

Protecting Windows and Openings in Buildings



FEMA

HURRICANES IRMA AND MARIA IN PUERTO RICO

Recovery Advisory 5, April 2018

Purpose and Intended Audience

The purpose of this Recovery Advisory is to provide guidance related to the use and installation of opening protection systems to protect glazed openings (windows) from wind-borne debris during high-wind events. The use of these systems has been required for new construction in specific areas near the coast since the government of Puerto Rico adopted the the 1997 Unified Building Code island-wide for all structures in response to Hurricane Georges in 1998. In 2011, the Puerto Rico Permit and Management Office, Oficina de Gerencia y Permisos (OGPE), produced the 2011 Puerto Rico Building Code (*PRBC*) which adopted the International Code Council (ICC) 2009 *International Building Code* (ICC IBC, 2009) and 2009 *International Residential Code* (ICC IRC, 2009) with local amendments. These codes specified that all new construction in Puerto Rico would require protection for glazed openings from debris impact and that the windows would need to resist design pressures without failure. The use of these systems to protect glazing openings on exterior walls is required for new construction for all buildings under the 2011 *PRBC* (and under the 2018 IBC and IRC, if they are adopted in Puerto Rico as part of the 2018 *PRBC*) and is recommended for use in existing buildings.

The guidance is primarily intended for design professionals and building contractors. However, it provides helpful information for building officials, building owners, building managers, and homeowners.

This Recovery Advisory Addresses

- Design and Construction Guidance for Window and Glazing Performance
- Design and Construction Guidance for Impact-Resistant Systems
- Building Code Requirements for the Protection of Glazed Openings (Windows)
- Installing Wood Panels for Opening Protection

Key Issues

1. Protecting glazed opening from failure (Figure 1) due to wind pressures and wind-borne debris improves overall building performance during hurricanes and other high wind events
2. Unprotected glazing systems (glass window and door systems) were damaged and failed during Hurricane Irma and Maria due to wind pressure and impacts from wind-borne debris.
3. Unprotected openings containing jalousie openings (glazed and non-glazed systems) were damaged and failed during Hurricane Irma and Maria due to wind pressures and impact from wind-borne debris.
4. Damage to both residential and non-residential buildings (including hospitals) was observed due to water intrusion around non-broken glazing systems, including window systems that were protected by impact-protective systems (shutters or plywood panel systems).
5. For existing buildings, it is recommended that the building owner hire a qualified architect or engineer to perform a wind vulnerability assessment and determine corrective action to mitigate significant vulnerabilities of glazed openings and windows



Figure 1. Residential windows protected (left) and unprotected (right). The unprotected windows were damaged and are temporarily covered with plywood.

Design and Construction Guidance for Window and Glazing Performance

This section provides examples of several types of opening, window, and storm shutter problems, as well as examples of various shutter systems that were observed after the 2017 hurricanes. A FEMA Building Performance Assessment Team (BPAT) was deployed to Puerto Rico in 1998 to study the damage and impacts to the built environment from Hurricane Georges. One of the key recommendations from that study effort, *Hurricane Georges in Puerto Rico* (FEMA P-339, 1999), was that glazing and openings on new and existing buildings should be protected from impacts from wind-borne debris. The observed good performance of shutter systems and other impact-resistant window systems in Puerto Rico after the hurricanes showed the successful implementation of the recommendations from the FEMA report.

As an initial step in the design process, or for post-event repairs, it is recommended that designers calculate wind loads on openings, windows, skylights, and shutters using whichever procedure below results in the highest loads:

- The current 2011 *PRBC*
- The 2016 edition of the American Society of Civil Engineers Standard 7 *Minimum Design Loads and Associated Criteria for Buildings and Other Structures* (ASCE 7-16, 2017)
- The 2018 *PRBC* based on the 2018 IBC and IRC, with local amendments, if adopted in the future

Per the 2011 *PRBC*, new glazed door, window, and skylight assemblies that are in a wind-borne debris region such as Puerto Rico, and that are 60 feet or less above grade, are required to be impact-resistant or protected with an impact-resistant covering (shutter).¹ A comparison between the current building code regulations of the 2011 *PRBC*, the 2018 IBC and IRC, and the Recovery Advisory recommendations is provided in Table 1. The table references publications by the American National Standards Institute (ANSI), ASTM International (ASTM), the Door and Access Systems Manufacturers Association International (DASMA), and the Engineered Wood Association (APA). Full citations and links to these documents are available in the references.

