Windows: An Integral Part of the Building Envelope

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WITH REPORTS FROM CLINICAL RESEARCH SUBSTANTIATING THE IMPORTANCE OF NATURAL LIGHTING AND VENTILATION IN WORKPLACE PRODUCTIVITY, HEALTH, AND WELL-BEING, WINDOW DESIGN HAS GONE BEYOND BUILDING AESTHETICS AND ENERGY EFFICIENCY. FROM THE CAPACITY TO CREATE DRAMATIC GESTURES IN GLAZING—AFFORDED BY GLASS CURTAIN WALL TECHNOLOGY—TO IMPROVEMENTS IN THERMAL TRANSFER MADE POSSIBLE BY CHEMICAL ADVANCES IN THE INDUSTRY, AND THE RACE TO DEVELOP CARBON-NEUTRAL STRATEGIES LIKE DAYLIGHTING IN ORDER TO REDUCE DEMAND ON THE POWER GRID, WINDOWS HAVE TAKEN ON A MULTIFACETED SIGNIFICANCE IN BUILDING DESIGN.

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

A window components primer

Before considering rehabilitation options for existing windows, it is important to know the composition and properties of the existing wall system to develop an appropriate, compatible repair or replacement design.

An architect or engineer experienced in window rehabilitation can determine the structural and material properties of the windows, as well as their condition.

Wall system construction

In contrast to a glass curtain wall—which supports only its own weight (not the weight of the building structure), and 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 it can be filled with a window, louver, door, or storefront. Whether the building is constructed with loadbearing walls and punch openings or glass curtain walls will determine the options available for retrofit or rehabilitation.

For the purpose of this article, the author will examine the standard punch-opening window, and not the glazed curtain wall, which has its own considerations and options. The basic components of a punch-opening window are:

- **Lintel**: It is 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. In order 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 precast or reinforced cast-in-place concrete, stone, reinforced concrete masonry unit (CMU), or steel angles. The lintel system also serves as a water infiltration barrier by means of flashings.
- **Sill:** A horizontal section at the bottom of the opening, the sill protects against water infiltration and carries the load of the window into the wall below.
- **Jambs:** As the vertical wall sections to each side of the opening, jambs carry the load transferred by the lintel into the wall below. Depending on the size of the opening, they may need to be reinforced.

Window type

The terms "double-hung vinyl windows," "casement wood windows," and "pivoted aluminum windows" represent two methods of classifying windows—by operability and 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 employed to fit the glass within the frame are also considered part of the glazing, not just the glass sheet itself. Depending on the style and operability of the window, various

Sealant failure at the exterior of a window.

When open, awning windows create a canopy-like projection, offering protection from the elements.

hardware elements, such as locks, weights, balances, handles, stops, hinges, or weather stripping, complete the system.

Listed below are some of the common window types, classified by operability:

- **Single- or double-hung:** Two sashes sliding vertically in adjacent planes. "Single-hung" refers to one operable sash, and "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:** These windows operate like their single- or double-hung cousins, but slide horizontally. Maintenance of track hardware to remove dust or accumulated particles is critical for proper operation.
- **Casement:** One or more sashes swinging 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 swinging outboard from the upper frame. The name is derived from the weather protection offered by the window in the open position, when it creates a canopy-like projection above the opening.
- **Hopper:** Operates like the awning style, but this window swings outboard from the lower frame, rather than the upper one.
- **Pivoted:** A single sash rotating around a vertical or horizontal axis centered on the frame. Easy to clean, but offers little resistance to wind stress.
- **Fixed:** Also known, more familiarly, as "picture windows," they do not need operable hardware, and so achieve the maximum glass area for a given opening.

Framing material

All of the styles of windows reviewed in this article can be manufactured 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 is the most widely preferred material for commercial applications due to its low cost, versatility, lightweight, 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 barriers.

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.

In the past, wood was used 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 timber. While wood windows are chosen, it is generally for aesthetic reasons, or for replacement of historic windows in residential and light commercial applications. While wood windows have a good reputation for thermal and insulating qualities, 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 for added protection.

