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Windows:

An Integral Part of the Building Envelope

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With the reports from recent clinical research substantiating the importance of natural lighting and ventilation in workplace productivity, health, and well-being, window design has become about more than building aesthetics or even energy efficiency. From the capacity to create dramatic gestures in glazing afforded by glass curtain wall technology, to the improvements in thermal transfer made possible by chemical advances in the glazing industry, to the race to develop carbon-neutral strategies like "daylighting" that reduce demand on the power grid, windows have taken on multi-faceted significance in building design. Even from humankind's earliest attempts at creating boundaries, we've found that our most successful efforts establish meaningful connections between inside and outside, which establish our control over the delimited structure by contextualizing that order against the vastness of the world beyond.

While it is tempting to give little thought to existing wall openings beyond immediate maintenance demands, periodic window repair or replacement projects are an opportunity to rethink the window design and to determine if the existing system meets the needs of the structure as a whole. Although window rehabilitation options may be limited by any number of factors, from landmark regulations to structural limitations to aesthetic concerns, within these limits it is often possible to improve energy efficiency, optimize light transmittance, and shape building appearance both inside and out. And, because deterioration in one building component can adversely affect interrelated components, addressing distress or inefficiency in the fenestration not only will impact other building systems, but, as new research has touted, will shape one critical part of the building dynamic: the occupants.

Whether the goal is historic preservation or an aesthetic overhaul, window rehabilitation improves appearance while optimizing performance.

A Window Components Primer

Before considering rehabilitation options for existing windows, it's important to know the composition and properties of the existing wall system, so that an appropriate, compatible repair or replacement design can be developed. An architect or engineer experienced in window rehabilitation can determine the structural and material properties of your windows, as well as their condition, through an investigation. To assess your options, the design team will consider:

Wall System Construction

In contrast to a *glass curtain wall*, which supports only its own weight, not that of the building structure, and

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Double-hung

Casement

Sliding

Awning

is composed mainly of glass units anchored to a frame, a *punch opening*, or *exterior wall opening*, is an open space in an exterior wall around which the weight of the wall is directed. The opening can remain unobstructed, as on a balcony or terrace, or can be filled with a window, louver, door, or storefront. Whether your building is constructed with load-bearing walls and punch openings or glass curtain walls will determine which options are available for retrofit or rehabilitation.

For the purpose of this article, we will consider not the glazed curtain wall, which has its own considerations and options, but the standard punch opening window. The basic components:

- **Lintel.** The horizontal section at the top of the opening, which distributes the load of the wall above the window into the vertical sections on both sides. To accomplish this structural task, the lintel employs one of various types of arches, or it manages the load via sturdy materials, such as structural pre-cast concrete, reinforced cast-in-place concrete, stone, or steel angles.The lintel system also serves as a water infiltration barrier by means of flashings.
- **Sill.** The horizontal section at the bottom of the opening, which protects against water infiltration and carries the load of the window into the wall below.
- **Jambs.** The vertical wall sections to each side of the opening, which carry the load transferred by the lintel into the wall below. Depending upon the size of the opening, they may need to be reinforced.

Window Type

If you own a home, you've probably heard of "double-hung" and "casement" windows, as well as "vinyl replacement windows." These terms represent two methods of classifying windows: by operability and by framing material. The first two terms refer to the manner in which the operable *panes*, or framed sheets of glass, move relative to the *frame*, or fixed portion of the window. The frame structurally secures the window to the perimeter of the wall opening, while the panes support the *glazing*. Spacers, seals, gaskets, and other accessories used to fit the glass within the frame are also considered part of the glazing, not just the glass sheet itself. Depending upon the style and operability of the window, various hardware elements, such as locks, weights, balances, handles, stops, hinges, or weather stripping, complete the system.

An overview of some common window types, classified by operability:

Single or double hung. Two sashes that slide vertically in adjacent planes. "Single hung" refers to one operable sash, "double hung" to two. Taller openings may have triple hung windows. Although familiar to many homeowners, this window type is also widely used on high rises, due to its ease of operation and good wind resistance.

Sliding. Operate like their single- or double-hung cousins, but slide horizontally, rather than vertically. Maintenance of track hardware to remove dust or accumulated particles is critical for proper operation.

Casement. One or more sashes that swing outboard or inboard from the vertical frames. Although common on residential applications, consideration must be taken with high-rise commercial use, because the sash and hardware have lower wind pressure tolerance.

Awning. One or more sashes that swing outboard from the upper frame. Their name derives from the weather protection offered by the window in the open position, when it creates a canopy-like projection above the opening.

Hopper. Operate like the awning

Curtain Wall

Historic Steel

Fixed

style, but swing outboard from the lower frame, rather than the upper one.

