory-assembled under controlled work conditions, instead of in the field. The unitized system offers many advantages, including higher quality. It allows for fabrication lead-time and rapid closure of the building.

The unit mullion system is a compromise between the stick and unitized systems. Pre-assembled units are installed behind one- or two-story individual mullions. The advantage of this particular system is that it provides some of the factory quality control of the unitized system, costs a little less, and offers a shorter

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Figure 1a.

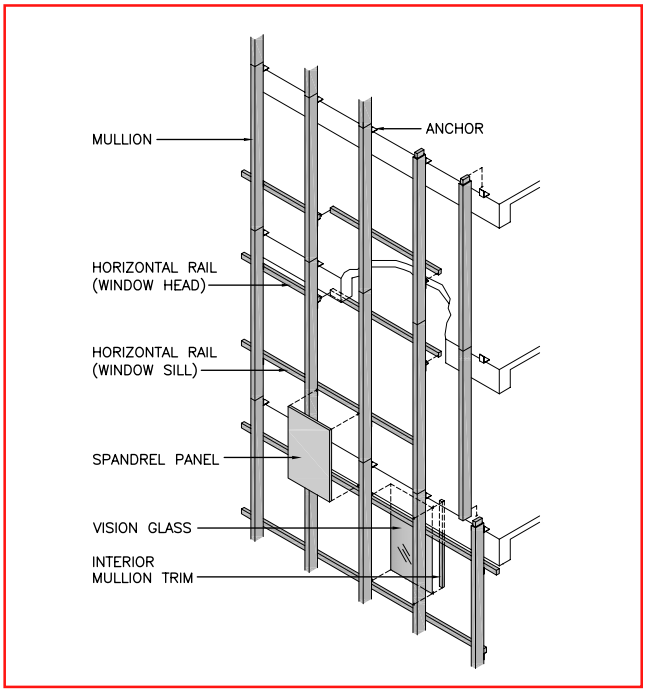

Figure 1b. Illustration demonstrates the characteristics in a typical stick curtain wall system, shown in Figure 1a to the left.

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manufacturing lead time because there is less customization than with a fully unitized system. Field labor time and building costs are more comparable with the stick system.

Column cover and spandrel systems are relatively new but are becoming increasingly popular because they offer aesthetic choices. Units can be pre-assembled or completed onsite and feature infill vision glass and spandrel panels between columns. The beauty of this system is that it allows for the structural framework of the building to be expressed in the façade and visually integrated with the fenestration. Since these systems are customized, manufacturing lead times are longer and framing construction tolerances more important, as the units must fit precisely within column bays.

Point-loaded structural glazing systems consist of laminated and tempered glass supported by proprietary hardware embedded in the glass. Unlike the alternatives, this system eliminates any visible metal framework. The variety of available support systems, including tension cables, trusses and glass mullions, offers considerable freedom and aesthetic options within varying degrees of transparency, stiffness and cost. Glass mullions are the most transparent and are the usual choice for very large, monumental spaces in spite of having very long lead times. Product and installation costs are higher than conventional frame-supported curtain wall systems.

A Room With A View: Glazed Curtain Walls

Glazed curtain walls are multiple-story exterior building walls constructed of vertical and horizontal metal framing members (mullions) that contain and support fixed glass vision panels, opaque glass panels or operable windows.

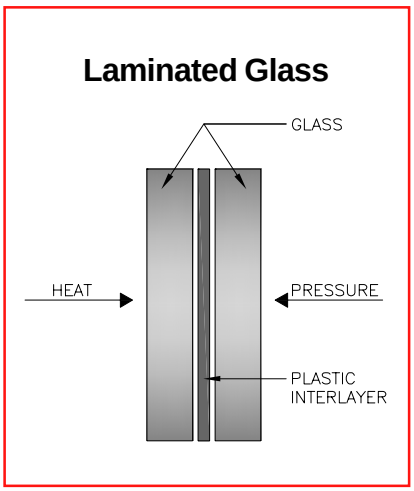

Figure 2

When designing and selecting glass for a glazed curtain wall, there are many factors to consider: safety, stability, impact-resistance, durability and cost are the most important aspects to look at in glazed curtain walls.

