Window-related water infiltration is a leading construction defect and frequent topic of litigation. Defects are often related to window selection, detailing, workmanship, installation or a combination of these factors.

When selecting windows, the designer or contractor should understand the performance grades identified in American Architectural Manufacturers Association (AAMA)/Window and Door Manufacturers Association (WDMA)/CSA Group (CSA) 101/LS.2/A440: North American Fenestration Standard/Specification for Windows, Doors, and Skylights (NAFS). NAFS identifies four performance classes aligned with the target application, as well as performance grades, which define a specific set of product performance requirements. While NAFS governs performance of windows, doors and skylights, these standards are based on laboratory testing. Actual in-place performance is highly dependent on the designer’s detailing and the contractor’s workmanship.

To assist the designer and contractor, the construction industry has developed several methods of flashing and installing windows. The methods are identified in ASTM E2112 - 07 (2016): Standard Practice for Installation of Exterior Windows, Doors and Skylights. They vary based on installation sequence, adjacent cladding types and level of flashing redundancy. When followed, these installation methods provide guidance on successful window design and installation.

Problems arise when someone selects a lesser grade window than the project type or performance expectation would dictate and/or utilizes a nonstandard window installation method. These circumstances may occur due to a lack of knowledge by the designer or value engineering by the owner or construction team. When cost drives window selection, the potential for errors in manufacturing or in the installation process increases, raising the risk of failures.

This article will review product selection, product installation and commonly observed window field test failures.

**Window Standards**
Window performance requirements are determined by local codes, industry standards and the owner’s performance requirements. Design teams should also consider the project climate, height of installation, building type and exposure. As noted earlier, NAFS identifies classes of performance and sets several levels of performance for those classes.

Window performance classes are designated as Residential (R), Light Commercial (LC), Commercial Window (CW) and Architectural Window (AW). These classes and performance levels are identified by minimal performance requirements, including structural strength, water penetration resistance, air leakage, operating forces and forced entry resistance where necessary. To qualify for a specific class, a window unit must be tested and pass all minimum standards for that grade. While the classes refer to construction types, they are not absolute but are intended to provide guidance as to the level of performance anticipated:

- **R** windows are commonly used in one- and two family dwellings.
- **LC** windows are often used in low- to mid-rise multifamily dwellings or buildings that require larger sizes and higher loading requirements than type R.
- **CW** windows are typically used in low- to mid-rise buildings where limits on deflection or heavy use are expected.
- **AW** windows are commonly used when the highest level of performance is required.

A correctly installed air-barrier system and window assembly. Window openings are prepared with self-adhered membrane flashing prior to installation. The exterior wall air barrier is installed over waterproofing and the edge seams are sealed.

Preparing rough openings and lapping self-adhered or liquid-applied air barrier provide continuity between the wall components.
NAFS defines minimum gateway performance requirements for each class. For a manufacturer to classify its window under a particular performance class, the assembly must be tested in a laboratory to show compliance with the gateway requirements. Once a window model specimen successfully passes the gateway minimums, that class is applicable to the tested size and smaller units.

In addition to the class designation, a window unit is labeled with a design pressure (DP) that represents the assembly’s tested structural wind load resistance and water penetration resistance. Wind loads are typically calculated and based on local building codes or American Society of Civil Engineering standards. Wind load pressures are divided into two zones: one in the center of the wall elevation and the other defined as a dimension off the corner, typically 10% of the elevation width and extending vertically from the ground to the roof. To ensure the fenestration performance satisfies project requirements, these pressures need to be identified on the drawings and specifications and should be considered for the design basis.

Many project designs include large windows to increase daylighting and maximize exterior views. When utilizing large windows, designers should confirm that the manufacturer’s tested window size is larger than the project window size. Oversized windows may be excluded from manufacturer warranties, may not comply with project performance requirements and will often come to the site as an ungraded window.

Additionally, for larger openings, multiple units may be assembled with mullions to combine several individual window units within one opening. The addition of integral reinforced mullions can be rated for class as well as performance but must be specified as unrated. Unrated or underperforming window assemblies with mullions may not meet structural loading requirements and can provide a potential path for air and water infiltration.

Mullion ratings can be specified through requirements and procedures established in AAMA 450: Voluntary Performance Rating Method for Mulled Fenestration Assemblies. The testing results should be incorporated into the project submittal package for the assembly. Manufacturers can qualify a mullion assembly as a combined unit or by submitting individual test data for air infiltration and water penetration resistance and the structural performance of factory-built or knocked-down field-mulled assemblies.

Window Performance

The performance requirements within each of the performance grades can vary significantly. For instance, R and CW windows have a minimum water penetration resistance test pressure equal to 15% of the design pressure, while AW assemblies have a water penetration resistance test pressure that is 20% of the design pressure.

The maximum allowable air leakage difference for R and LC assemblies is 0.3 cubic feet per minute (cfm) per square foot under negative pressure differential of 1.57 pounds per square foot (psf), while CW assemblies are also tested at negative pressure differential of 1.57 psf, but the allowable air leakage is 0.1 cfm psf. AW assemblies are tested at a higher negative pressure differential of 6.27 psf and an allowable air infiltration of 0.1 cfm psf. Further variations in allowable air infiltration occur between double- and single-hung units and casement fixed windows.

