Best Practices for Minimizing Wind and Water Infiltration Damage

FEMA

HURRICANE MICHAEL IN FLORIDA — *Recovery Advisory 2, June 2019*

Purpose and Intended Audience

This Recovery Advisory presents important recommendations to reduce wind and water infiltration damage to new and existing residential buildings. The recommendations discussed are from existing Federal Emergency Management Agency (FEMA) Building Science resources, including recovery advisories published after Hurricane Irma, and also include new recommendations and best practices based on observations made by the Mitigation Assessment Team (MAT) after Hurricane Michael struck in 2018 (Figure 1 shows an example of observed damage).

This advisory describes specific issues observed in newer residential buildings after Hurricane Michael. The buildings observed were built after the adoption of the first edition of the Florida Building Code (FBC) (March 2002). The advisory provides key points for consideration during rebuilding and mitigation activities. The references cited in the advisory contain additional best practices and guidance for issues commonly observed after storm events.

The primary audience includes building owners, operators, and managers; design professionals; building officials; contractors; and municipal building and planning officials.

Note that roof covering damage is not visible in the photograph. The resulting interior water damage is indicated by the debris pile near the curb.

Figure 1: House with typical envelope damage (siding, soffit, and fascia cover) observed on newer buildings after Hurricane Michael (Panama City area)

The State of Florida requires product approval for the building envelope components addressed in this Recovery Advisory. For more information on Florida product approval, see Hurricane Irma in Florida Recovery Advisory 2, *Soffit Installation in Florida* (in FEMA P-2023, 2018).

Key Issues

- Widespread wind damage to envelope components (roof coverings, wall coverings, roof ventilation components, and windows and doors) resulted in extensive and costly water intrusion damage from wind-driven rain. Water intrusion occurred where there was roof covering damage, loss of roof ventilation components (i.e., ridge vents and soffits), damage to exterior wall coverings, and around windows and door openings.
- Water infiltration can saturate attic insulation, allow water seepage into exterior and interior wall systems, damage interior finishes and furnishings, and lead to algae and mold growth.
- Wind and water infiltration damage can lead to extensive operational impacts and loss of (or degraded) building usage over extended periods of time, until adequate repairs are made.
- There is a lot of existing guidance that can be used to reduce wind damage and water infiltration for residential buildings, which can make it difficult for users to find the best guidance.

This Recovery Advisory Addresses

- Roof coverings, underlayment, and vents
- Exterior wall coverings
- Soffits
- Glazed openings and doors

Roof Coverings, Underlayment, and Vents

Roof covering damage due to high winds has been noted by several MATs to be a primary source of water intrusion. The recommendations in this section provide for enhanced wind resistance of roof coverings (see 'Wind Resistance') and also include a secondary underlayment system designed to prevent water intrusion in the event that the primary roof covering is lost or punctured by wind-borne debris (see "Water Infiltration"). Recommendations are also provided for improved performance of roof ventilation products.

Roof Repair and Replacement in Accordance with Florida Building Code

The FBC limits how much of an existing roof can be repaired within a specific period of time before triggering the requirement to comply with the latest code. Additionally, when a roof covering system on a single-family dwelling is removed and replaced, the FBC requires the following components be investigated and subsequent measures taken if deficiencies are found:

- Roof deck attachment
- Enhanced underlayment (secondary water barriers)
- Roof-to-wall connections

These requirements are discussed in detail in Hurricane Irma in Florida Recovery Advisory 3, *Mitigation Triggers for Roof Repair and Replacement in the 6th Edition (2017) Florida Building Code* (in FEMA P-2023, 2018).

Wind Resistance

Wind-related damage was observed after Hurricane Michael on roof coverings, including asphalt shingles, concrete and clay roof tiles, and metal roof systems. Applying the following best practices will improve wind resistance for these systems. Information on ridge vents and off-ridge vents is also provided.

Asphalt shingles. The Hurricane Michael MAT noted widespread poor wind performance of asphalt shingles. While the reason for their poor performance is not fully understood, recent studies and post-hurricane observations point to a few issues. A recent study of existing homes of various ages in Florida (Masters et al., 2013) identified unsealed and partially unsealed shingles as sources of failures during high-wind events. Additionally, observations from Hurricane Michael and previous hurricanes have shown that incorrect fastener location for asphalt shingles also likely contributes to failure. Although the number of fasteners is important, the location of the fasteners is also important.