Float glass is ordinary glass, and can be referred to as sheet or plate glass. Unlike the other types of glass, it undergoes no special treatment to increase its strength. Float glass breaks into large, sharp shards that can constitute a safety hazard. Annealed float glass is becoming popular; annealing (heating and cooling) helps reduce breakage during handling and in service. The advantages of float glass are availability, workability and low cost.

Tempered glass is typically used when better impact resistance, increased bending strength and shatter control are required. Tempered glass shatters into very tiny pieces without sharp edges instead of large shards, providing a greater degree of safety in case of glass breakage. It has been factory-treated by a heat-tempering process that makes it resistant to breakage. Any cutting, drilling or edging must be done before the tempering process or the glass will shatter. Tempered glass also is relatively costly.

Heat-strengthened glass is stronger than standard annealed float glass, but not as strong as tempered glass. When shattered, heat-strengthened glass shards are larger than those of tempered glass, though not as sharp as annealed glass shards. Heat-strengthened glass undergoes factory treatment to increase its breakage resistance. It exhibits less distortion and is less costly than tempered glass, making it suitable for windows with limited access.

Chemically strengthened glass is similar to tempered glass in its qualities and uses. The strengthening process involves chemical tempering rather than heat tempering.

Laminated glass is made of two or more layers of any type of glass with a plastic interlayer, usually polyvinyl butyral (PVB). In the manufacturing process, a vinyl, polycarbonate or cured resin interlayer is bonded applying heat and pressure to the glass layers (Figure 2). This interlayer holds the pieces together when the glass is broken, keeping the glass from shattering. Like tempered and chemically strengthened glass, it can meet safety glazing requirements. This glass can be assembled in combination with any other type of glass. For example, combining laminated and tempered glass in a single pane produces a very strong, secure product. This combination provides an unsurpassed level of security from breakage, and is typically specified for overhead applications and areas vulnerable to impact damage, such as storm debris, bullets or a bomb blast. Laminated glass also deadens sound impact, as in airports or near highways, but is very costly due to the additional steps required in manufacturing.

Tinted/reflective glass blocks portions of

(continued on page 4)

Figure 3. Failed gasket at the base of the glazed curtain wall will permit water and air penetration.

Figure 4. The metal support system behind the mullion cover has rusted, causing it to extrude.

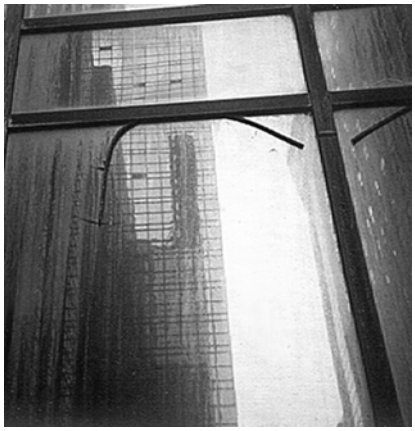

Figure 5. Loose gaskets permit water infiltration; winds can loosen and eventually blow out the glass panel. Staining is the result of contaminants that have washed into the glass panel and may lead to permanent etching.

(continued from page 3)

solar light transmittance and are typically used for aesthetic reasons or to control the amount of light and heat entering a building.

Spandrel glass is tinted, reflective-coated or film-coated and is typically used for aesthetic reasons in the fenestration. Solid insulated metal panels are often used in place of glass.

Insulating glass units (IGUs) are manufactured with a powdered gas or air-filled space between two or more panes of glass to provide energy efficiency.

What Causes Failure Of a Curtain Wall?

Many factors affect the performance of curtain walls, and can lead to deterioration and failure if not addressed in a proper and timely fashion. Weather, especially wind and rain, is a leading source of deterioration to the exterior components of a building. Gasket and sealant material selection is critical in preventing air and water infiltration; inferior quality can lead to early disintegration and failure. And proper installation of the components is key.

A curtain wall is a combination of many elements with two common interfaces between the parts: gaskets and seals. Gaskets and seals provide watertight, flexible connections between the panels and framework. Generally, curtain wall framework and panel materials rarely deteriorate; failure of those components is a result of damage. But gaskets and seals are made of compounded elastic materials that can dry, shrink and crack and lose adhesion (Figure 3).