Pivoted. A single sash that rotates around a vertical or horizontal axis centered on the frame. Easy to clean, but offer little resistance to wind stress.

Fixed. Do not need operable hardware, and so achieve the maximum glass area for a given opening. Also known, more familiarly, as "picture windows."

Framing Material

All of the styles of windows reviewed above can be made from a variety of materials, so it is important when assessing both existing windows and replacement and repair options to consider not only the operability of the window, but its material composition, as well.

Aluminum. The most widely preferred material for commercial applications due to its low cost, versatility, light weight, ease of maintenance, broad availability, and variety of finishes. Aluminum windows have a poor reputation for thermal integrity, which has been addressed by incorporating thermal breakers.

Steel. Although broadly used before the development of its aluminum counterparts, steel's higher cost, density, and difficult maintenance (due to possible corrosion) have substantially reduced its prevalence. Nevertheless, steel windows have found their role in the industry whenever fire resistance is required.

Wood. Also used in the past on commercial applications, especially on large institutional or educational buildings. In both replacement and new construction, aluminum windows are now usually specified in place of wood. When wood windows are chosen, it is generally for aesthetic reasons, or for replacement of historic windows in residential and light commercial applications. Wood windows have a good reputation for thermal and insulating qualities, but proper maintenance and care to reduce exposure to moisture are crucial to avoid rapid deterioration. Wood frames can also be clad with vinyl or aluminum.

Vinyl. Made from polyvinyl chloride (PVC), a rigid and tough material extruded to form the window elements at a reasonable cost. Vinyl offers good sound and thermal insulation properties. However, limitations on size and finish colors, vulnerability to fire, sensitivity to extreme cold and to ultraviolet light, and difficulty with refinishing have limited vinyl window use primarily to residential applications.

Identifying Problems

When an architect or engineer evaluates an existing window, he or she will first establish the style and composition of the window system, then investigate common sources of trouble typical to the type of window assembly and materials. In general, the architects or engineers will look for:

Water Infiltration

Catching leaks early. Water infiltration can be as minor as small droplets on the interior after a storm, or as major as ongoing moisture intrusion that leads to structural degradation and mold issues. In both instances, it is critical to determine and address the root cause of the water entry, because even a minor leak over time can begin to cause serious damage.

Finding the source. Moisture-related failures can occur in the window itself, in the rough opening around the window perimeter, and sometimes in the adjacent wall assembly entirely separate from the window. It is a good idea to have a building envelope consultant confirm the source of the failure, so that the most appropriate repair program can be developed for the window or windows in question.

Ventilation

With the arrival of HVAC (Heating

Window Replacement Project

Existing Windows


Sealant failure at window exterior.


Damaged flashing at window head.


Water intrusion and interior damage.

Replacement Process


Window removed; wall opening ready for replacement window installation.


Installation of replacement windows.


Installation of new flashing at window head.


Reconstruction of brick exterior wall after flashing replacement.

Completed Project

Ventilation Air Conditioning) systems, windows have become only a secondary or emergency means of ventilation. Moreover, in order to maintain HVAC system efficiency, windows need to remain air-tight to minimize heat and humidity transfer. The same seals that protect against moisture infiltration also guard against unwanted air transfer. Drafts observed near windows, usually accompanied by water entry, can be signs of compromised glazing, perimeter seals, or weather stripping.

Thermal Performance

With the advent of Insulated Glass Units (IGUs), Low-E coatings, and other heat-conserving developments, today's window technology has become advanced to the point where high-end thermally improved windows can rival the insulation value of a stud-cavity wall. But rising energy costs aren't the only reason to address thermally deficient windows; exposure to exterior temperature and humidity fluctuation through insufficiently insulating windows carries a risk of damage to interiors due to condensation. Moisture in the air will condense on any surface in a room colder than a specific temperature, or *dew point*, which is associated with the relative humidity. Windows with poor thermal performance readily conduct cold ambient temperatures, leading to moisture condensation on windows and surrounding surfaces, and, eventually, water damage and possible fungal growth.

The occurrence of condensation may merely be a sign that the interior is being maintained at high heat and humidity when it is cold outside. However, under normal conditions, frequently occurring condensation is a sign that the windows are performing poorly with respect to thermal insulation. Check the accompanying table to determine the most likely explanation for recurring condensation in various locations on the window assembly.

Window Exposure

One of the most important considerations for evaluating existing windows and scheduling repairs has nothing to do with the window itself. The location of a window on the façade and its exposure to the exterior elements must be considered when determining the window's risk for damage and deterioration, or when assessing any deficiencies in its performance.

