

Window Design and Detailing

By Steven R. Marshall, RRC, CDT

When developing designs for window installations, specific guidelines should be followed to ensure system performance and owner satisfaction with the end product. This paper presents a guideline for designing windows, including wind-load analysis, selection of window types, various glass configurations, window framing selections, and installation detailing. Whether they are windows being installed within small punched openings or erection of curtain walls that encompass the entire elevation, window systems are often a key component and focal point of a building's appearance. Windows are one of the most important elements relating to energy conservation, building aesthetics, and weatherization. Therefore, proper selection and design of window systems are necessary to achieve a balance between aesthetics, use, and efficiency. This balance can be achieved by understanding window systems and how their individual parts affect overall performance.

With each project, the designer must assess the budget and building style. This paper will detail the selection criteria that designers should take into consideration.

WINDOW SELECTION

Windows are available in a variety of materials, constructions, frame dimensions, performance grades, and operation types.

There are various options to consider when choosing the frame material, such as wood, vinyl/vinyl-clad, aluminum, steel, and fiberglass. Each material has positive

and negative attributes and will usually depend on the designer's and owner's preferences and budget considerations. Various frame compositions include the following:

- **Wood frames** are typically constructed of oak, mahogany, pine, or Douglas fir. Wood can be formed into complex shapes and is capable of relatively large spans. It is easily repaired and available in a variety of colors and finishes. It can be limited to thinner glass thicknesses and is typically coupled with storm windows, which increase the thermal performance of the window unit. Wood frames require fairly high maintenance because the wood and finish deteriorate over time. This maintenance can be reduced by using vinyl-clad wood frames.
- **Vinyl frames** are constructed of polyvinyl chloride (PVC), which has a high resistance to heat, cold, and humidity and will not rot, rust, flake, peel, blister, or corrode. Vinyl also has a high thermal efficiency and is typically the least expensive of the frame materials,

unless it is used as cladding for wood frames. Vinyl is limited in finish colors and cannot span wide openings, due to limited resistance to high wind loads.

- **Aluminum frames** are constructed of extruded aluminum of varying thicknesses. Aluminum can accept a wide variety of glass thicknesses and will not rot, rust, or corrode with a suitable finish. It is available in many colors and finishes and is capable of forming large and complex shapes. It can be less costly than wood, steel, and fiberglass frames. However, aluminum frames do have a low thermal efficiency and

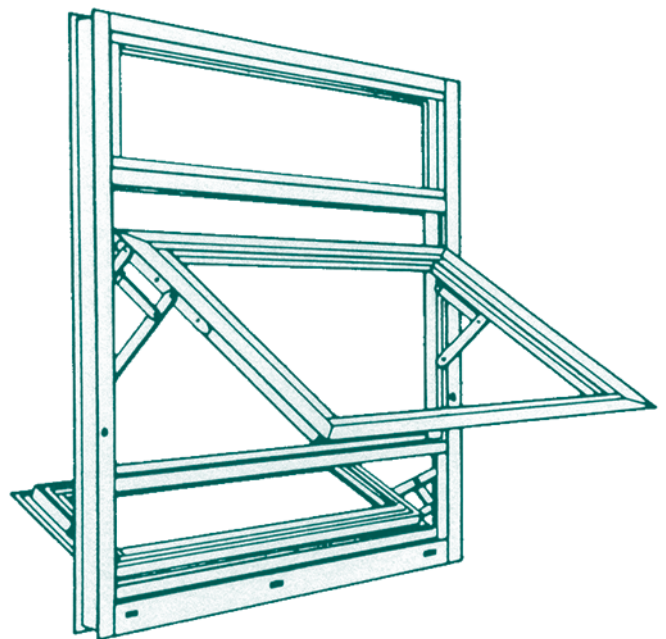


Figure 1 - Hopper and awning.

require in-frame thermal breaks.

- **Steel frames** are constructed of cold- or hot-rolled sections with welded construction for durability. Steel can accept various glass thicknesses and is available in many colors. It is capable of forming large, complex shapes and has a fair thermal efficiency. Steel is typically the most expensive of all framing materials and is not easily repairable, but it generally has a long lifespan.
- **Fiberglass frames** are constructed of pultruded fiberglass cured under high pressure and high heat. Fiberglass is stronger than aluminum and wood and has a thermal conductivity equal to wood and PVC. It can be finished in a wide selection of colors and will not rot, rust, or corrode. Fiberglass is a relatively new technology that has not been time-proven and is not easily repaired.