As this happens, tiny openings occur, allowing water or air to intrude. Moisture can enter a curtain wall system and rear its ugly head in a multitude of ways.

Dripping water at window heads or wet flooring are the most obvious indications of moisture problems. If the existing curtain wall is a thermal pane system, condensation can form between the panes of glass. Insulated panels that no longer provide insulating qualities can mean that moisture is entering the system. Deformation of the framework can occur if water that has intruded the system collects and expands during freeze-thaw cycling (Figure 4).

A compromised thermal seal in the curtain wall can have several effects. The most obvious is water infiltration into an interior space. Fogged or etched thermal windowpanes can be one result of a less-than-tight seal (Figure 5). Air leaks may not be quite as obvious, but can show up as drafts, hot and cold spots at panel edges or increased heating and cooling costs.

Leaks in a curtain wall, in the forms of both air and water, can contribute to indoor air quality problems by supplying moisture for mold growth. Water or condensation can often remain hidden within the wall system and not become evident until concealed wall components experience significant deterioration and mold growth, requiring costly repairs or replacement.

Repair or Replace: Fish or Cut Bait?

Once your building's curtain wall has gone awry, it's time for a difficult decision. Are repairs sufficient or is a complete replacement in order? Weighing the benefits with the long-range costs often helps guide this determination. Rehabilitation of an old curtain wall system may refurbish the existing system, but not resolve all of the issues. And depending on the extent of the rehabilitation, the work might need to be repeated within the next decade as a maintenance task.

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Renewable Energy and Thermal Performance

Most renewable energy comes from the sun. The sun's energy can be collected and stored using electrical or mechanical devices called solar systems. Sunlight, or solar energy, is used for heating and lighting buildings, generating electricity and hot water heating and solar cooling.

Solar cells, or *photovoltaics*, convert sunlight directly into electricity (Figure 6). Solar cells are made of semi-conducting materials similar to those used in computer chips. When these materials absorb sunlight, the solar energy knocks electrons loose from their atoms, allowing the electrons to flow through the material to produce electricity.

Thin film technology has made it possible for solar cells to be used in glazed curtain walls. Thin film solar cells use layers of the semiconductor materials only a few micrometers thick. The solar cells are laminated and make up the solar modules, which are the fundamental building blocks of photovoltaic systems. Solar panels include one or more photovoltaic modules assembled as a pre-wired, field-installable unit. A photovoltaic array is the complete power-generating unit, consisting of any number of photo-voltaic modules and panels.

As technology has progressed, the thermal performance of newer systems has improved greatly. Replacement with new panels or augmentation with additional panels can help achieve greater thermal efficiency. The thermal performance of insulating glazing depends mainly on the solar energy transmittance through the glazing and the reflectance of the glazing. Reflective coatings help to minimize interior solar heat gain by reflecting solar energy.

Glass and glazing choices are instrumental to the curtain wall's thermal performance. Single glazing has poor thermal performance and is suitable only where interior and exterior temperatures do not vary substantially. If the curtain wall system comprises single-pane, non-insulating glass panels, a fair amount of heat loss/gain may take place through the curtain wall.

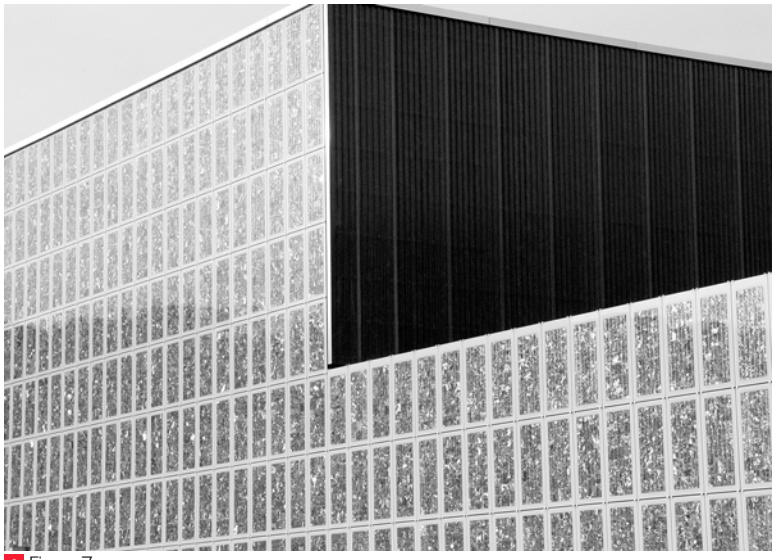
Double-pane and triple-pane glass panels can effectively enhance thermal performance in a curtain wall. A double-glazed panel combines two glass panels, creating an air space between the panels, while a triple-glazed panel has two separate air spaces. Use of these panels provides improved insulation and condensation control, and allows for between-glass shading options, such as blinds or pleated shades.

