Design Criteria for Windows + Doors

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Learning Objectives

After reading this article, you should be able to:

- ✔ List and describe the key factors driving the choice and application of window and door products.
- ✔ Understand how heat gain, thermal bridging, light transmittance, and other variables are affected by window and door product selection.
- ✔ Compare fenestration strategies based on such factors as energy efficiency, LEED ratings and sustainability, and occupant comfort and safety.

By C.C. Sullivan and Barbara Horwitz-Bennett

Whether it's offering a pleasant view, providing a fresh breath of air, or contributing to overall comfort and mood, windows and doors go a long way toward ensuring the well-being of building occupants. The Washington, D.C.-based U.S. Green Building Council's LEED rating criteria reward the use of ample fenestration; in some European countries, it's the law.

At the same time, incorporating windows and doors into the building envelope presents one of the toughest tasks for the Building Team. In the construction phase, fenestration demands high levels of coordination and skill. Moreover, the design and specification of these important building components requires careful attention to such factors as material selection, fenestration performance, energy efficiency, sustainability, acoustical performance, security, and code compliance.

"In addition to allowing light into the building and providing a visual link to the exterior, windows must provide the same environmental separation functions as other parts of the building enclosure," says Paul Kerman, MAIBC, BEP, LEED AP, a principal with RDH Group, Vancouver. "Heat loss, air leakage, and vapor diffusion must be controlled, water ingress prevented, and applied structural loads must be resisted. This range of functional requirements makes windows one of the more complicated components of the building enclosure."

Considered a weak link the building envelope, windows currently consume 3.8 quadrillion British thermal units (Btu) of energy in the U.S. annually in the form of heating and air conditioning loads, at a cost of more than $30 billion, according to the U.S. Department of Energy's Building Technologies Program.

"Windows are where many leaks occur and the interface with the wall is often a no man's land of responsibility," says nationally recognized building envelope expert Richard Keleher, AIA, CSI, LEED AP, Concord, Mass. "Window manufacturers typically don't identify where air and water barrier connections are to be made, and architects and contractors have to make it up as they go."

Consequently, it behooves the Building Team to focus in on innovations in glazing and glass coatings, thermal barriers, flashing and sealing, and other energy-efficient measures to make window and door specification as efficient and cost effective as possible.

COMPARING FENESTRATION MATERIALS

One of the first decisions that must be made when specifying window frames and doors is choosing the right material. For window frames, the main options are aluminum, vinyl, wood, fiberglass, and steel, with each material presenting its own pluses and minuses.

From an environmental perspective, wood stands out the most, according to New York City architect and writer Barbara A. Nadel, FAIA, who cites U.S. and U.K. life cycle assessment studies of aluminum, vinyl, and wood window frames. Nadel says that these studies, based on production methods and energy consumption and related factors, often confirm that wood window frames have the smallest total environmental footprint.

For example, a 2002 study by the Edinburgh Napier University School of Engineering academic titled "Life Cycle Analysis of Window Materials—A Comparative Assessment" (http://www.cibse.org/pdfs/Masif.pdf) analyzed the embodied energy—the amount of energy required to manufacture and supply a material—for wood, aluminum, and polyvinyl chloride (PVC). The report concluded that aluminum windows used the most embodied energy, with PVC using three times as much embodied energy as wood.

In addition, wood delivers good installed performance in terms of reducing thermal bridging, or the transfer of heat and cold from the building exterior to the interior. Such studies provide a logical rationale for Building Teams to consider wood windows and doors beyond pure aesthetics, which has long been the main draw of the material.

"Wood windows and doors have an enduring, timeless stat-

PHOTO: COURTESY AAMA AND EFCO

Buildings with large window areas, such as this hotel, require windows with a solar heat gain coefficient, or SHGC, that matches the needs of the climate and the interior environments.

ure," says contractor Kurt Lavenson, owner of Lavenson Design & Building, Alamo, Calif. "They have been around for centuries and regardless of how modern the design of new windows or doors, they benefit from this historic association. Additionally, the depth of grain radiating from a hardwood door or the hefty section of a painted wood window communicates substance and solidity regardless of style."

On the downside, wood products tend to be expensive as compared to the other materials, especially for monumental sizes and custom shapes. The prepping, priming, and painting or staining required in the field also add labor and time to the project budget.