Table 1 provides guidance that will help to improve performance of asphalt shingles in high-wind areas. Table 2 identifies the required classification of asphalt shingles based on the basic wind speed. Figures 2 and 3 illustrate the correct and incorrect fastener location for asphalt shingles.

Table 1: Key Practices Related to Wind Performance of Asphalt Shingles

Item	Key Points	Source for Information/Guidance
Testing and labeling	Verify that asphalt shingle packages are labeled to indicate compliance with ASTM D7158. Asphalt shingles should have a classification that corresponds to the required basic (design) wind speed.	• This advisory: Table 2, *Classification of Asphalt Shingles*
Installation	Install asphalt shingles in accordance with guidance (see right-hand column). Pay particular attention to the recommendations for installing shingles at rakes, eaves, hips, and ridges.	• Hurricane Harvey in Texas Recovery Advisory 2, *Asphalt Shingle Roofing for High-Wind Regions* (in FEMA P-2022, 2019)
	Pay close attention to the fastener location.	• FEMA P-55 (2011): Section 11.5.1.1 • This advisory: Figures 5 and 6
	For improved performance, use enhanced flashing techniques.	• Technical Fact Sheet No. 5.2, *Roof-to-Wall and Deck-to-Wall Flashing* (FEMA P-499, 2010)

FEMA = Federal Emergency Management Agency

Table 2: Classification of Asphalt Shingles

Wind Speed, V(1)	ASTM D7158 Classification(2)
V ≤ 116 mph	D, G, or H
116 mph < V ≤ 155 mph	G or H
155 mph < V ≤ 190 mph	H

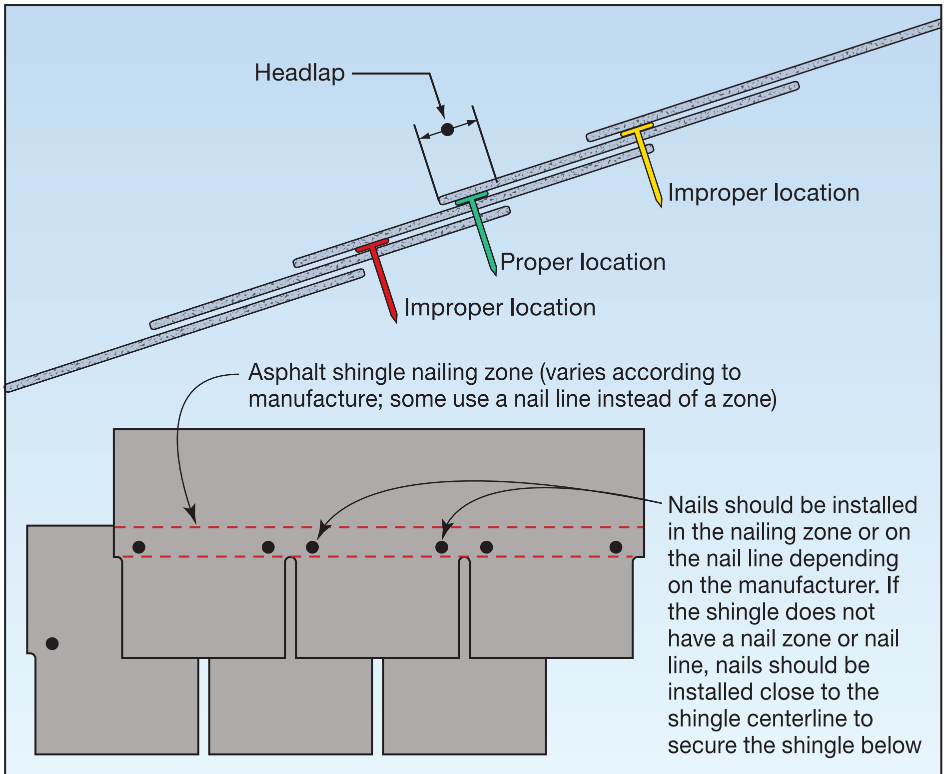
mph = miles per hour

Table notes:

(1) Determine wind speeds (V) for a particular site using the International Residential Code (IRC), Florida Building Code, Residential (FBCR), or American Society of Civil Engineers (ASCE) 7.