Made from polyvinyl chloride (PVC), vinyl is a rigid and tough material extruded to form the window elements at a reasonable cost. It offers good sound and thermal insulation properties. However, limitations on size and finish colors, vulnerability to fire, sensitivity to extreme cold and ultraviolet (UV) light, and difficulty with refinishing have limited vinyl window use to primarily residential applications. An alternate material to vinyl is fiberglass, which has similar sound and thermal insulation properties, but is more durable. However, fiberglass windows are more costly than vinyl and need to be painted from time to time.

Figure 1

Investigating Condensation

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

Reasons for condensation on a window assembly.

An example of damaged flashing at window head.

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.

Water infiltration

Water infiltration can be as minor as small droplets on the interior after a huge storm, or as major as ongoing moisture intrusion leading 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 can cause serious damage over time.

Moisture-related failures can occur in the window itself, in the rough opening around the perimeter, and sometimes in an adjacent wall assembly. It is good practice to have a building envelope consultant confirm the source of failure, so as to develop the most appropriate repair program for the window or windows in question.

Ventilation

With the arrival of HVAC systems, windows have become a secondary or emergency means of ventilation. Moreover, the windows need to remain airtight to minimize heat and humidity transfer as well as maintain the HVAC system's efficiency. The same seals protecting 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 insulating glass units (IGUs), low emissivity (low-e) coatings, thermal breaks, and other heat-conserving developments, today's window technology has become very advanced to the point where high-end, thermally-improved windows can rival the insulation value of a stud-cavity wall. But rising energy costs are not 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 (RH). 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 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 the windows are performing poorly with respect to thermal insulation. Check Figure 1 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

Assessment of the historic windows on this rare book research library involved evaluation of 11 distinct window types for efficiency, waterproofing, and finish integrity.

with the window itself. The location of a window on the façade and its exposure to exterior elements must be also considered when determining the unit's risk for damage and deterioration, or when assessing any deficiencies in its performance.

In general, the many factors to consider for the exposure of a building include:

- the structure's height relative to adjacent buildings;
- density of surrounding buildings;
- geography and topography of the area, such as the climate and proximity to the coast; and
- orientation/elevation on the building (sun exposure).

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

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 greater risk for moisture ingress than 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 windows on the north face.

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

A window's level of noise control, especially in dense urban areas or adjacent to noise-producing equipment, can be a critical performance criterion for occupant comfort. Additionally, the selection of glass should achieve a balance of visible light transmittance and avoidance of glare.

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;
- heavy drafts; and
- cloudy appearance between panes.

To ensure 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 protected and unprotected wall openings, taking into account additional fire-resistance measures (*e.g.* sprinkler systems). Fire-tested window assemblies and materials are considered protected openings. The design team can establish how the building code and adjacent buildings affect the window sizes, number, and placement.

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.

Review the wall system construction

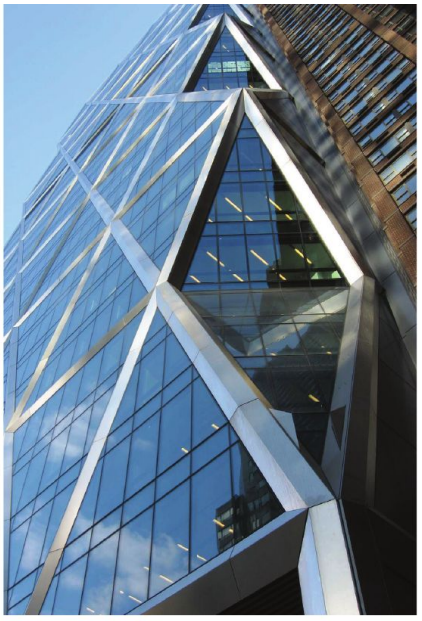
Determine whether the windows are to be curtain wall, storefront, window wall, or punched windows; the selection will often be determined by the opening sizes and structural requirements for the windows as well as the cost differences between types. Investigate the existing conditions of the surrounding building elements, such as lintels, flashings, and exterior wall materials, to determine if they are watertight. Evaluate what repairs need to be made to surrounding building materials prior to the installation of repaired or new windows.