Table 1. 2018 IBC and IRC Requirements Comparison to Recovery Advisory Recommendation

Component	Hazard	Code Requirement	Additional Recommendation
Door Assemblies	Wind Pressure Testing	ASTM E330 Note: glazed openings impact tested per ASTM E1886, ASTM E1996.	ASTM E1233 Note: E2133 is a cyclical test, whereas E330 is a static test.
Rolling or Sectional Door Assemblies	Wind Load Pressure Testing	ASTM E330 or ANSI/DASMA 108, and shall meet the acceptance criteria of ANSI/DASMA 108 Note: glazed openings impact tested per ANSI/DASMA 115.	DASMA Technical Data Sheet 115 (DASMA, 2014) Note: 115 is a cyclical pressure test and an impact test, whereas 108 and E330 are static pressure tests.
Awning, Casement, Hopper, Single-Hung, or Double-Hung Operable Windows, Fixed Windows, Skylights	Wind Load Testing, Impact Testing or Protected by Storm Shutter, Water Infiltration	ASTM E330, ASTM E1186, ASTM E1996	ASTM E1233 Performance Level 10 be specified according to the American Architectural Manufacturers Association specification AAMA 520-12 (2012).
Storm Shutters	Wind Load Testing, Impact Testing	ASTM E330, ASTM E1886, ASTM E1996 For residential up to 45 foot mean roof height, wood shutters are allowed when constructed and anchored in accordance with IRC provisions.	For residential up to 45 foot mean roof height, wood shutters; APA Form T460.

¹The 60 foot height limitation is predicated on the reduced likelihood of wind-borne debris occurring above this height. However, nearby topography may present an increased debris potential. It is recommended that the designer consider specifying impact-resistant assemblies at heights greater than 60 feet where topographic conditions present increased debris potential.

Although the current 2011 *PRBC* refers to the 2009 IBC and IRC, the authors expect that Puerto Rico will adopt the 2018 IBC and IRC. With respect to their opening protection requirements, the primary change from the 2009 to the 2018 IBC and IRC is an update to the design wind speed maps incorporated by referenced from ASCE 7-16 which results in a change in the calculation of wind pressures on the and entire building, including the window and door assemblies that are to be rated to resist wind pressures and forces. It is important to note, however, that the there is no change to the requirements of the 2011 *PRBC* for all new buildings throughout Puerto Rico to have impact-resistant glazing or protective systems for glazed openings (windows and doors consisting of glass elements) to protect them from impacts from wind-borne debris.

Jalousie Openings

A jalousie opening has metal or glazed louvers that can be opened or tilted to control airflow. Jalousies are common in homes, schools, and other types of buildings in Puerto Rico. Figure 2 shows a home with glass jalousies that were not protected and were heavily damaged during Hurricane Maria; this was a common observation of the performance of glazed panel jalousies. Further, both the metal and glazed jalousies are very susceptible to wind-driven rain, even when the louvers are undamaged (Figure 3). Depending upon the floor and wall construction, finishes, and location of furniture, entrance of wind-driven rain may cause minimal damage or it may result in significant interior damage. If the magnitude and consequences of wind-driven rain infiltration associated with jalousies is unacceptable, fixed windows, or other types of operable windows, such as awning, casement, hopper, single-hung, or double-hung windows, can be specified.

The school shown in Figure 4 had widespread use of Jalousie openings. The jalousies either had a screen or glazed panel behind them. The classrooms used screens while the offices, laboratories, or technical spaces (with computers) had glazed panels mounted inside the jalousies to prevent air flow and keep air conditioned space in those rooms. Even when the panels remain in place, interior water leakage can occur, because the panels are typically not sealed to the jalousie frame. Water intrusion occurred in the classroom shown in Figure 4 but resulted in limited damage to the hard surface finishes used. Common metal jalousie openings may be undamaged by low-momentum debris, but they can still be breached by wind-borne debris that is common during strong hurricanes. Neither the IBC nor IRC require metal jalousies to be wind-borne debris resistant. However, glass jalousies are required to be resistant to wind-borne debris or protected by a shutter system or opening protection device when used within the wind-borne debris region.