Aluminum, on the other hand, tends to be more cost-effective, durable, and owner-friendly, with fewer maintenance demands. The base material is produced from the ore bauxite, which is abundantly available and can be recycled repeatedly with little deterioration in quality. However, aluminum production and recycling require a significant amount of energy and generate considerable quantities of toxic waste. Aluminum windows and doors may also experience thermal bridging: because the metal conducts heat and cold so efficiently, aluminum window and door frames require well-designed thermal breaks to offer a level of thermal efficiency competitive with wood and vinyl.

Vinyl frames stand out as the second-most-popular fenestration product (after wood) as measured by market volume. Vinyl products are very cost-effective. As with aluminum door and window frames, however, they require energy-intensive manufacturing and produce attendant toxic effluents, factors that may influence green-minded Building Teams. In addition, recycling of vinyl is complicated and not commonly available for end users. As for the material itself, vinyl is tough but it can be prone to bending and bowing as a result of pressures induced by thermal cycling.

Last, fiberglass frames present a relatively new addition to the choices available for window and door frames. Several studies have confirmed that fiberglass is highly durable; in one case, fiberglass was shown to be about eight times as strong as comparable sections of vinyl. Some green building experts rate fiberglass second to wood in terms of overall environmental friendliness. The downside, however, is cost: fiberglass is often more expensive than aluminum or vinyl.

The Window & Door Manufacturers Association (WDMA), Des Plaines, Ill., points out that, in addition to aesthetics, wood offers certain performance advantages over metal doors. For example, while wood is associated with temperature-induced effects, wood assemblies tend to resist air infiltration better than many metals, which are a common commercial specification. "Between 70º F and 130º F, the air infiltration rate on steel doors accelerates as exterior temperatures work to separate the door from the frame and weather stripping," according to WDMA, which notes that about 75% of a door's heat loss occurs around its edges.

As for typical applications of the various materials, the Whole Building Design Guide's section on building envelope fenestration systems (http://www.wbdg.org/design/env_fenestration.php), by Nik Vigener, P.E., and Mark A. Brown, of Simpson Gumpertz & Heger's Washington, D.C., office, states: "Doors

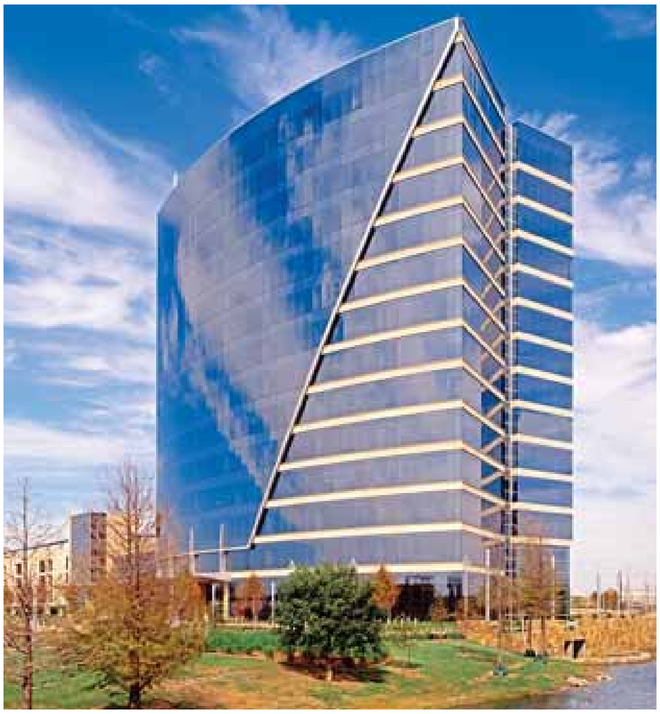

IMAGE: COURTESY AAMA

Curtain walls such as this at Granite Park Three, Plano, Texas, provide large glazed areas but demand an effective thermal barrier system, because materials with high conductivity such as aluminum, steel, and glass quickly carry heat and cold across the enclosure. Thermal breaks within and near curtain wall frames are an effective measure.