When selecting the operation type, the following options are available:

- **Awning (project out)** – The operable sash projects horizontally, away from the user.
- **Hopper (project in)** – The operable sash projects horizontally, towards the user (*Figure 1*).
- **Casement (roto or free swing)** – The operable sash projects vertically towards or away from the user.
- **Double- or single-hung** – The operable sash slides vertically, either up or down within the window frame.
- **Slider** – The operable sash slides horizontally, either left or right.
- **Pivot** – The operable sash pivots vertically or horizontally.
- **Fixed** – There are no operable units.

Although operation types are usually afterthoughts to designers and building owners, selecting the windows' operation type can be as important as the windows' air and moisture resistance, thermal performance, and weather resistance, because it provides many functions. Regardless of operation, most windows perform very specific functions, such as providing natural light, ventilation, and emergency egress, while contributing to the building's aesthetics. It is usually desirable to have the windows provide as many of these functions as possible while still remaining cost-effective. To determine the most appropriate window, the designer should evaluate

the following factors:

- **Building use (i.e., residential, educational, commercial, industrial, etc.) and occupant restrictions** – Perhaps the best starting point for determining the most appropriate window is building use. Building use often goes hand in hand with occupant restrictions. Therefore, these two considerations have been combined as one. Determining the building use is usually not sufficient to establish the desired or required window type. Some commercial- or industrial-use facilities may suggest fixed windows that will not cause disruptions in the building's mechanical heating and cooling systems. In some buildings, such as housing for the elderly or physically challenged occupants, windows that are easy to access and operate are needed.
- **Access to the window sash** – Difficult-to-reach window sashes can make use of windows with heavy sashes or brake forces difficult to operate. Some out-of-reach windows are installed where ventilation is necessary or desirable. They will require operation by long poles or mechanical operators, limiting the types of sashes available. (See *Photo 1*.)
- **Existing wall-opening dimensions** – Existing wall-opening dimensions often limit the operation of the window. Small or narrow window-opening dimensions may restrict the use of an operable sash within the window frame, due to minimum sash-dimension requirements imposed by the window manufacturers.
- **Emergency egress requirements** – Most local, state, and national building codes, as well as life-safety codes, require specific room occupancy types, such as sleeping quarters or classrooms, to have a minimum of two means of egress from the space. Where rooms contain only one means of egress, the win-



Photo 1 – Bay window with restricted access due to deep interior-sill dimension.

dow may need to be the second means of egress.

- **Ventilation requirements** – Building codes require that all occupied space within a building must be vented either mechanically or naturally. Natural ventilation is accomplished through windows, doors, louvers, or other openings to outside air. The minimum opening dimension is typically determined by a percentage of the floor area of the room being ventilated.
- **Historical restrictions** – Historically significant buildings are often limited when it comes to window replacement options, because protecting the original appearance of these buildings is often crucial. When replacing windows in buildings that are on the National Register of Historic Places or are located within historic districts, the replacement windows must replicate the windows used during the original construction.
- **Input from building users and owners** – When the window's operation is not restricted, the building



Photo 2 – Exterior fencing restricts this window from projecting out.

Photo 3 – Air leaks through sash/frame connections.



user may have a specific type of window operation that he or she prefers, while taking into account the project budget, possible number of operable units allowed, and future considerations of the interior space.

- **Exterior and interior impediments** – Exterior and interior impediments can include air conditioners, partition walls, columns, and screens. Limited window openings, coupled with emergency egress requirements, may make accommodating air conditioners impossible. In addition, interior or exterior impediments can restrict the use of projecting or pivot-type sashes. (See *Photo 2*.)
- **Safety concerns** – Safety concerns are in addition to emergency egress requirements and pertain to walking into open windows or vandalism protection. Building codes have provisions for items that project into walkways or hallways.

One way to address vandalism is to install security screens that cover the window openings on the exterior of the building. The security screens will protect the windows from vandalism; however, they are typically exterior-mounted and fixed in place, which limits the type of window operations that can be used.

Based on the frame material and operation type, the selection of the window system

can vary, depending on site conditions and location. The next step in selecting a window would be reviewing the published test results of the windows' design pressure, structural performance, air infiltration, and water resistance. Typical performance criteria include but are not limited to the following:

- Structural performance to meet wind-load requirements is critical, but factors such as blast resistance, vandalism, and frequency of use may also need to be considered.
- Air infiltration is the amount of air that moves through the window perimeters, the frame, or the seal between the sash and frame (Photo 3).
- Water resistance is the amount of moisture that can travel through the window unit or sash.
- Condensation resistance is the window unit's ability to resist interior condensation through performance of the frame and glass.
- Thermal performance can vary by site location and frame type but generally must be suitable to resist heat and cold transfer and to improve interior climates. In cold climates, thermal breaks in aluminum frame systems are necessary to reduce thermal transfer through the highly conductive aluminum.