Building location. In general, factors to consider for the exposure of a building include:

- the height of the building relative to other adjacent buildings,
- the density of the surrounding buildings, and
- the geography and topography of the area, such as the climate and proximity to the coast.

In addition to the general exposure characteristics of the building as a whole, each individual window is subjected to a unique set of environmental forces which impact its risk for deterioration.

Window orientation. When reviewing windows for water infiltration, the design team must consider the prevailing direction for wind-driven rain, as windows in that orientation are at a much greater risk for moisture ingress than are leeward facing windows. The orientation of a window is also important to thermal performance evaluation, as exposed windows on a south façade receive considerably more sunlight than do windows on the north face.

Overhang protection for windows can be provided by various building components, such as roofs, awnings, cornices, decorative elements, or balconies. Even the degree to which a window is recessed into a wall cavity effects its exposure risk, because rain and snow will drain clear of a recessed window. Below the window, architectural features such as sills, ledges, terraces, and other elements can contribute to the possibility of moisture infiltration from standing water or snow drifts at the base of the window.

Noise exposure. Especially in dense urban areas or adjacent to noise-producing equipment, windows' level of noise control can be a critical performance criterion for occupants' comfort.

Lateral forces. In some orientations and locations, wind pressure and suction forces can be severe enough to compromise a window's structural integrity or capacity for air infiltration protection. Some warning signs include: cracked glass, misaligned frames, difficult operation, and heavy drafts.

Fire exposure. To insure that windows adequately protect against the spread of fire, building codes and zoning ordinances establish a fire separation distance, or space between buildings. Depending on this distance, building codes also dictate the allowable area of

Investigating Condensation

Moisture Location		Probable Deficiency
On the interior surface of the window	→	Inadequate thermal performance of glazing unit
Between the panes of an Insultated Glazing Unit (IGU)	→	Failed hermetic seal
On the window frames	→	Missing or insufficient framing insulation or thermal breaks

protected and unprotected wall openings, taking into account additional fire resistance measures, such as sprinkler systems. Window assemblies and materials that have been fire tested are considered protected openings. Your design professional can establish how the building code and adjacent buildings affect your windows.

Window Selection Criteria

Selecting new windows can seem daunting, as there are countless alternatives from which to choose, but systematic review of window needs and options can reap long-term rewards.

1. **Review the wall system construction.** Determine whether the windows are to be curtain wall, storefront, window wall, or punched windows; the selection will often be determined by the window opening sizes, the structural requirements for the windows, and the cost differences between types. Evaluate the existing conditions of the surrounding building elements, such as lintels, flashings, and exterior wall materials, to determine if they are watertight.
2. **Select the frame materials and window type.** Consider with the architect the pros and cons of each material and window type that can be installed on the building. Once a selection has been made, it is important to discuss frame finishes. Today's windows have a wide variety of available finishes, with a broad color palate, as well as performance characteristics such as fade and scratch resistance.
3. **Consider window performance ratings.** Generally the main criteria for the performance of a window are structural capacity, ventilation, waterproofing, light transmittance, and thermal and acoustic insulating capacities. The window manufacturer should be able to provide test results confirming that the proposed window meets or exceeds the current standard for each performance criterion.
4. **Check building codes.** New and rehabilitated windows must meet code regulations for the performance characteristics listed above, as well as for fire resistance, emergency egress, energy conservation, and wind resistance. Minimum performance standards and applicable codes vary depending upon the authority having jurisdiction over the project; consult your architect to guide you through this process. Historic or landmark structures may have additional restrictions on window rehabilitation options. For applicable regulations, check with the local historic preservation commission.
5. **Determine design goals.** Selection of new windows provides an opportunity to make more dramatic functional and aesthetic changes to the building envelope. Reconfiguring the fenestration can open up glass area for greater viewing range, improve window operability for better passive ventilation and reduced drafts, and update the overall exterior appearance of the building.

Energy Considerations

Windows are the modulators of heat, light, and air. At the perimeter of a building, their effect on the interior environment can be significant. High-performance windows reduce both heating and cooling costs by preventing heat transfer, and they also provide more comfortable surroundings for occupants by stabilizing the temperature throughout the interior space.

Installation of higher-insulating windows can mean reductions in both the size and output of heating and cooling systems. While a majority of heating is provided by central HVAC systems in commercial buildings, additional heating is often needed near conventional windows, where heat loss is greatest. In buildings in which thermally efficient windows have been installed, perimeter heating may no longer be necessary, and demand on mechanical systems can be reduced overall due to lower peak heating and cooling loads.

