



# Fenestration Hurricane Codes Effective, but Irma Illuminates Room for Improvement

By Steven Saffell

*Figure 1 – A home in Sebring, Florida, after Hurricane Irma hit. According to the Insurance Journal, hurricanes Harvey, Irma, and Maria together caused approximately \$265 billion in damage, with each hurricane joining Katrina and Sandy among the top five costliest U.S. hurricanes on record. Photo by John L. Carkeet IV, LimpingFrog Productions.*

For the first time, 2017 saw three Category 4 hurricanes hit U.S. shores in one season (followed by Hurricanes Florence, Michael, and others in 2018). According to the *Insurance Journal*, hurricanes Harvey, Irma, and Maria combined caused approximately \$265 billion in damage, with each hurricane joining Katrina and Sandy among the revised top five costliest U.S. hurricanes on record (*Figure 1*). Such results have rekindled interest in the efficacy of building codes of all varieties—notably those governing fenestration products.

Because there had not been a major

landfalling hurricane since Sandy in 2012, construction engineers were interested in learning how more recently constructed buildings, built under current building codes, had fared in high wind events. Accordingly, several teams were mobilized to assess the aftermath: the National Science Foundation (NSF), via Project Award 1761461; the National Institute of Standards and Technology (NIST); the Federal Emergency Management Agency (FEMA); the American Society of Civil Engineers (ASCE); and private consulting firms. These teams sought to understand how engineering standards (such as ASCE 7, *Minimum Design Loads for Buildings and Other*

*Structures*), international building codes (I-Codes), test standards (such as ASTM), and design guidelines might be improved.

The fenestration industry launched its own effort to assess the degree of damage to—and caused by—failed fenestration products and how effective fenestration-related codes, standards, and test methods are in anticipating actual conditions and minimizing the damage. Building code expert Dean Ruark, PE, serves as vice president of engineering and product management at PGT Innovations and as president of the American Architectural Manufacturers Association (AAMA) Southeast Region Board. He and PGT Innovations' engineers

Lynn Miller, Robert Beard, and Erin Koss joined a statewide study, sponsored by the Florida Building Commission and led by the University of Florida's Department of Civil and Coastal Engineering, to assess post-storm building damage in Florida.

As results of the assessments come in, the growing body of evidence suggests that the stronger building codes that have been developed over time, starting as a result of the catastrophic losses sustained by Hurricane Andrew in 1992, greatly reduced potential devastation which could have been caused by the storms (Figure 2).

### THE ROLE OF FENESTRATION

Newer structures typically fared well, seemingly untouched in some locations, while older construction more commonly experienced significant damage (Figure 3). Upgrades in glazing systems and windows provided greater resistance to wind pressures, water leakage, and air leakage.

More stringent building code requirements, including those for impact glazing, kept newly built homes, critical facilities, and other engineered structures more secure than during past storms.

Despite that, most of the experts agree that more work needs to be done to further improve building codes.

For windows and doors intended for use in hurricane zones, there are three key considerations involved:

1. Structural strength to resist high wind pressures
2. Resistance to impact from wind-borne debris
3. Protection from water penetration from torrential wind-driven rains

### STRUCTURAL STRENGTH

The primary performance consideration in withstanding high winds is structural integrity; i.e., keeping the windows or doors intact to prevent the pressure of high-velocity wind from entering the building and causing catastrophic structural damage.

The basic standard governing window and door performance factors is AAMA/WDMA/CSA 101/I.S.2/A440, the *North American Fenestration Standard/Specification for Windows, Doors, and Skylights* (NAFS). The 2018 I-Codes reference the 2017 edition of this standard (NAFS-17).

NAFS delineates four performance classes of windows and doors based on increasingly stringent structural requirements.

These are identified as R, LC, CW, and AW. For a product to gain entry to one of these performance classes, it must be tested to withstand progressively higher minimum design pressures (DPs) derived from the maximum wind velocity likely to be experienced at a given geographical location.

ASCE and the Structural Engineering Institute (SEI) standard ASCE/SEI 7, *Minimum Design Loads for Buildings and Other Structures*, and its well-known wind speed contour map for the U.S. are the primary references for determining maximum wind speeds that are likely to be experienced at various U.S. localities. It also is used for determining fenestration design wind load and performance class under NAFS. The most recent version, ASCE/SEI 7-2016, is referenced within the 2018 I-Codes.