Other Types of Operable Window Assemblies

In addition to jalousie openings, other operable windows such as awning, casement, hopper, single-hung, and double-hung windows may be used. Detailed information about window and door installation is provided in *Standard Practice for Installation of Exterior Windows, Doors and Skylights* (ASTM E2112, 2016), which concentrates on detailing and installation procedures that are aimed at minimizing water infiltration. However, even with excellent detailing and installation, it is challenging to avoid water infiltration during strong hurricanes, particularly when low thresholds for doors are required for complying with accessibility codes and standards. When designing operable windows, it is recommended that design professionals specify assemblies that comply with wind load testing in accordance with *Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights, and Curtain Walls by Cyclic Air Pressure Differential* (ASTM E1233, 2014). It is also important to specify an adequate load path and to check its



Figure 2. Residence where unprotected glazing louvers were broken by wind-borne debris on the left and right sides of the entry door.



Figure 3. New secured housing units with metal jalousie openings.



Figure 4. High school in a coastal community with metal jalousie openings. Screens were installed behind the jalousie openings.



Figure 5. Numerous operable casement and awning windows were damaged due to wind pressures and wind-borne debris at this waterfront building.

continuity during submittal review. Approximately $\frac{1}{3}$ of the unprotected casement and awning window systems in a waterfront multi-family residential building (Figure 5) were damaged from wind pressures, wind-borne debris, or a combination of these forces.

With respect to wind-driven rain resistance of window assemblies, it is recommended that Performance Level 10 be specified according to the American Architectural Manufacturers Association (AAMA) *Voluntary Specification for Rating the Severe Wind-Driven Rain Resistance of Windows, Doors and Unit Skylights* (AAMA 520-12, 2012).² Even assemblies that meet Performance Level 10, to achieve successful performance, must be integrated into the wall system via robust design detailing (as discussed in FEMA P-424) and quality application in order to avoid entrance of wind-driven rain. It is recommended that ASTM E2112 and the *Homebuilder's Guide to Coastal Construction* (FEMA P-499), Fact Sheet 6.1 "Window and Door Installation" be considered. Where water infiltration protection is particularly important, it is recommended that on-site water infiltration testing be specified in accordance with the *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* (ASTM E1105, 2015).

Fixed Glazing Assemblies

Fixed glazing assemblies are generally more resistant to wind-driven rain than operable assemblies, particularly as gaskets and seals at the operable interfaces age. As with operable window assemblies, the assembly should be carefully integrated into the wall system. While fixed glazing assemblies typically provide better performance against wind-driven rain over jalousie

openings and operable windows, homeowners and business owners need to be aware of trade-offs to using these window systems. Specifically, homes and buildings with fixed glazing assemblies typically rely on power to support the air-conditioned space within the homes. When power is lost after an event, there is limited ability to open the windows and air dry the homes when windows are not operable (see Figure 6). Also, a notable observation during the hurricanes was that a number of homes and businesses with fixed windows experienced failure of the entire window assembly due to wind pressures (Figures 7 and 8). The large windows in Figure 7 did not appear to have an adequate number (and size of) fasteners to secure the window frame to the supporting structure. The same observation was seen at the hospital



Figure 6. Fixed and operable window assemblies at a home performed without failure.



Figure 7. Two-story window assemblies (fixed and operable) failed at the frame-to-wall connection due to lack of proper fasteners.



Figure 8. An entire bay of windows is missing from the upper floor of this hospital in Bayamon due to a lack of adequate fasteners.

² AAMA 520-12 establishes 10 different levels of performance utilizing ASTM *Standard Test Method for Water Penetration of Exterior Windows, Skylights, and Doors by Rapid Pulsed Air Pressure Difference* (ASTM E2268, 2011). Performance Level 10 is the highest level. All the performance levels permit a specified maximum amount of water leakage.

in Figure 8, where a bank of windows on the upper floor of a building addition was secured by small fasteners and failed during the hurricanes. It is important for design professionals to be aware of and apply both ASTM E2112 and ASTM E1233 when addressing the wind forces and wind pressures from hurricanes. As a result, when hurricane winds impacted the homes, many units in this development experienced complete failure of the window systems due to wind pressure.