GLASS SELECTION

Since the glass area constitutes the majority of the window system, it is therefore critical to the performance of the window unit. The glass must be carefully selected based on window loading, interior climate, function, and its thermal properties.

- Glass units need to be sized to resist the design wind loads without excessive deflection, seal failure, or cracking. There are various types of glass production, and these can increase or decrease the strength of the glass. Heat-strengthened glass is typically twice as strong as regular annealed glass, while wire glass can be half as strong as annealed glass. (See Figure 2.)

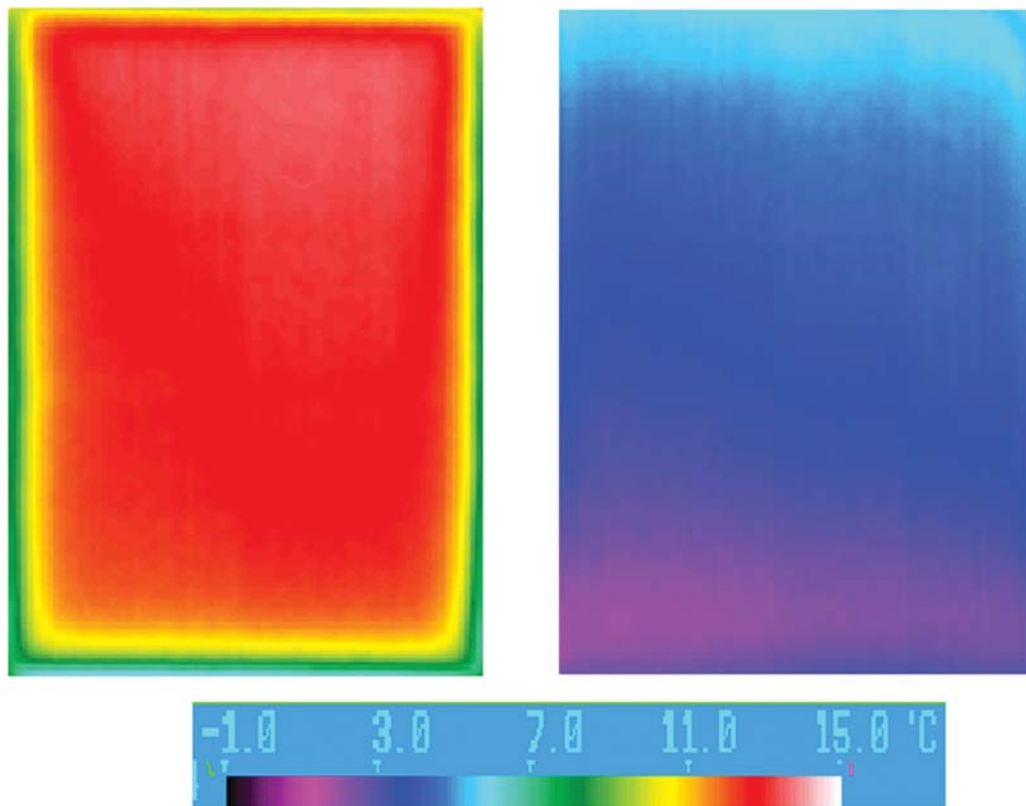


Figure 2 – On the left is a double-glazed window; on the right is a single-pane window. The single-pane window is only slightly warmer than the cold air behind it. The dual-pane window is considerably warmer, indicating that less heat is flowing out through the window.



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- The glass may need to reduce heat gain; if so, the designer can specify a tinted unit or a unit with a reflective coating.
- The designer should consider any specific needs that the glass should fulfill, such as safety, fire resistance, blast or bullet resistance, or opacity.
- A high thermal performance may require the glass to be manufactured as an insulated unit and filled with air or an inert gas. Applied coatings such as low-emissivity, tinted, or reflective coatings can reduce heat transfer through the glass.

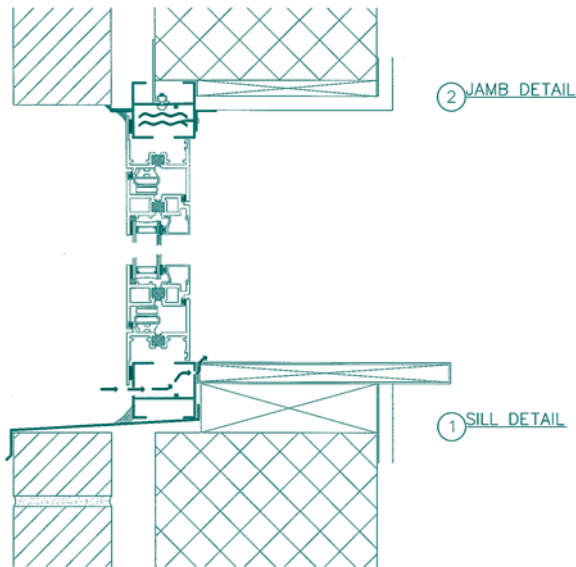


Figure 3 – Jamb and sill detail.