In essence, wind pressure is proportional to the square of the wind velocity, meaning that as wind speed increases, the force it exerts increases exponentially. The relationship is defined in the context of IP units by the basic equation:

$$q_z = \text{Velocity Pressure} = 0.00256 V^2$$

where wind velocity  $V$  is expressed in miles per hour and  $q_z$  is expressed in pounds per square foot.

As an example, the higher design pressure of windows as required by coastal codes—e.g., 50 psf or greater—implies that the impacted structure can withstand winds of a Category 4 (139.8-mph) storm.

Note, however, that the actual wind speed used in the above equation can vary significantly from the base wind speed determined by the ASCE-7 wind speed contour maps alone. The specific building's surroundings and exposure category, as well as its shape, height above ground, and location of the fenestration installation being analyzed (e.g., near corners) must be taken into account (as also discussed in ASCE-7) to arrive at an accurate assessment of design pressure for a specific installation.

Observations from these hurricanes showed that structural resistance to pressures imposed by high winds proved mostly adequate under current codes.

### IMPACT RESISTANCE

A significant majority of window breakage during major storms is caused by impacts from airborne debris. Furthermore, if an opening is penetrated by flying debris,



*Figure 2 – As results of the assessments come in, the growing body of evidence suggests that the stronger building codes developed in Florida following Hurricane Andrew in 1992 greatly reduced the devastation caused by the storms. Photo by Cayobo.*



*Figure 3 – Flooding in a residential area. Photo by Cayobo.*



*Figure 4 – In homes that survived and managed well structurally, with impact-rated windows and doors performing as intended against wind and windborne debris, the biggest issue reported was water intrusion that caused damage to buildings’ supporting structures and interior finishes. One of the leading reasons for insurance claims following Hurricane Irma was the cost of such damage and necessary repairs. Photo by John L. Carkeet IV, LimpingFrog Productions.*

the added forces exerted on the structure by the sudden rush of wind can blow off the roof and cause the collapse of the building.

Accordingly, stronger code requirements for impact-resistant windows have been adopted in many coastal jurisdictions. They range from those that reference current I-Code requirements (typically referencing ASTM impact resistance testing standards E1886-13a, *Standard Test Method for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protective Systems Impacted by Missile(s) and Exposed to Cyclic Pressure Differentials*; E1996-17, *Standard Specification for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protective Systems Impacted by Windborne Debris in Hurricanes*; the Southern Building Code Congress International SSTD-12; and Texas Department of Insurance TDI-98) to those in defined High-Velocity Hurricane Zones (HVHZs), such as Miami-Dade Testing Application Standards (TAS) 201, *Impact Test Procedure*; TAS 202, *Criteria for Testing Impact and Nonimpact Resistant Building Envelope Components Using Uniform Static Air Pressure*; and TAS 203, *Criteria for Testing Products Subject to Cyclic Wind Pressure Loading*.

The ASTM tests mentioned above for determining impact resistance are not trivial. For example, for windows to be located less than 30 ft. above ground level, the impact of large missiles is simulated by impelling a 2- x

4-in. stud into the product at 50 ft. per second (fps), or 34 mph. An enhanced version accelerates the missile to an impact speed of 81 fps, or 55 mph. For windows located more than 30 ft. above ground, the impact of roof gravel and other small objects is simulated by firing a shotgun-like pattern of 2-gram ball bearings into the window at a speed of 130 fps, or 88 mph. To pass these tests, there can be no penetration upon impact, no opening formed larger than 3 inches in diameter, or no tear longer than 5 inches.

ASCE-7 also defines a windborne debris region as a subset of the hurricane-prone zone. Within this region, glazing in buildings up to 60 ft. tall in Categories II, III, and IV must be impact resistant or protected with an impact-resistant covering such as hurricane shutters. The windborne debris region occurs within one mile of the coast, where the basic wind speed can hit 130 mph or greater.

“Early findings from the post-hurricane study showed that missiles were larger and moving faster than current [fenestration] industry test criteria [specified],” Ruark said. He also observed “windborne debris size, speed, and frequency that exceeded the design limits of current industry standards. Hurricane Irma was a true test of impact glazing codes in the most heavily impacted areas, like the Florida Keys and Marco Island. Windows and doors took major debris impacts to window framing

members, as well as multiple debris strikes to the glazing. We saw types of impact that pushed beyond the way that most windows are tested.”