PHOTOS: COURTESY AAMA

For resistance to blasts and wind-borne debris, window and door glazings can use fully tempered or laminated glass as a safety glazing, which limits the risk of injury by controlling glass breakage.

that are integrated with commercial storefronts are typically aluminum frames with glass in-fills, or all glass. Steel-clad doors are generally utilized for service entrance/exit functions. Wood doors are most commonly employed in low-density residential construction. Monumental wood or wood-and-glass doors are sometimes used in commercial or institutional buildings."

Yet many project teams find that their window and door product choices often focus on materials as a by-product of desired performance characteristics. "It is important to evaluate windows and doors for their performance, maintenance, design capabilities, etc., instead of basing comparisons on the actual materials," advises John Lewis, technical director of the American Architectural Manufacturers Association, Schaumburg, Ill.

George M. Blackburn, III, AIA, NCARB, general manager of Construction Consulting International, Carrollton, Texas, states, "The use of wood, aluminum, vinyl, fiberglass, and steel are all viable materials for fenestration frames. Instead, the choice of materials should be based on window and building types and code requirements."

FENESTRATION PERFORMANCE AND CLIMATE

Properties such as coating, glazing, visible light transmittance (VLT), and solar heat gain coefficient (SHGC) are important to consider when specifying high performance windows.

- ✔ **Low-emissivity (low-E) coatings.** These are microscopically thin layers of metals or metallic oxides applied to glazings in order to reduce their U-factor by mitigating radiative heat flow. U-factor is a measure of how well a product prevents heat from escaping. A low U-factor is important, especially in cold climates, because the lower the window's thermal conductivity, the less heat loss there will be.
- ✔ **VLT.** The higher the visible light transmittance (VLT), the

PHOTO: COURTESY OF KAWNEER

Window frames that have high thermal conductivity, such as aluminum and steel systems, need to be installed according to manufacturer's recommendations to avoid thermal bridging, potentially carrying heat and cold across the building enclosure.

greater the amount of light coming through the window—and the greater the amount of daylight received in the interior space.

- ✔ **SHGC.** The solar heat gain coefficient measures the solar radiation that passes through the window. The lower the SHGC, the less the amount of solar heat transmitted from the exterior to the building's interior.

When determining which values to choose for each of these properties, climate is a big consideration. Providing some general specification guidelines, the Washington, D.C.-based Efficient Windows Collaborative (EWC) suggests the following:

- ✔ *Northern climate*—To reduce heating loads, select the highest solar heat gain coefficient (SHGC)—usually 0.30-0.60 for the U-factor ranges required in colder climates —so that winter solar gains can offset a portion of the heating energy need. If cooling is a significant concern, select windows with an SHGC less than 0.55.
- ✔ *North/central climate*—To offset significant air-conditioning costs or summer overheating problems, look for SHGC values of 0.40 or less. For moderate HVAC loads, select windows with an SHGC of 0.55 or less. While windows with lower SHGC values reduce summer cooling and overheating, they also reduce free winter solar heat gain.
- ✔ *South/central climate*—To best address moderate air-conditioning requirements, windows with an SHGC of 0.55 or less are recommended. While windows with lower SHGC values reduce summer cooling and overheating, they also reduce free winter solar heat gain.
- ✔ *Southern climate*—A low SHGC is the most important window property in warm climates. Select windows with an SHGC less than 0.40.

By way of confirmation of these recommendations, a 2003 report by scientists at Lawrence Berkeley National Laboratory (http://windows.lbl.gov/adv_Sys/ASHRAE%20Final%20Dynamic%20Windows.pdf) for the American Society of Heating, Refrigerating and Air-conditioning Engineers concluded that windows with "dynamic solar heat gain properties are found to offer significant potential in reducing energy use and peak demands in northern and central climates, while windows with very low (static) solar heat gain properties offer the most potential in southern climates."

Building Teams are finding more options in glass products on today's market. Windows and doors now incorporate varying levels of the key measures and properties to match application needs and desired performance. "Glass manufacturers are coming out with new products that allow the designer to select glazing that combines high levels of visible light transmittance with solar heat control," says AAMA's Lewis. Among low-E glass offerings are high solar heat gain products, which are best suited for the northern climate zone, and low solar heat gain products, which are recommended for the southern climate zone.