Another reason to consider redesigning windows is to reduce electricity consumption. A window replacement project offers an opportunity, where structurally feasible, to enlarge glass area, admitting more daylight into the building interior. This *daylighting* in turn reduces the need for artificial illumination, enabling some lights at the building perimeter to be switched off during the daytime.

Occupant Comfort

Daylighting has become a hot topic in environmentally sound building design not only for its reduction in energy consumption, but also for its impact on building occupants. Attention has been paid in recent years in the scientific and architectural literature to the positive effects of natural light on health and productivity, but the importance of connecting interior spaces with the cycle of the sun has been incorporated into building design for centuries.

More might seem to be better when it comes to visible transmittance and window selection, but large, non-tinted windows on a west-facing computer center might mean increased interior temperatures and closed blinds for half the day. Care must be taken to balance building use with glare control, heat moderation, and light distribution to achieve a pleasing indoor atmosphere.

A Window's Work Is Never Done

Windows have a greater impact on the comfort of occupants than does

(continued on page 8)

representative projects

Windows

Hoffmann Architects specializes in remediating distress and failure at building exteriors. Because windows are particularly prone to water and air infiltration, they require special attention. Hoffmann Architects' design team understands the critical interplay between windows and other façade elements. As such, project teams treat windows not as isolated units, but rather as a fenestration system which depends, both aesthetically and structurally, on related building components.

Hoffmann Architects has worked in a variety of capacities on window projects. A sampling:

Burr Hall
Eastern Connecticut State University
Willimantic, Connecticut
Window Replacement:
Addressed deterioration and water infiltration conditions and improved efficiency.

Rockefeller Center Complex
New York, New York
Weathertightness/Air Infiltration/Cost-Benefit Study:
Analyzed over 40,000 windows in 12 buildings.

Various New York City Public Schools
New York, New York
Window Failure Investigation:
Inquired into premature deterioration of replacement windows.

The Sheffield
New York, New York
Window Consultation:
Addressed recurrent water infiltration.

Former Southern New England Telephone Headquarters in New Haven, Connecticut. *Historic Window Refurbishment: Restored steel windows to preserve historic materials and provide cost savings.*

Schering-Plough Buildings
Summit, New Jersey
Window Replacement:
Mitigated air and water infiltration and improved heat retention.

Pfizer, Inc. World Headquarters
New York, New York
Window Replacement:
Upgraded lot-line windows for high-performance-demand exposure.

Verizon Communications
New York, New York
Window Replacement:
Rehabilitated leaks and inefficiencies at fourteen buildings.

Art and Architecture Building
Yale University
New Haven, Connecticut
Landmark Window Replacement Consultation:
Investigated window failure and collaborated on new design.

Various Fairfield Public Schools
Fairfield, Connecticut
Window Rehabilitation:
Provided investigation, restoration, replacement, and maintenance master planning services.

Scholastic Inc. Global Headquarters
New York, New York
Landmark Window Rehabilitation:
Restored antique windows and designed historically accurate replacements where needed.

The Bank of New York
New York, New York
Window Investigation:
Addressed heat loss from 1,500 original steel windows.

Folger Shakespeare Library in Washington, District of Columbia. *Historic Window Assessment: Evaluated eleven window types for efficiency, waterproofing, and finish integrity.*

(continued from page 6)

Where Is This Water Coming From?

Water pooling at sill.

Stains on frame.

Possible sources:

- Misaligned or corroded frames.
- Cracked or loose seals.
- Irregular weather stripping.
- Gaps in joints.
- Loose fasteners.

Interior finish damage.

Exterior finish damage.

Possible sources:

- Missing or damaged flashing.
- Faulty perimeter sealant.
- Blocked weep holes.
- Wall system failure.

any other building element. Acting as "gatekeepers," they permit entry of desirable exterior forces (light, air), while locking out undesirable ones (water, cold, heat, noise, pollution). They must withstand the pressures of wind, ice, temperature fluctuations and extremes, and ultraviolet radiation, while remaining ever beautiful, ever youthful, ever fluidly operational. With such continuous and critical demands, windows need attentive care and maintenance in order to meet these challenges without distress or failure.

Because the optimal performance of windows is essential to building function, replacing improperly installed or selected windows or updating inefficient windows can dramatically impact building operation overall. Whether considering current trends in sustainable design or ancient principles of interior to exterior relationship, you'll find that windows provide much of a building's vitality and ambiance. Making their proper function a priority is an investment in the integrity and sustainability of building systems—inside and out. ■

JOURNAL is a publication of Hoffmann Architects, Inc., specialists in the rehabilitation of building exteriors. The firm's work includes investigative and rehabilitative architecture and engineering services for the analysis and resolution of problems within roofs, facades, glazing, and structural systems of existing buildings, plazas, terraces and parking garages.

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