## WATER PENETRATION

In homes that survived and managed well structurally, with impact-rated windows and doors performing as intended against wind and windborne debris, the biggest issue reported was water intrusion that caused damage to buildings’ supporting structures and interior finishes (Figure 4). One of the leading reasons for insurance claims following Irma was the cost of such damage and necessary repairs.

Paul Beers, of GCI Consultants, said, “Often, the cause of the leaks can be attributed to deflection, frame rotation, frame movement, or frame separation, to name a few. The sealing of the windows—like gaskets and weather strips—that were subjected to stress during the violent storm were often compromised.”

It should be noted that rain driven by high winds may actually enter the wall cavity at any number of points. Some entry points may be well above the location at which it appears. Examples include the attic or roof, soffit, or wall penetrations such as exhaust fans. Running down the inside of the wall, water may exit the wall around the rough opening at a window or door. This underscores the importance of treating the building envelope as a complete system that must be optimized to resist water intrusion.

AAMA SER-1-18, a white paper about water penetration in hurricane conditions recently updated by the AAMA Southeast Region, noted, “In the aftermath of tropical storms and hurricanes, questions are often raised concerning wind-driven rain leaking through or around windows, doors, and skylights that otherwise remained structurally intact and with little to no apparent damage following these extraordinary events.”

The primary consideration for wind-load resistance in building codes is the structural integrity of the window, door, or skylight, to keep the product intact and to prevent the pressure of high-velocity wind from entering the building and causing catastrophic structural damage. However, in tropical storms and hurricane wind-driven rain conditions, the product selected may still experience water leakage because these extraordinary conditions can exceed the product’s rating for water penetration. Water resistance performance of these prod-

ucts is often affected by a variety of design parameters, including operational or functional concerns, market or economic preferences, life safety, accessibility and egress codes, or other physical limitations.

Hurricane-resistant windows and doors are tested in labs under prescribed wind and water pressures outlined in NAFS. “The record duration of Irma’s sustained powerful winds and rain far exceeded the strength of an impact-resistant window’s or door’s tested ability,” said Ruark. “The consequence was an unprecedented number of water leaks in buildings.”

In practice, water penetration resistance capability of a fenestration product is linked to structural integrity through the DP. To simulate wind-driven rain, testing to determine the water penetration resistance under NAFS is conducted at a pressure equal to 15 percent of the DP, subject to a minimum of 2.86 psf (equivalent to the pressure generated by a 33-mph wind) and a maximum of 12 psf (15 psf in Canada)—equivalent to the pressures generated by wind velocities of 68 and 77 mph, respectively.

The exception is the AW class, which is tested for water penetration at a pressure of 20 percent of DP. The test methods—ASTM E547, *Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Cyclic Static Air Pressure Difference*; and E331, *Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure Difference*—subject the exterior surfaces to a water application rate of 5 gallons per sq. ft. per hour (5 gal/ft<sup>2</sup>/hr)—roughly equivalent to 8 inches of rain per hour—at these test pressures. To pass these tests, no water is permitted to pass the interior plane of the framing or to penetrate corner seals and enter the wall cavity.

#### MORE CODE CHANGES DUE?

As noted, homes built since the implementation of the more stringent Florida Building Code (March 2002 and after) generally performed better. Nevertheless, there is still room for improvement.

In Miami-Dade and northern Florida, Hurricane Irma turned out to be a relatively minimal wind event.

“Many are praising our preparedness and our ability to survive a code-level event,” said consultant Rick De La Guardia, president of DLG Engineering. “But we have a lot more to do to be prepared for a power-

ful storm, such as Irma was at its peak. We dodged a bullet.”

#### CONSTRUCTION PRACTICES

In general, specifiers should select windows and glass doors independently certified by a recognized certification body, such as AAMA, and tested by an accredited third-party laboratory for compliance with NAFS at the desired DP (e.g., 50 psf or greater). Certification to ASTM E1886/E1996 and to AAMA 506, *Voluntary Specification for Hurricane Impact and Cycle Testing of*

*Fenestration Products*, or to TAS 201/203 for enhanced impact resistance, is also optionally available; windows and doors so tested are identified as such on certification label tabs.

To maximize hurricane protection, the best solution is to use impact-resistant windows featuring impact-resistant glazing of appropriate thickness, a strong framing system, and an appropriate sealant and anchorage that together resist both the structural and impact loads as well as pressure-driven water incursions.