One relative newcomer to low-E technology is called "heat mirror," a high-tech glazing material whose energy efficiency can exceed that of triple-pane windows. The product is constructed by suspending low-E film between panes of insulated glass. Two layers of heat mirror may also be suspended between panes of glass with gas-filled spacers to form “super-glass”—“the most expensive glazing system on the market, but one of the best insulators,” according to the Efficient Windows Collaborative.

Another new technology, developed by Lawrence Berkeley National Laboratory, is the transition-metal switchable mirror, or TMSM. According to the Efficient Windows Collaborative, these are “dynamic glass panels with a magnesium alloy-transition metal coating that can switch back and forth between a transparent state and a reflective state.” This is done by application of an electric field (a process known as electrochromic switching) or by exposure to dilute hydrogen gas (a process called gasochromic switching) says the EWC.

Most experts concur that electrochromic glazings are a growing trend in terms of new product development. Architect Richard Keleher further observes that more sun shading is being incorporated into new window and door products. The practice, which is commonplace in Europe—both within the glazing unit itself and on the exterior of the building—seems to be gaining popularity in the U.S., too.

Other newer products now available include insulated glass units and monolithic float glass, both available in a variety of colors, coatings, and strengths, including laminated glass for high strength needs, according to Construction Consulting International’s Blackburn. “The insulated glass units come with double and triple glazing, and there are glazing spacers that are thermally broken, reducing thermal transfer at the unit perimeter,” he says.

Daylighting vs. thermal heat gain. One sensitive design point that Building Teams must carefully calculate is how best to maximize daylighting while controlling thermal heat gain. “Daylight and view are two of the fundamental attributes of a window. Unfortunately, windows are also the source of significant solar heat gain during times when it is unwanted,” says the Efficient Windows Collaborative. “Traditional solutions to reducing solar heat gain [are] tinted glazing or shades, and glazings with low-solar-gain low-E, spectrally selective coatings to provide better solar heat gain reduction with a minimal loss of visible light.”

New technologies, such as exterior sun control devices and high-performance glazing (particularly electrochromic glazing) are effective strategies as well. At the same time, Keleher points out, “Exterior sun-control devices are the most effective for controlling heat gain because they keep the sun out of the building entirely. However, there are issues of maintenance, operability in ice and snow, and cost that are hampering the growth of this strategy in the United States.”

Another approach is simply to not overdo it in the daylighting department. “Don’t design more windows than you need [for illumination] while accomplishing your passive solar and aesthetic objectives,” recommends Donald F. Evans, president of The Evans Group, an Orlando-based architecture and planning firm. “Consider room use, orientation, and shading when making your window selection. And balance the placement and type of windows to ensure the best possible resistance to heat transfer within the context of your plan.”

AAMA’s Lewis suggests integrating skylights, roof windows, and space frames into the daylighting plan to address this issue, in addition to the proper selection of solar heat gain properties in windows to best strike a balance between daylighting and thermal load.

Thermal systems. Another key component contributing to a window’s overall energy efficiency is its thermal barrier system. Wood has low thermal conductivity, while materials with high conductivity such as aluminum and steel present a thermal bridge, potentially carrying heat and cold across the enclosure. For that reason, metal windows, curtain walls, storefronts, and skylights should provide ample thermal breaks within and near their frames.

“It is common practice to incorporate thermal breaks of low thermal conductivity materials, traditionally polyurethane and more recently nylon, for improved thermal performance,” according to Simpson, Gumpertz & Heger’s Vigener and Brown. Alternatively, a glass-reinforced polyamide system, which allows for a larger gap between the exterior and interior of the frame, has been reported to improve the window’s overall energy efficiency, as compared to a traditional polyurethane thermal break. As Construction Consulting International’s Blackburn notes, however, “Thermal breaks in the metal frames are critical for energy efficiency, but they do cost more.”

As a general design tool, AAMA’s Lewis recommends that the specifier request products be tested and rated by one of the nationally recognized test methods for measuring thermal transmittance and condensation resistance—for example, AAMA 1503-98, Voluntary Test Method for Thermal Transmittance and Condensation Resistance of Windows, Doors, and Glazed Wall Sections, a widely accepted tool to compare thermal performance of products.

Common thermal issues concerning doors include:

- ✔ Heat loss from air movement during operation and through the perimeter detail.
- ✔ Radiant heat loss through the door materials themselves.
- ✔ Door frames lacking adequate thermal isolation form thermal bridges and often have condensation issues, especially in the winter.