Double-skin systems, which use a ventilated space between the inner and outer walls, are becoming increasingly popular in the U.S. The ventilated space helps conserve energy by balancing the temperatures surrounding the curtain wall. During the heating season, the space acts as a buffer between the exterior and interior and can be used to temper the cooler outdoor air. During the cooling season, warm interior air is exhausted into the ventilated space.

V Below, Figure 6 shows a factory built with spandrel glass incorporating photovoltaic cells.

> At right, Figure 7 shows a sports stadium with solar cells incorporated into the curtain wall.

Λ Figure 6



Λ Figure 7

Photos courtesy of Open Energy, a manufacturer of photovoltaic glazing systems for curtain walls, skylights and canopy systems. (openenergycorp.com)

Figure 8

Figure 9

Figure 10

Figure 11

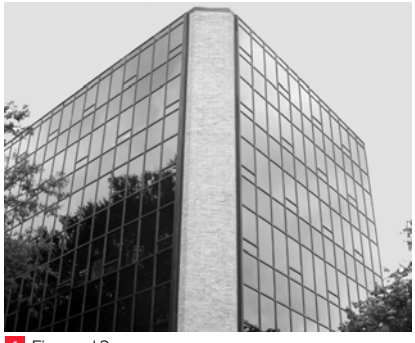


Figure 12

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There are a variety of assessments to measure how well your curtain wall system is performing. These tests include measuring air leakage; water resistance; water drainage; wind resistance; ability of the curtain wall to support its own weight; safety; and thermal performance.

If a curtain wall is intact but its gaskets and seals are deficient, rehabilitation might be limited to replacement of gaskets and seals, depending on the availability of the correct gaskets. When replacement gaskets cannot be obtained, wet sealing the assembly might offer the only option. Replacing troubled panels can resolve moisture infiltration and achieve greater thermal efficiency.

Extensive repairs can turn into expensive repairs, and in some cases it might be more economically practical to replace that failing curtain wall.

A building owner might opt to overhaul a curtain wall for simple aesthetic reasons. The curtain wall might function properly, but its appearance cries for an update, which can be accomplished by curtain wall replacement.

Design Considerations For Replacement

During the design and construction process of a replacement curtain wall, there are several important points to take into consideration. Cost is a factor; therefore, a choice must be made between a custom curtain wall system and a standard curtain wall system. Custom curtain wall systems are designed and built specifically for one particular project. Standard systems utilize manufacturers' stock components and details, and are generally less expensive than custom systems.

Preventing water penetration is a primary focus when designing and constructing a curtain wall. Steps to prevent moisture migration are critical. Many curtain wall systems include condensation drainage provisions, such as condensate gutters, that collect and weep condensate from spandrel areas to the exterior. Water penetration resistance is a function of glazing details, frame connection and drainage details, weather stripping and frame gaskets, and perimeter flashings and seals.

Building code requirements govern many aspects of curtain wall design, such as thickness and type of glass required for a certain application, maximum area of glass permitted, design wind loads and firestopping of the cavity behind the wall at each floor.

In high-rise curtain walls, the spread of fire from floor to floor is prevented by firestops, which are fire-resistant materials placed in concealed hollow spaces of the building frame. Close cooperation between the architect and the builder in the early stages of design is essential to ensure that proper firestops are provided and potentially hazardous conditions are eliminated.