Design and Construction Guidance for Impact-Resistant Systems

After Hurricane Georges in 1998, the use of impact-resistant systems (e.g., rated shutters, screens, other panel systems) was required for new buildings in many areas. Existing buildings are not required to have glazed openings protected; however, at the time of Hurricanes Irma and Maria, many existing buildings in Puerto Rico had been retrofitted with impact-resistant systems and impact-resistant glazing. Buildings without these protections were vulnerable to damage from wind-borne debris, which can lead to extensive interior building damage (Figure 9). Most manufactured opening protection systems performed as expected during the storms when installed properly on the buildings; this applies to shutter panels, accordion shutters, and roll-down shutter systems. Unfortunately, there were a number of notable instances where shutters were improperly installed, could not be deployed because they were obstructed by other building elements, or were not operable because the systems, primarily the tracks, had not been properly maintained.

Impact-Resistant Systems

A variety of impact-resistant systems are available, including shutters, screens, and other panel systems in the marketplace. FEMA recommends using shutters bearing a label indicating they have been tested to comply with the standard *ASTM Standard Specification for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protective Systems Impacted by Windborne Debris in Hurricanes* (ASTM E1996, 2017) and are installed in accordance with building codes and requirements referenced by this Recovery Advisory. If wind-borne debris glazing protection is provided by impact-resistant systems, the glazing is still required by ASCE 7-16 to meet the positive and negative design wind pressures. Impact-resistant systems placed over windows to provide wind-borne debris protection should not be relied upon to protect against wind-driven rain as they are not designed to provide resistance to this hazard. If existing windows are susceptible to debris impacts and water leakage, it is recommended that the windows be replaced with new assemblies to avoid interior water damage.

Vulnerable glazed openings on buildings are protected when these systems are installed on single-family homes; the appropriate lower floors of low-, mid-, and high-rise buildings; and critical and essential facilities. Common elements of impact-resistant systems that performed well during Hurricanes Irma and Maria include adequately mounted tracks for panels or accordion shutters to the building exterior (not mounted to the window frames) and well-maintained shutters or panels that were secured and properly attached/fitted within supporting tracks. Instances of properly deployed window protection systems are shown in Figures 10-12.



Figure 9. Glazing damage at the main entrance to a community building/convention center.



Figure 10. A two-story residence with windows and gill doors (upper porch) protected with metal panel shutters.



Figure 11. A high-rise residential tower where approximately 85% of units have a form of shutter or impact-resistant system in place that was installed as a retrofit.

Installation of Impact-Resistant Systems

It is important that impact-resistant systems are installed properly to ensure glazed windows and doors are protected as intended. It is also very important that all sides of the building have glazing protected to the heights specified in the building codes. If only one or two sides of a building are protected, the unprotected sides may still be damaged by windborne debris, allowing water intrusion and further progressive damage to the building, most likely resulting in unnecessary facility downtime or damages after a high wind hazard event occurs.

The building presented in Figure 13 illustrates challenges and inconsistencies that impact the ability of shutter systems to provide the impact resistance intended. While the red arrow identifies a properly installed shutter system, the following issues related to the installation of the shutters lower the level of protection and effectiveness of the shutters:

- Shutters for glazed door entry were not secured with a bottom track (green oval).
- Window air conditioner obstructed deployment of the shutter system (red circle).
- Metal jalousie openings do not require impact-protective systems per the PRBC, and the 2018 IBC and IRC, since it is not glazed; however, the metal panels provide less protection for this opening (yellow circle) as they are typically not rated for wind-borne debris impact resistance.



Figure 12. A fire station with metal panel shutter system deployed provided adequate protection for the facility.

Building Code Requirements for the Protection of Glazed Openings

The building codes, and standards referenced by those codes, identify the geographic areas where impact-resistant systems are required to protect glazed openings. The 2011 *PRBC* requires, through reference, protection of openings for new buildings constructed in the wind-borne debris region as defined by the American Society of Civil Engineers Standard 7-05 *Minimum Design Loads for Buildings and Other Structures* (ASCE 7-05, 2005). The adoption of this standard by the *PRBC* was important, as this placed **all the islands** of Puerto Rico within the wind-borne debris region.



Figure 13. Installation issues that affected the performance of the impact-resistant systems include the lack of a bottom track (green oval), a window air conditioner preventing shutter deployment (red circle), and a metal jalousie opening with no impact-resistant system (yellow circle).

All new construction in the wind-borne debris region is required to have appropriate protection for glazing (through impact-resistant glazing systems or through impact-resistant systems)³.