(2) Classifications assume Exposure Categories B and C and mean roof heights of 60 feet or less. Additional calculations are required for conditions outside of these assumptions.

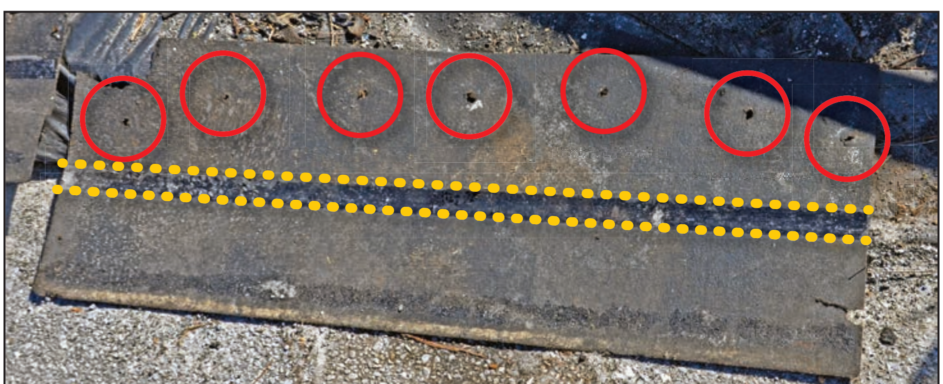
Table source: Adapted from Table R905.2.4.1 in the IRC and Table R905.2.6.2 in the Florida Building Code, Residential.



When properly located, the nail engages the underlying shingle in the headlap area (center nail).

Figure 2: Proper and improper locations of shingle fasteners

Source: Adapted from FEMA P-55 (Figure 11-36) and FEMA P-2023



Red circles show where fasteners were driven through the shingle. Yellow dotted lines show the approximate location of where fasteners should have been placed.

Figure 3: Incorrect location of fasteners in an asphalt shingle

Source: Adapted from FEMA P-55 (Figure 11-36) and FEMA P-2023

Concrete and clay roof tiles. While the use of concrete and clay roof tiles was not widely observed by the MAT in the areas impacted by Hurricane Michael, previous post-hurricane observations have indicated issues with concrete and clay roof tiles. Table 3 provides guidance that will help improve performance of concrete and clay roof tiles in high-wind areas.

Table 3: Key Practices Related to Wind Performance of Concrete and Clay Roof Tiles

Item	Key Points	Source for Information/Guidance
Design	Determine appropriate design wind loads.	• IBC/FBC: Sections 1609.5.3 and 1504.2, using ASCE 7-16
Installation	Install in accordance with guidance using the most current edition (see right-hand column).	• TRI, *Concrete and Clay Roof Tile Installation Manual* • FRSA/TRI, *Florida High Wind Concrete and Clay Roof Tile Installation Manual*
	For improved performance, use enhanced installation techniques.	• Technical Fact Sheet No. 7.4, *Tile Roofing for High Wind Regions* (in FEMA P-499, 2010) • FEMA P-55 (2011): Section 11.5.4

ASCE = American Society of Civil Engineers; FBC = Florida Building Code; FEMA = Federal Emergency Management Agency; FRSA = Florida Roofing, Sheet Metal & Air Conditioning Contractor's Association; IBC = International Building Code; TRI = Tile Roofing Institute

Metal roof systems. While metal roof coverings appeared to perform better than other roof coverings on buildings built to the FBC, metal roof damage to some buildings was observed after Hurricane Michael. Table 4 provides guidance that will help improve performance of metal roof systems in high-wind areas.

Table 4: Key Practices to Improve Wind Performance of Metal Roof Systems

Item	Key Points	Source for Information/Guidance
Testing and labeling	Verify metal panel roof systems were tested to meet appropriate wind pressures.	• ASTM E1592* (to meet the design wind pressures specified in ASCE 7-16)
Installation	For improved performance, use enhanced installation techniques for design and installation.	• Technical Fact Sheet No. 7.6, *Metal Roof Systems in High-Wind Regions* (in FEMA P-499, 2010) • FEMA P-55 (2011): Section 11.5.5 • Hurricanes Irma and Maria in the U.S. Virgin Islands Recovery Advisory 3, *Installation of Residential Corrugated Metal Roof Systems* (in FEMA P-2021, 2018)

* The IBC and FBC require metal panels to be installed over a solid or closely fitted deck to comply with ANSI/FM 4474, UL 580, or UL 1897. While FEMA recommends ASTM E1592 because it gives a better representation of the system's uplift performance, the local jurisdiction should be consulted before specifying ASTM E1592 for metal roof coverings over solid or closely fitted decks.