**WE BRING  
LANDMARK TESTING  
TO EVERY PROJECT**

The most thorough, accurate and professional testing in the United States of America. That's why we've been selected for prestigious projects like the Statue of Liberty since 1984.

Roof Moisture Surveys  
ELD Fusion® Leak Detection  
Electronic Leak Detection Systems  
TruGround™ Conductive Primer

**IR ANALYZERS**  
**Vector Mapping**  
Smarter Testing. Faster Response.™  
800-879-1964 • info@iranalyzers.com

Impact-resistant glazing usually features laminated glass with a heavy interlayer—commonly polyvinyl butyral (PVB)—sandwiched between two pieces of double-strength glass bonded together under heat and pressure. For impact-resistant windows to function as intended, they must stay anchored to the substrate (component of framing or wall) to which they are attached. To accomplish this, additional fasteners are used to secure the window, and those fasteners must penetrate deeper into the structural member of the substrate, which can be concrete, concrete block, wood frame, or steel stud. The diameter of the fasteners might also be increased to help secure the window. For coastal locations, fasteners should be made from a noncorrosive material, such as stainless steel.

For protection against hurricane water penetration, the simple solution lies in a robust integration of the window or door with the drainage plane, in which the window frame or mounting flange must join together with the exterior facing material, sheathing, and the water-resistive barrier (WRB) to form a unified, fully integrated “drainage plane”—a pathway from roof to ground that channels rainwater that penetrates the cladding system down and away from the building. Even then, the performance of the building envelope regarding

moisture penetration is dependent on a quality installation and is limited by the strength of the design.


A membrane/drainage wall system that utilizes building paper, building wrap, sheathing, or other water-shedding material behind an exterior cladding (e.g., siding, brick veneer, etc.) as the WRB, is generally best suited for areas that experience frequent heavy rain. Water that passes through the exterior cladding encounters the secondary barrier, and drains down the inner cavity, where it is flashed to the exterior.

Even if the window, door, or skylight has been properly anchored for structural integrity, it may leak if not correctly flashed and sealed in accordance with manufacturers’ instructions. Improper installation may leave gaps that are sufficient to allow rainwater penetration when driven by storm-force winds.

### CONCLUSION

Until Hurricane Florence, the Atlantic basin had been unusually quiet in 2018. Cooler water temperatures in the Atlantic and warmer temperatures in the Pacific (as was the case during the 2018 season) typically slow hurricane development and intensity, according to the Weather Channel. However, Hurricane Michael was one of the most severe to impact Florida, and the eval-

uation of these storms should evoke even more stringent requirements.

“As we come together once again to rebuild from recent storms, we must continue to collaborate to generate new and better ways to prepare for the next storm. It has been gratifying to see how impact-resistant windows and doors helped limit windborne debris destruction during a major storm. However, our work is far from over,” concluded Ruark. 



Steven Saffell

*Steven Saffell serves as AAMA’s technical director, overseeing the standards, product certification, and codes and regulatory affairs aspects of the association. His background is a tapestry of architectural firm work*

*and modular design, as well as residential and commercial fenestration experience. Saffell also spent three years teaching as an adjunct professor. He is experienced in managing technical teams, including employee development, operational strategy, and financial management. With 32 years of experience, Saffell previously worked with Simonton Windows and Ply Gem.*

## Hackers Could Take Over Construction Worksites



Research hackers recently proved that they could take over a large construction crane by using nothing more than a laptop, radio hardware, and some code knowledge. Working on behalf of Japanese cybersecurity firm Trend Micro, two hackers arrived at 14 different locations and successfully hacked into devices that controlled the cranes, excavators, scrapers, and other large machinery on construction worksites.

The hackers pinpointed a vulnerability in the communication between the equipment and the controllers. They said that remote-controlled toy cars contain more security than the equipment controllers did. The devices that were hacked into were made by Saga, CircuitDesign, Juuko, Autec, Hetric, Elca, and Telecrane.

Thanks to Trend Micro’s work with the U.S. government-funded Computer Emergency Response Team, manufacturers are being alerted to these vulnerabilities and rolling out fixes.

To view a video of how it’s done, visit: <https://bgr.com/2019/01/15/hacking-threat-construction-cranes-vulnerable/>.

— [bgr.com](https://bgr.com)