To deal with heat loss, designers like Vigener and Brown suggest utilizing revolving doors, entrance vestibules, weather stripping, and air curtains. “In colder climates, air curtains provide a barrier of fast-moving warm air that limits penetration of cold exterior air while the door is open and are frequently used with sliding doors. The warm air may also be used to raise the surface temperature of the doors, which limits condensation,” they note.

As for aluminum-framed doors that are part of a curtain wall or storefront, thermally broken frames and insulating glass units provide good energy performance. For opaque entrance doors and loading dock entries, foamed-in-place insulation between the exterior and interior metal skins is a common strategy, according to Vigener and Brown.

Yet another important aspect of the building envelope is flashing and sealing around the window perimeter. "Maintaining the integrity of the building envelope at the window-to-wall interface is a critical task in all building design projects, and one of the most challenging design tasks faced by designers and builders," states Paul Kernan, MAIBC, BEP, LEED AP, principal and manager of design services with RDH Group, Vancouver, B.C.

According to Vigener and Brown, "punched" window openings in a wall system threaten to create holes in the water, air, or vapor barriers. "Careful detailing is required to integrate water/air/vapor barriers with the window frames and maintain their continuity at the window perimeters," they note.

RDC's Kernan, a former building envelope specialist for the city of Vancouver, advises: "The head detail must intercept water draining down the wall above the window and divert it away from the vulnerable joint between the window and wall. In order to achieve this, some form of diverter flashing is required. The flashing must be carefully integrated with the wall assembly above to ensure that all elements are positively lapped."

Blackburn recommends that the entire perimeter be flashed, especially the interface between the flashing and substrate materials. "The head flashing must extend beyond the jamb flashing, the jamb flashing must terminate at the base within the sill pan flashing, and the sill pan flashing should be a three-sided pan with end dams and have an interior up stand depending on the frame type," he says. "Also, the joints between the head, jamb, and sill flashings must be sealed as part of the air-barrier system's continuity."

AAMA's Lewis cites AAMA 711, Voluntary Specification for Self-Adhering Flashing Used for Installation of Exterior Wall Fenestration Products, to provide additional direction on flashing installation guidelines.

With regard to sealants, Blackburn states that the specifier's choice should be based primarily on functional longevity. "Silicones perform by far the best in that regard, but there are other considerations, such as anticipated joint movement, type of materials in the joint for adhesion, and staining considerations."

EFICICENCY AND SUSTAINABILITY

In terms of sustainability, Building Teams often want to consider how recyclable the constituent materials are in their chosen window and door products. Another more complex and possibly subjective consideration is the extent to which the materials and components are "sustainably produced." The production of such materials as vinyl and aluminum require a great deal of energy and generate toxic by-products. On the other hand, wood, especially timber from responsibly managed, sustainably certified forests, offers a high level of sustainability. However, the finishing processes for wood often raise questions about toxicity.

Aluminum and steel frames are easily recyclable. As a rule of thumb in most markets, as long as there is a minimum of 1,000 sf of curtain wall or storefront, or a large quantity of unitized windows, salvage and demolition contractors are happy to take on the job. However, if the aluminum is mixed up with sealants and glass fragments, the material is worth considerably less to the recycling contractor. Insulated glass units are typically not recycled because they contain a mix of glass, metallic coatings, sealants, and aluminum spacers.

In terms of utilizing recycled materials, wood frames rank high. On the other hand, Vigener and Brown say that "aluminum window and door frames generally do not incorporate post-consumer recycled material because manufacturers have reported problems with the appearance and durability of anodized coatings."

LEED ratings. Whereas a number of choices regarding the specification of energy-efficient windows—specifically U-factor, solar heat gain coefficient, window size, and orientation—can directly contribute to points under the U.S. Green Building Council's new LEED for Homes rating system in the "Energy and Atmosphere" category, fenestration-related points are awarded more indirectly in other LEED rating systems. Even so, LEED Accredited Professionals point out that in LEED-NC, for example, windows and doors can contribute toward a prerequisite and toward as many as 25 of the 69 total LEED-NC points. Among those contributions are:

❶ Up to five points in the "Materials and Resources" category by utilizing certified wood, renewable materials, and recycled content.