ANSI = American National Standards Institute; ASCE = American Society of Civil Engineers; ASTM = ASTM International; FBC = Florida Building Code; FEMA = Federal Emergency Management Agency; IBC = International Building Code

Ridge vents and off-ridge vents. The loss of vents, particularly ridge vents, can expose large openings in the roof deck to water infiltration. The interior of the home shown in Figure 4 suffered extensive interior water damage due to the failure of ridge shingles and the ridge vent. The ceilings in several rooms were saturated with water and collapsed. According to the homeowner, roof damage was limited to the loss of ridge shingles and ridge vents. Table 5 provides guidance that will help improve performance of ridge vents and off-ridge vents in high-wind areas.

Figure 4: House with significant interior damage from water intrusion (Panama City area)

Interior damage occurred when ridge shingles and the ridge vent were blown off; the drywall on the ceiling collapsed and was removed.

Table 5: Key Practices to Improve Wind Performance of Ridge Vents and Off-Ridge Vents

Item	Key Points	Source for Information/Guidance
Testing and labeling	Verify that ridge vents were tested for resistance to wind and wind-driven rain.	• ICC™: TAS 100(A) of the *Florida Building Code, Test Protocols for the High-Velocity Hurricane Zone*
Installation	Attach roof ventilation products properly (see guidance in right-hand column). Ensure fasteners for ridge vents are of a sufficient length to fully penetrate the roof sheathing below or into the roof framing where possible.	• Technical Fact Sheet No. 7.5, *Minimizing Water Intrusion Through Roof Vents in High-Wind Regions* (in FEMA P-499, 2010) • FEMA P-55 (2011): Section 11.6

FEMA = Federal Emergency Management Agency; IBC = International Code Council; TAS = Testing Application Standard

Water Infiltration

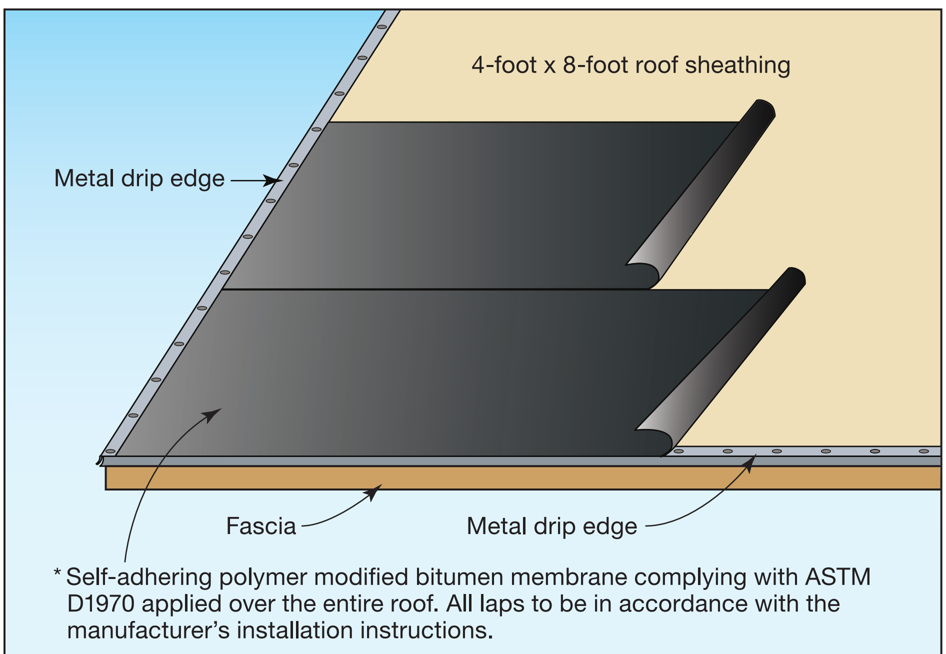
Water infiltration can be reduced by applying a secondary barrier. A secondary roof sealing strategy using underlayment products can significantly reduce water infiltration through the roof when the primary roof covering is lost or damaged due to wind loads. This secondary roof sealing strategy is often referred to as a sealed roof deck.