Fire safing and smoke seal at gaps between the floors and the back of the curtain wall are essential to slow the passage of fire and combustion gases between floors. Spandrel areas must have non-combustible insulation at the interior face of the curtain wall. Fireman

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< From top to bottom, figures illustrate how a curtain wall is reclad. Figure 8 shows the curtain wall prior to replacement. Figure 9 shows the horizontal rail attached to the structural mullion. Figure 10 shows new veneer rails attached to existing curtain wall mullions. Figure 11 shows the installation of new vision, spandrel and insulation panels. Figure 12 shows the completely reclad curtain wall.

representative projects

Curtain Wall Rehabilitation

These representative projects included curtain wall rehabilitation:

Chase Manhattan Centre
Wilmington, Delaware
Concrete panel curtain wall

780 Third Avenue
New York, New York
Granite panel curtain wall with metal-framed windows

Altria Corporate Headquarters
New York, New York
Granite panel curtain wall with metal-framed windows

MetLife Building
New York, New York
Concrete panel curtain wall with metal-framed windows

101 Avenue of the Americas
New York, New York
Brick masonry curtain wall with metal-framed windows

Hoffmann-La Roche Building 76
Nutley, New Jersey
Glass and marble panel curtain wall

Pfizer Inc. World Headquarters
New York, New York
Aluminum-framed glass curtain wall

1251 Avenue of the Americas
New York, New York
Metal and glass curtain wall

1425 New York Avenue
Washington D.C.

American Express Tower
New York, New York

Bristol-Myers Squibb Pharmaceutical Research Facility
Wallingford, Connecticut
Steel structure supports curtain wall with granite or concrete spandrel panels and metal-framed ribbon windows

Montgomery College Campus Tower Building
Rockville, Maryland
Aluminum-framed curtain wall with glass and metal spandrel panels

Verizon
240 E. 38th St
New York, New York
Limestone, granite and aluminum-framed insulated glass curtain wall

The Ford Foundation Headquarters
New York, New York
Granite panel curtain wall with metal-framed windows

American Express Tower
New York, New York
Polished granite curtain wall with aluminum-framed windows

633 Third Avenue
New York, New York
Masonry curtain wall with aluminum-framed insulated glass windows

One Beacon Street
Boston, Massachusetts
Pre-cast concrete panel curtain wall with aluminum-framed glass windows

One Magnificent Mile
Chicago, Illinois
Aluminum-framed polished granite and glass curtain wall system

GMH Management, Inc.
King of Prussia, Pennsylvania
Curtain wall system with aluminum-framed, double thermal pane windows and pre-cast concrete panels

Verizon Headquarters
1095 Avenue of the Americas
New York, New York
Aluminum-framed insulating glass and marble panel curtain wall

25 Sigourney Street
Hartford, Connecticut
Metal-framed glass and brick masonry veneer curtain wall

1211 Avenue of the Americas
New York, New York
Metal and glass curtain wall

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knock-out glazing panels are often required for venting and emergency access from the exterior. Generally, knock-out panels are made of fully tempered glass, which allows complete fracturing of the panel into small pieces and relatively safe removal from the opening.

Evaluation and Maintenance

Once you've invested in a new curtain wall, you'll want to optimize the benefits from that investment. Routine inspections and evaluations will help identify any issues that can crop up and compromise your curtain wall's efficiency.

Regular checks of the system are paramount to resolving problems. A thorough evaluation will include surveying the condition of the various gaskets and seals, inspecting the system joints to ascertain if the framing components are admitting water into the curtain wall system, and evaluating the thermal insulation capabilities of the vision and insulating panels of the system.

Facility managers must routinely examine gaskets or sealants for splits, breaks or openings and replace any that have failed.

The three keys to a maintenance program are:

- Follow the preventive maintenance program recommended by the manufacturer of the system or product installed.

- Schedule regular inspection, cleaning and prompt repair of minor problems. It is essential that inspection reports of problems be referred to management for long-range planning and action. Any repairs or replacement of hardware should be performed by professionals.

- Maintain written records of the maintenance procedures to document problems and their solutions. This facilitates long-term tracking of the maintenance program, improving the ability of maintenance personnel to make effective decisions.

Conclusion

Curtain wall performance is essential to any façade, in terms of function and aesthetics. As with any building envelope component, curtain walls need repairs and sometimes replacement to combat the effects of deterioration and allow maximum performance of a building. With routine inspections and a consistent maintenance schedule, any rehabilitation can be kept to a minimum. ■

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