Whether design professionals are using the 2011 *PRBC* or are anticipating the adoption of the 2018 IBC and IRC by Puerto Rico, a few key factors should be considered.

- Since the adoption of the 2011 *PRBC*, all islands of Puerto Rico are designated to be within the wind-borne debris region, requiring the protection of glazed openings for all new buildings.
- Opening protection systems required by ASCE 7 must meet the appropriate debris impact criteria set forth in ASTM E1996 based on the design wind speeds in the code and the use and occupancy type of the building.
- The vulnerability to damage of any existing building from wind-borne debris can be reduced by installing impact-resistant systems (e.g., shutters, screens, and other panel systems) rated for the same level of protection as required for new construction.
- Wind speeds, wind pressures, and other criteria have changed in newer editions of the ASCE 7 standard since the 2011 *PRBC* (which references the ASCE 7-05 edition) was adopted. When determining wind pressures and wind load acting on a building, design professionals should use the specific wind speed maps, tables, and criteria that are referenced by specific editions of the codes and that are effective for the given jurisdiction.

To install impact-resistant glazing or shutter systems to comply with the 2011 *PRBC*, as well as 2018 IBC and IRC, Table 1 presents a summary of code requirements that are to be followed.

Installing Wood Panels for Opening Protection

The 2011 *PRBC* and the 2018 IBC and IRC refer to ASTM E1996 as well as the *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* (ASTM E1886, 2013). They state that, “in wind-borne debris regions, glazing in buildings shall be impact resistant or protected with an impact-resistant covering meeting the requirements of an approved impact-resistant standard such as ASTM E 1996 and ASTM E 1886” (IBC 2018, 1609.2). Wood structural panels are permitted to be used as a low-cost alternative to provide protection so long as they meet local building code requirements.

Figure 14 illustrates the successful uses of wood panels for an impact-resistant system. The homeowner had retrofitted the building with a plywood shutter system. This system used permanent tracks on the top and bottom to support and restrain pre-cut plywood panels. This simple and cost-effective solution provided protection for window

Wind-Borne Debris Hazard in Puerto Rico

Since 1998, portions of Puerto Rico were included within the wind-borne debris region defined by the ASCE. In 2011, the *PRBC* and the reference standards incorporated, placed the entirety of Puerto Rico within the wind-borne debris region, thereby requiring new buildings to protect all glazed openings from high wind pressures and impacts from wind-borne debris. This standard clearly identifies the risk of glazing and windows assemblies that are vulnerable to damage from wind-borne debris during hurricanes impacting Puerto Rico. Based on these risks to existing buildings, FEMA recommends that building owners and operators consider retrofitting applicable or appropriate building envelope systems with rated shutters to protect glazing on building exteriors in accordance with the requirements of ASCE 7-16.



Figure 14. Top, metal louverie window that was protected from wind-borne debris by wood panels, bottom, during Hurricanes Irma and Maria.

³ See ASCE 7-05 and the 2009 IBC and IRC for additional specific requirements for opening protection in relation to height above grade and height above lower building roof surfaces.

openings on the home even though the window openings were metal panel jalousies. For larger commercial and other non-residential construction, the IBC does not permit wood panel shutters as an alternative for tested shutter assemblies. However, the IRC permits them up to a 45 foot mean roof height, when constructed and anchored in accordance with the IRC provisions. The Engineered Wood Association (APA) *Hurricane Shutter Design Considerations for Florida* (APA Form T460, 2013) provides guidance for constructing and installing wood panel shutters. If wood panels are installed, it is important to adequately anchor them so that they do not become wind-borne debris.

For additional information on the installation and use of plywood shutters to protect openings, see FEMA P-499, Fact Sheet 6.2 and documents such as APA Form T460. These documents provide guidance on the wood panels, the size and placement of connection points, and how to adequately design and install them so they remain in place to help protect your home during high-wind events such as hurricanes.

References and Useful Links

References

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Useful Links

FEMA. "FEMA Puerto Rico." <https://www.facebook.com/FEMAPuertoRico>. Note, this Facebook page was created for the Hurricanes Irma and Maria recovery process and is regularly updated with useful information.

For more information, see the FEMA Building Science Frequently Asked Questions Web site at <https://www.fema.gov/frequently-asked-questions-building-science>.

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