❷ Under "Indoor Environmental Quality," project teams can earn up to five points by incorporating window design in a way that employs low-emitting materials, increases building ventilation, and optimizes daylight and views.

❸ Under "Energy & Atmosphere," project designs should minimize undesirable air infiltration by using window weatherstripping between the sash and the frame. Backer rods and sealants should be detailed for the intersection of the window unit and the rough opening.

Other strategies for earning LEED points include simply locating windows and shading devices where they will do the most to enhance daylighting without causing excessive heat gain. High-performance glazing, including low-E glass and even triple glazing, have been featured in LEED-rated projects. Other product choices, such as window and glazing units with integral shading devices, can enhance performance enough to contribute to LEED points.

Simply gaining LEED points is not the goal, but the process can afford building owners and occupants the opportunity to enjoy the effects of low U-values, better visible light transmittance, and more balanced temperature conditions throughout the occupied spaces.

Important note: The USGBC's new LEED for Homes rating system features a baseline requirement for windows, doors, and skylights that conforms to the U.S. Environmental Protection Agency's Energy Star product designation. This labeling essentially demonstrates to building owners that the products reduce heating and cooling demand, increase comfort, reduce condensation, and decrease UV radiation as compared to conventional products. Another rating system for multifamily developments and residential-type window applications is the National Fenestration Rating Council (NFRC) label, which currently provides ratings for U-factor, solar heat gain coefficient (SHGC), visible light transmittance (VLT), and air leakage, and will soon be adding a rating for condensation resistance. The NFRC label provides an easy way to determine window energy properties and compare fenestration products.

RENOVATION AND REPLACEMENT

When is it appropriate to renovate windows, and when is replacement the better option? While new windows offer increased energy performance over existing windows, the relatively high cost of installation creates a long payback period, ranging from 15 to 25 years.

"One of the most basic mistakes made in existing facilities is to conclude [that] windows need to be replaced without considering restoration of existing units," states renowned facilities consultant Dr. James Piper, P.E., of Bowie, Md. "With the cost [of restoration] running only 25% to 30% that of replacement, restoration can extend the life of existing windows while providing many of the benefits of a replacement project."

On a life cycle cost basis, however, Piper notes that replacement may provide a much better rate of return for the investment. He offers this rule of thumb: If more than 20% of a facility's windows require restoration, replacement may be the better option.

Viable renovation strategies include adding storm sashes to reduce thermal conductivity, weather-stripping to decrease the rate of air infiltration, installing reflective film to reduce heat gain, and refinishing materials to increase their service life.

Construction Consulting International's Blackburn adds this caution: "Aluminum, steel, and wood windows and doors can generally be economically refurbished with new finishes, but framing systems will have to be replaced to change from monolithic glass to insulated glazing units."

To help you make the restoration vs. replacement decision, the Steel Window Institute offers the following pointers:

- ✔ The cost of new windows is often less than restoration, and the end-product is often superior.
- ✔ The cost of field labor is high compared to factory labor.
- ✔ Field welding of small pieces often leaves rough appearance and difficult glazing areas.
- ✔ New windows are always properly fitted with the vent fitted to the frame. Field fitting of a new vent to an old frame is often difficult.
- ✔ New windows can usually replicate the existing window section, even for historic projects, achieving the exact same sightlines and appearance.
- ✔ Specifications normally require sections to be continuous from jamb to jamb and head to sill, with the muntins being interlocked—another strike against piecemeal welding and addition of small sections in the field.
- ✔ New windows can have coatings and finishes vastly superior to those applied in the field over older degraded windows.

CODES & STANDARDS

Probably the most significant recent development in the realm of codes and standards for windows and doors has been the publication of AAMA/WDMA/CSA 101/I.S.2/A440-05 Standard Specification for Windows, Doors and Unit Skylights, which has been included in the 2006 edition of the International Code Council's family of codes and is under consideration for inclusion in Canada's National Building Code's 2010 edition.

According to WDMA acting president Jeffrey D. Lowinksi, the completion of this standard marks a turning point for the industry: "Developed by representatives from the WDMA, the AAMA, and the Canadian Standards Association, the standard is the first edition jointly published by all three organizations. More importantly, it is the first standard that gives manufacturers the tools to produce products under a single standard that can be distributed in the U.S. and cross-border to the neighboring building and construction communities of Canada."