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, including aesthetics and warranties. Once a selection has been made, it is important to discuss frame finishes. Today's windows have a variety of available finishes, with a broad color palette, as well as performance characteristics such as fade and scratch resistance.

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.



A glass curtain wall supports only its weight and not the weight of the building structure. It is composed mainly of glass units anchored to a frame.

Reconstruction of brick exterior wall after flashing replacement.

The manufacturer should be able to provide test results confirming the proposed window meets or exceeds the current standard for each performance criterion. Performance standards—such as American Architectural Manufacturers Association/Window and Door Manufacturers Association/Canadian Standards Association (AAMA/WDMA/CSA) 101/I.S.2/A440-08, *North American Fenestration Standard (NAFS)/Specification for Windows, Doors, and Skylights*—have been created to assist in the selection of the proper window unit for the type, location, and use. Also, the National Fenestration Rating Council (NFRC) labels guide selection of the proper window relevant to energy compliance.

Check building codes

New and rehabilitated windows must meet code regulations for the performance characteristics that were listed earlier in the article, as well as for fire resistance, emergency egress, energy conservation, and wind resistance. Minimum performance standards and applicable codes vary depending on the authority having jurisdiction (AHJ) over the project. One must seek the architect's guidance on the process. Historic or landmark structures may have additional restrictions on window rehabilitation options. For applicable regulations, check with the local historic preservation commission.

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 and glare throughout the interior space. Some strategies used for the prevention of heat transfer are:

- incorporation of thermal barriers;
- use of IGUs; and
- incorporation of high-performance coatings or inert gases within IGUs.

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. Perimeter heating may no longer be necessary in buildings with thermally-efficient windows. Additionally, 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 structure's 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 occupants. Attention has been paid 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.

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

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.

Conclusion

Windows have a greater impact on the comfort of occupants than any other building element. Acting as gatekeepers, they permit entry of desirable exterior forces (*e.g.* light and air), while locking out undesirable ones (*e.g.* water, cold, heat, noise, and pollution). They must withstand the pressures of wind, ice, temperature fluctuations and extremes, and UV radiation, while remaining ever beautiful, and fluidly operational. With such continuous and critical demands, windows need attentive care and maintenance to meet these challenges without distress or failure.

Since optimal performance of windows is essential to building function, replacing improperly installed or selected windows or updating inefficient windows can dramatically impact the structure's overall operation. Whether considering current trends in sustainable design or ancient principles of interior to exterior relationship, one will find 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. **CS**

ADDITIONAL **INFORMATION**

Author

Juan Kuriyama, AIA, is vice-president of Hoffmann Architects, an architecture and engineering firm specializing in rehabilitation of building exteriors. He has extensive experience designing and overseeing the rehabilitation of historic windows and design detailing for new windows, developing solutions balancing cost-effectiveness with energy performance and durability. Kuriyama earned architecture degrees from Ricardo Palma University, Peru, and Pratt Institute, New York. He is an active member of the American Institute of Architects (AIA), the Architects League of Northern New Jersey, and the Historic Preservation Commission in his hometown of Ridgefield Park, New Jersey. He can be reached at j.kuriyama@hoffarch.com.

Abstract

Windows have a greater impact on the comfort of occupants than any other building element. With reports from clinical research substantiating the importance of natural lighting and ventilation in workplace productivity, health, and well-being, window design is more than building aesthetics and energy efficiency. Acting as gatekeepers, windows permit entry of desirable exterior forces (*e.g.* light and air), while locking out undesirable ones (*e.g.* water, cold, heat, noise, and pollution). They must withstand the pressures of wind, ice, temperature fluctuations and extremes, and ultraviolet (UV) radiation, while remaining beautiful and fluidly operational. With such continuous and critical demands, windows need attentive care and maintenance to meet these challenges without distress or failure.

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