Design, Installation, and Retrofit of Doors, Windows, and Shutters

FEMA

HURRICANES IRMA AND MARIA IN THE U.S. VIRGIN ISLANDS *Recovery Advisory 4, March 2018*

Purpose and Intended Audience

The purpose of this Recovery Advisory is to recommend practices for selecting, detailing, and installing doors, windows, and storm shutters that will enhance their wind and water leakage resistance in the U.S. Virgin Islands. This guidance is intended for building owners, architects, engineers, and contractors; however, it provides helpful information for other stakeholders as well.

Key Issues

1. **Facilities in the planning stage:** Designers should do the following:
   - Calculate wind loads on exterior doors, windows, and shutters.
   - Specify assemblies that have sufficient strength to resist the specified loads.
   - Specify attachment of the assemblies.

   Also, contractors should implement quality control and quality assurance procedures to confirm the design's intent is met.

Repairing Wind Damaged Public Facilities Using the FEMA Public Assistance (PA) Program

According to the *Public Assistance Program and Policy Guide* (FEMA PAPPG, 2018), additional grant funding may be available on eligible repairs to provide hazard mitigation against future events. For more information see *PAPPG*, Appendix J, Section VIII. Buildings and Structures, I. Doors and Windows.

2. **Existing doors, windows, and shutters:** 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.
3. **Preparations prior to hurricane landfall:** It is recommended building owners have their maintenance staff or contractor perform the following:
   - Adjust door weatherstripping to confirm a tight fit.
   - Deploy shutters at doors and windows that are intended to be protected from wind-borne debris.
   - Consider applying expanding foam insulation (available in aerosol cans) at door sill gaps and jambs (Figure 1) to avoid entrance of surface water and wind-driven rain. Removal of the foam may be difficult and time-consuming. Note that the window in Figure 1 was also taped. Tape is ineffective in increasing wind and wind-borne debris resistance.

Figure 1. Expanding foam insulation was applied at gaps around and between these doors (red arrows).

4. **After a high-wind event**: This post-event assessment may note new measures that can be taken to improve resilience.

This Recovery Advisory Addresses

- Existing facilities (including but not limited to post-event repairs) and facilities in the planning stage, including residential, commercial/industrial buildings, and critical facilities.
- Wind pressure and wind-driven rain resistance of doors and windows.
- Wind-borne debris resistance of glazed doors, jalousie openings, glazed windows and skylights, and storm shutters.
- Preparations prior to hurricane landfall.

FEMA Mitigation Guidance

For additional design and construction mitigation guidance, see the *Design Guide for Improving School Safety in Earthquakes, Floods and High-Winds* (FEMA P-424, 2010) Sections 6.3.3.1, 6.3.3.2, 6.3.3.3 and 6.4.2.1.

Design and Construction Mitigation Guidance

This section provides examples of several types of door, window, and storm shutter problems, as well as examples of various shutter systems that were observed after the 2017 hurricanes.

As an initial step in the design process, or for post-event repairs, it is recommended that designers calculate wind loads on doors, windows, skylights, and shutters in accordance with the local building code or 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), whichever procedure results in the highest loads. According to the International Code Council (ICC) *International Residential Code* (ICC IRC, 2018) and *International Building Code* (ICC IBC, 2018), new glazed door, window, and skylight assemblies that are in a wind-borne debris region such as the USVI, 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 building code regulations and the Recovery Advisory recommendations is provided in Table 1.

Doors

For added protection, design professionals should consider new personnel, sectional, and rolling door assemblies that comply with wind load testing in accordance with the *Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights, and Curtain Walls by Cyclic Air Pressure Differential* (ASTM E1233, 2014) or the Door and Access Systems Manufacturers Association International (DASMA) *Technical Data Sheet 115, Standard Method for Testing Garage Doors: Determination of Structural Performance Under Missile Impact and Cyclic Wind Pressure* (DASMA 115-17, 2017), respectively. This guidance provides additional protection above code requirements. Design professionals should also take into consideration the attachment of the door frame to the wall (e.g., type, size, spacing, and edge distance of frame fasteners) as failures have been seen between these components.

Figure 2. Rolling door damage at a new fire station.

Wind pressure failure of personnel doors is rare. When failure occurs, it is typically due to inadequate latch throw, inadequate attachment of hinges, or inadequate attachment of the door frame to the building. If such deficiencies exist, they can often be cost-effectively mitigated with new hardware and/or fasteners.

Wind pressure failure of older sectional and rolling doors that were not manufactured to resist high wind loads is common. Surprisingly, several rolling door slats at a new fire station disengaged from their track (Figure 2). Also, two of the other five apparatus bay doors at this same fire station were not operational. The doors had a label that indicated pressure and impact resistance testing in accordance with Florida test standards, rather than DASMA test standard 115. DASMA 115 is more stringent than the applicable Florida test standards.

[1] The 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.

The most common door problem during hurricanes is entrance of surface water and wind-driven rain at the gap between the door and the threshold, jamb, or head. 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 are required for accessibility.

An effective approach to avoid water infiltration damage associated with personnel doors is to design a vestibule with water-resistant finishes (e.g., concrete or tile) and a floor drain. Equip both the inner and outer doors with robust weatherstripping as described below. In addition, installing exterior threshold trench drains can be helpful (openings must be small enough to avoid trapping high-heeled shoes). Note that trench drains do not eliminate the problem, since water can still penetrate at door edges.

Where the topography slopes towards doors, it is recommended that the grade be reconfigured with swales and/or berms to direct surface water flow away from doors. At the house shown in Figure 3, the driveway sloped down towards the entry door. A curb directed water away from the door, but it was too short to divert all the torrential rain.