Window Selection

During the submittal phase of a project, the contractor and designer typically vet multiple manufacturers for window performance, aesthetics and costs. Often, these decisions are based on typical window units. If an atypical window is considered, compromises may reduce performance on the project.

Once selected, the manufacturer will provide shop drawings with window elevations, noting performance, size and wind load design pressures. A review of these documents may indicate that the basis of a design window complies with project design pressures in the field of the wall zone but may not comply with the increased design pressure at corner zones or the project may include a uniquely sized window that is unrated. Failure to consider all window types may force designers to use a different window manufacturer or a different system designed to handle higher wind loading, often increasing costs on an already tight construction budget. The designer and owner may decide to reduce the design pressure at the corner zones to accommodate the manufacturer’s maximum design pressure, resulting in windows with less air and water infiltration performance than required for the condition.

Field Testing and Failure Rates

It is not rare for projects to have window sizes larger than the maximum size tested for qualification under gateway requirements. In these cases, additional laboratory testing should be considered. Manufacturers will typically design a window to pass their target size with minimal extra material on the frame. For larger units, the manufacturer may be required to...
make modifications, which tend to include extensions at the sill leg as well as additional sealant or tighter weather stripping. System deficiencies often go unnoticed until field testing occurs. Over a two-year period (2016–2017) of field testing, Gale Associates found a 53% rate of water infiltration in 190 windows of various types and sizes. Of the failed windows, installation defects and window assembly deficiencies each accounted for roughly 50% of the failures. The test method was ASTM E1105-15: Standard Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Skylights, Doors, and Curtain Walls, by Uniform or Cyclic Static Air Pressure Difference.

The assemblies tested included aluminum, vinyl, clad wood and fiberglass windows. Fenestration assemblies typically push the limits of the performance requirements for each of the classes, and do not tolerate construction abuse well. Damage to tested units frequently involves broken welds at flange corners, racked frames, displaced weather stripping and damaged hardware.

After failed in-field evaluation testing, the manufacturer and contractor will typically review the window unit and provide recommendations for in-field repairs. These repairs may consist of additional shim support, application of additional sealants or replacement of system components. It is important for the design team and owner to determine if these repairs are isolated or systemic throughout the project. The owner should follow up with the manufacturer to confirm that the repairs made do not affect the warranty or long-term performance. Repairs that depend on sealants will typically require periodic maintenance that often gets overlooked through a building’s life.

Other window assembly failures often involve installation issues caused by a lack of project design detailing or a contractor not adhering to a manufacturer’s installation procedures and industry standard flashing details. ASTM E2112 – 07(2016): Standard Practice for Installation of Exterior Windows, Doors and Skylights provides guidance for window installation. For installation of flanged windows, the standard has four methods (A, A1, B and B1). The applicable method is determined by the installation sequencing of the water-resistant barrier/air-barrier and window assembly, as well
as if the mounting flanges at the jambs are covered with membrane flashing or if the membrane is returned into the rough opening.

To complicate matters more, many manufacturers provide proprietary flashing methods or systems. One familiar building product manufacturer provides up to four different methods to flash a window. These methods are often not equal and, in some instances, do not comply with ASTM E2112 standards. If a designer has not indicated a preferred flashing method for the project, the contractor may utilize an approved method that is more cost effective but may sacrifice redundancy within the window installation. Lack of redundancy in the flashings can lead to water infiltration if one component isn’t properly installed and there is no backup method to direct water to the exterior side of the wall assembly.

Failures often occur due to material incompatibilities around sealants, flashing membranes and the respective water-resistant barrier or air-barrier wall membrane. Lack of adhesion due to incompatible materials, weathering exposure or failure to follow the manufacturer’s installation procedures for proper rolling can affect system continuity. The deficient water-resistant barrier/air-barrier conditions may lead to loose edges and unadhered membranes that provide potential paths of moisture infiltration around the mounting flange, where a single gap in the interior air seal or a protruding window shim can allow water into the interior. This problem can be avoided with a quality control plan that includes review of the window flashing steps and the installation of cladding and trim elements.

Another common installation defect occurs when a contractor neglects good building practices and a manufacturer’s recommended shimming requirements. The result can be a lack of shims, improperly located shims and overdriven fasteners. The use of power-actuated or pressure-actuated nails can lead to bowing and cracking of the frames and deformation of the nailing flange, which can affect the bed sealant and allow air and water infiltration.

A successful window installation depends on a properly prepared window specification that ensures the assembly complies with the project performance requirements. Sufficient details must be provided to indicate level of flashing durability. Even with compliant window specifications and a contractor quality control plan, the researchers’ field testing found that more than 60% of the windows failed during the initial testing of in-place window assemblies. Testing a mockup installation helps to vet potential issues in design and to develop project-specific installation methods that confirm the project performance requirements are met.

Vinyl window assemblies can create adhesion problems for self-adhered membranes. A primer should be applied to the nailing flange to promote adhesion.

A self-adhered membrane flashing is installed over a rough opening sill and lapped up the jambs. A splice of exterior wall air-barrier was installed to provide a weather lapped tie-in from the window sill to the curtain wall.

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