By providing multiple lites of glass and using a more inert gas in the air space, increased thermal performance can be achieved. However, heat transfer and energy loss can still occur through the conductive edge spacer. Manufacturers have begun using Warm Edge Technology (WET) in an effort to increase the thermal performance of the insulated unit. This technology incorporates less conductive materials to use as edge spacers, reducing the heat transfer through the edge of the insulated glass, improving the overall glass performance, and reducing the potential for condensation.

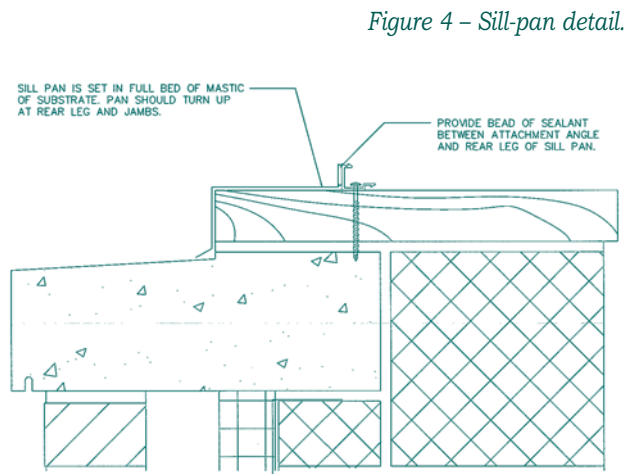


Figure 4 – Sill-pan detail.

INTERNATIONAL ROOFING SYMPOSIUM COMING TO DC

The National Roofing Contractors Association (NRCA) and the Oak Ridge National Laboratory (ORNL) will host the 2011 International Symposium: Emerging Technologies and Roof System Performance from September 7-9, 2011, in Washington, DC. The symposium provides a forum for formally presenting roofing industry research and the latest information about the science of emerging technologies, including reflective roof surfaces, vegetative roof systems, and rooftop photovoltaic systems.

Preferred presentation topics include high-performance roof systems, sustainable roof systems, roof systems that incorporate renewable energy, energy efficiency, and roof system life-cycle analysis. Abstract submissions are due in June, and acceptance will be announced in July. The paper submission deadline will be in December, and the paper review process will take place through spring 2011. The *Proceedings* will be published in August 2011.

A Web site will be created for information about abstract submission, registration, housing, and all other relevant information and will be accessible in April.



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DETAILING


Proper window detailing involves knowledge of the window systems and associated components used for installation (i.e., attachment clips, flashings, sealants, and substrates). With all the construction materials used today, there are countless variations of window openings. (See *Figure 3*.)

Most windows should be installed with sheet metal or durable membrane pan flashings that can sit under the window and reduce the potential for moisture infiltration below the window frame. The flashing must completely cover the windowsill and be set in a full bed of mastic to limit air or moisture infiltration below. The flashing should also incorporate end dams and, if formed out of sheet metal, should be fabricated in two pieces to reduce the potential of heat transfer through the conductive metal. A thermal break should be used between the two-piece flashing. (See *Figure 4*.)

In conjunction with using pan flashing below the window unit, interior attachment angles should be used to eliminate the need for securing the window system downward, penetrating the pan flashing. Where the rear leg of the pan flashing turns up behind the interior face of the window unit and the attachment angle, a bead of sealant should be used between the metals. This will provide an additional seal against air and water penetration below the window unit.

Head and jamb flashings should also be used as needed to reduce the potential for air and moisture entering the window frame from above or from the sides by enclosing the wall cavity.

To determine acceptability of materials and how they will relate to the actual window opening, a mock-up of one complete window opening is also recommended. This gives all parties a chance to review the installation and substitute or make changes prior to complete installation.

In conclusion, the design and selection of window types can affect the overall appearance of the building, as well as building envelope performance, since they relate to energy savings, comfort of occupants, and resistance to air and water infiltration. Proper consideration will result in enhancement of the building's aesthetics and a comfortable atmosphere for the occupants. 

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Steven R. Marshall, RRC, CDT, specializes in site investigations, design, administration, and coordination of roof, wall, and window projects. His project involvement includes design and bid throughout construction and project closeout. Marshall has extensive experience in evaluation, repair, and replacement of roofs, windows, curtain walls, storefronts, doors, and masonry wall projects. He gave a presentation titled "Design and Selection of Operable Windows" at Build Boston and also wrote an article on the same subject for *Condo Management Magazine*.



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