This standard is the first performance-based fenestration standard to include unit skylights. It also contains a specification section for side-hinged exterior doors, as well as an updated glass strength standard based on ASTM E 1300-02.

Another important guideline when it comes to the specification of windows is the International Energy Conservation Code (IECC), with requirements based on climate and region. Essentially, the code sets forth eight different climate zones and assigns counties throughout the U.S. to a single zone. Regulated window components include U-factor maximums for fenestration and SHGC maximums for all glazed fenestration.

To make it easier for specifiers, the Efficient Windows Collaborative offers a compliance aide to determine IECC requirements for each state and county, available at: http://www.efficientwindows.org/code.cfm.

ACOUSTICS

Another important consideration in the selection of windows and doors is acoustics. According to AAMA's Lewis, the following factors will affect how a given fenestration unit performs acoustically:

- ✔ The window's mass relative to the sound.
- ✔ The materials used relative to the wavelength of the sound waves.
- ✔ The glass-to-frame ratio.
- ✔ The tightness of the seal.

In order to provide proper sound insulation, Vigener and Brown suggest increasing the mass of the frames—although they acknowledge that this can have a negative effect on thermal performance—and improving the air tightness of the perimeter construction. Other measures they recommend: placing sound-absorptive materials at the perimeter of the windows, increasing the insulated glass airspace, using laminated glass, and using insulated glass units of uneven glass thicknesses.

Essentially, using laminated and insulated glass is a good strategy because the laminate dampens vibration and the air space limits sound transmission. The additional mass lent by the thicker glass helps with sound absorption as well.

With regard to doors, the weak point in the assembly can come from air leakage around the door itself or the materials. Consequently, "sound attenuation through doors can be improved by increasing the mass of the frames and sash, improving the air tightness of the glazing, sash-to-frame and frame-to-perimeter joints, and placing sound-absorptive materials at the perimeter of the doors," say Vigener and Brown.

In addition, revolving doors and entrance vestibules with inner and outer doors offer better acoustic performance, as they limit air leakage during door operation.

SECURITY AND SAFETY

Perimeter security and occupant safety are important factors in choosing window and door units. Intrusion, fall-out or blast protection, fire safety, and weather impact all need to be taken into account, even though they may come into conflict with each other.

For example, WDMA points out that even though security bars, grilles, window guards, and grates are ideal for keeping intruders out, they also lock occupants in. Consequently, it's crucial to ensure that for emergency egress, it's possible to exit through the window without the use of tools, keys, special knowledge, or effort.

Also, when color or tint is applied to glass to control VLT or SHGC, this can also have ramifications on security. During daylight hours, according to consultant James Piper, low visible-light-transmission factors make it hard for authorities and rescue teams outside the building to observe interior conditions; this situation is reversed at night. For fall-out protection, approved window guards are recommended, but insect screens should not be relied upon for this function.

As for fire safety, Vigener and Brown recommend providing fire-rated steel frames with suitable glazing, such as wired glass or fire-rated ceramics. Knock-out glazing panels, typically fully tempered to reduce shards, are recommended for venting and emergency access from the exterior. For blast protection, fully tempered or laminated glass is commonly used for safety glazing, the designers say. "Tempered glass limits the risk of injury by fracturing into small fragments," according to Vigener and Brown. "Laminated glass limits the risk of injury by retaining the fractured glass on the plastic interlayer and thereby limiting fall-out of glass fragments."

NOT AS EASY AS IT LOOKS

Whether it's safety, acoustical performance, energy efficiency, or sustainability, window and door specification is no simple task. These key architectural elements offer important value to the overall design. "Since windows are the 'eyes' of the building, they often are the most expressive part of the design," says architect Richard Keleher.

Furthermore, fenestration contributes significantly to the total building system. Consequently, any advances in window and glass technology can go a long way in improving the overall efficiency and operability of buildings.

According to the U.S. Department of Energy, "Through ongoing advances in R&D, tomorrow's windows and glass can further enhance the comfort, safety, well-being, and productivity of occupants, and open the way to innovations in architecture and construction, while increasing the energy and environmental performance, functionality, and longevity of buildings." BD+C