Figure 3. A substantial amount of water entered this house at the door (yellow arrow). The curb (blue line) was too short to divert the water running down the driveway.

Besides water entering at the threshold, wind-driven rain can enter at the door head and jambs. Adjustable jamb/head weatherstripping is recommended because the wide sponge Ethylene Propylene Diene Terpolymer (EPDM), which is a synthetic rubber, offers good contact with the door. The adjustment feature also helps to make good contact, provided the proper adjustment is maintained.

Figure 4. Several of the metal jalousie louvers at this school were blown away.

Jalousie Openings

A jalousie opening has metal or glazed louvers that can be tilted to control airflow. Jalousies are common at schools, homes, and other types of buildings in the USVI. However, they are very susceptible to wind-driven rain, even when the louvers are undamaged (Figure 4). Depending upon the floor and wall construction, finishes, and location of furniture, entrance of wind-driven rain may cause limited or significant 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.

Figure 5. Glazed panels (red arrow) were mounted to the inside the jalousie. Such panels are typically ineffective in preventing entry of wind-driven rain.

At the school shown in Figure 5, panels glazed with plastic were mounted inside the jalousies for energy conservation. Most of the glazed panels were blown away. Even when the panels remain in place, interior water leakage can occur because the panels are not typically sealed to the jalousie frame.

Common metal jalousie louvers may be undamaged by low-momentum debris, but they can be easily breached by wind-borne debris that is common during strong hurricanes. Neither the IBC or 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.

Other Types of Operable Window Assemblies

When specifying awning, casement, hopper, single-hung, or double-hung operable windows, it is recommended that design professionals specify assemblies that comply with wind load testing in accordance with ASTM E1233. It is also important to specify an adequate load path and to check its continuity during submittal review.

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 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. Whether operable or fixed assemblies are specified, the assembly should be carefully integrated into the wall system. Figure 6 is an example where windows were replaced after Hurricane Marilyn (1995) with glazing systems that provided wind-borne debris and high wind pressure resistance. However, during Hurricane Irma, some of the wall covering blew away, and wind-driven rain entered the hospital. In addition, one window assembly blew into the facility, apparently due to inadequate attachment of the window frame to the wall framing.

Figure 6. Blow-off of the wall covering at the window head recess at a hospital allowed entrance of wind-driven rain.

Storm Shutters

A variety of storm shutters are available. If wind-borne debris glazing protection is provided by shutters, the glazing is still required by ASCE 7 to meet the positive and negative design air pressures.

Shutters placed over windows to provide wind-borne debris protection should not be relied upon to protect against wind-driven rain. If existing windows are susceptible to debris and leakage, it is recommended that the windows be replaced with new assemblies to avoid interior water damage.

It is recommended that only shutters bearing a label indicating that they have been tested and are building code compliant be installed. Figure 7 shows a damaged shutter without a label indicating whether it was a tested assembly. It is possible that the shutter experienced loads that exceeded those specified in the test standards, or it may not have been a tested assembly.

Figure 7. The red oval indicates where the head track was deformed. Plywood was temporarily installed after the storm.

[2] AAMA 520 establishes 10 different levels of performance utilizing Standard Test Method for Water Penetration of Exterior Windows, Skylights, and Doors by Rapid Pulsed Air Pressure Difference (ASTM E2268, 2016a). Performance Level 10 is the highest level. All the performance levels permit a specified maximum amount of water leakage.

Figure 8 illustrates a permanently mounted screen shutter. With this type of shutter, future deployment time and costs are eliminated.

Hurricane Shutter Design Considerations for Florida, published by APA – The Engineered Wood Association (APA 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. Figure 9 shows traditional shutters made from thick wood boards. This type of shutter provides substantial resistance to wind-borne debris, provided the hardware and connecting bolts are not corroded and the shutters are adequately latched. As shown in Figure 9, the boards were inadequately bolted.

Skylights

Skylights are also required to meet wind pressure and wind-borne debris criteria. At the airport terminal building shown in Figure 10, the skylights appeared to be adequately attached to their curbs, although some of the screws were corroded. A few of the skylights were broken by wind-borne debris, illustrating the importance of specifying skylights that have been tested to meet wind-borne debris criteria.

Figure 8. Permanently mounted wind-borne debris-resistant screen at a medical clinic. The inset shows a close-up of the screen and a label indicating that the shutter was a tested assembly.

Figure 9. Damaged traditional-type shutter.

Figure 10. Skylight damaged by wind-borne debris. The red arrows indicate patches where debris punctured the roof membrane.

Table 1. 2018 International Code 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 (ASTM 2014) Note: E2133 is a cyclical test, whereas E330 is a static test.
Rolling or Sectional Door Assemblies	Wind Load 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, 2017) 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 the IRC provisions.	For residential up to 45 foot mean roof height, wood shutters; Form T460, The Engineered Wood Association, (APA, 2013).

References and Resources

References

American Architectural Manufacturers Association (AAMA). 2012. *Voluntary Specification for Rating the Severe Wind-Driven Rain Resistance of Windows, Doors, and Unit Skylights*. AAMA 520-12.

American National Standards Institute (ANSI), Doors and Access Systems Manufacturers Association (DASMA). 2017. *Standard Method for Testing Sectional Garage Doors: Determination of Structural Performance Under Missile Impact and Cyclic Wind Pressure*. ANSI/DASMA 115-17. http://www.dasma.com/dasma-pages/D-AS-standards.asp

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Useful Links

FEMA. 2018. *FEMA U.S. Virgin Islands*. FEMA U.S. Virgin Islands Recovery Facebook Page. https://www.facebook.com/FEMAUSVirginIslands

Note: this page was specifically setup 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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