Figures 5, 6, and 7 illustrate three options for installing a sealed roof deck under the primary roof covering. These sealed roof deck methods have been tested by IBHS and qualify for the FORTIFIED designation (see text box). Additional information on underlayment to reduce water intrusion can be found in FEMA P-499 (Technical Fact Sheet No. 7.2) and FEMA P-55 (Section 11.5.1.1).

FORTIFIED Homes™

A "beyond code" program developed by the Insurance Institute for Business and Home Safety (IBHS). The program was developed to help strengthen homes from high- wind events such as hurricanes.

For more information, see: https://disastersafety.org/fortified/fortified-home/



***Self-Adhering Polymer Modified Bitumen Membranes:**
Some oriented strand board (OSB) structural panels have a factory-applied coating that can interfere with the bonding of the self-adhering modified bitumen. To facilitate bonding, a field-applied primer is often needed. If self-adhering modified bitumen is applied to OSB, the OSB manufacturer should be contacted to determine whether a primer needs to be applied.

Figure 5:
Option 1 for installing a sealed roof deck to reduce water infiltration through the roof
Source: Hurricane Irma in Florida Recovery Advisory 3, *Mitigation Triggers for Roof Repair and Replacement in the 6th Edition (2017) Florida Building Code* (Figure 4) (in FEMA P-2023,2018)

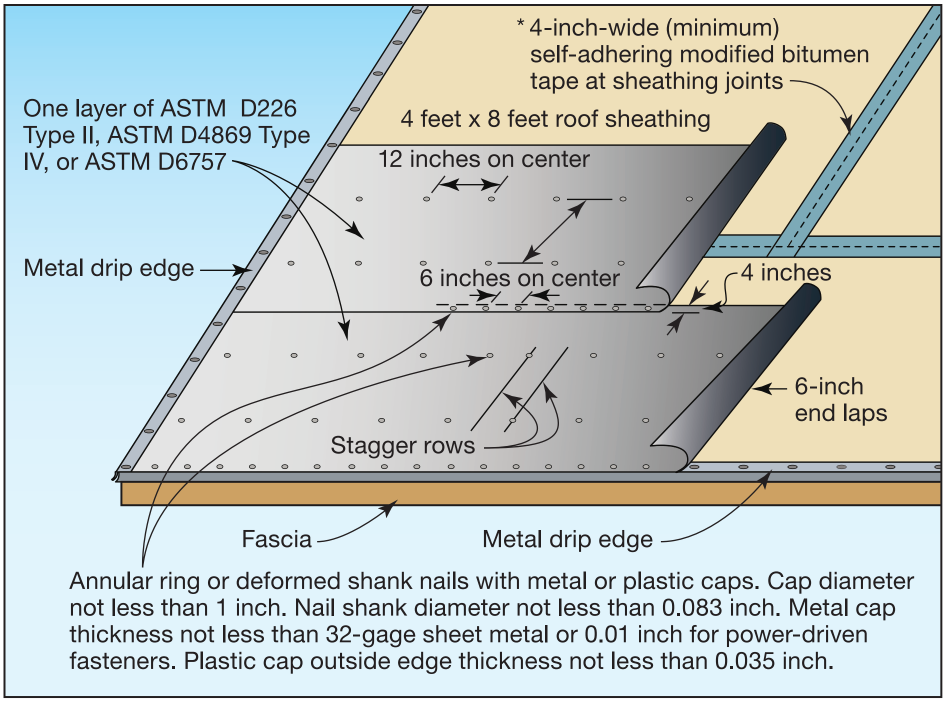


Figure 6:
Option 2 for installing a sealed roof deck to reduce water infiltration through the roof
Source: Hurricane Irma in Florida Recovery Advisory 3, *Mitigation Triggers for Roof Repair and Replacement in the 6th Edition (2017) Florida Building Code* (Figure 6) (in FEMA P-2023,2018)

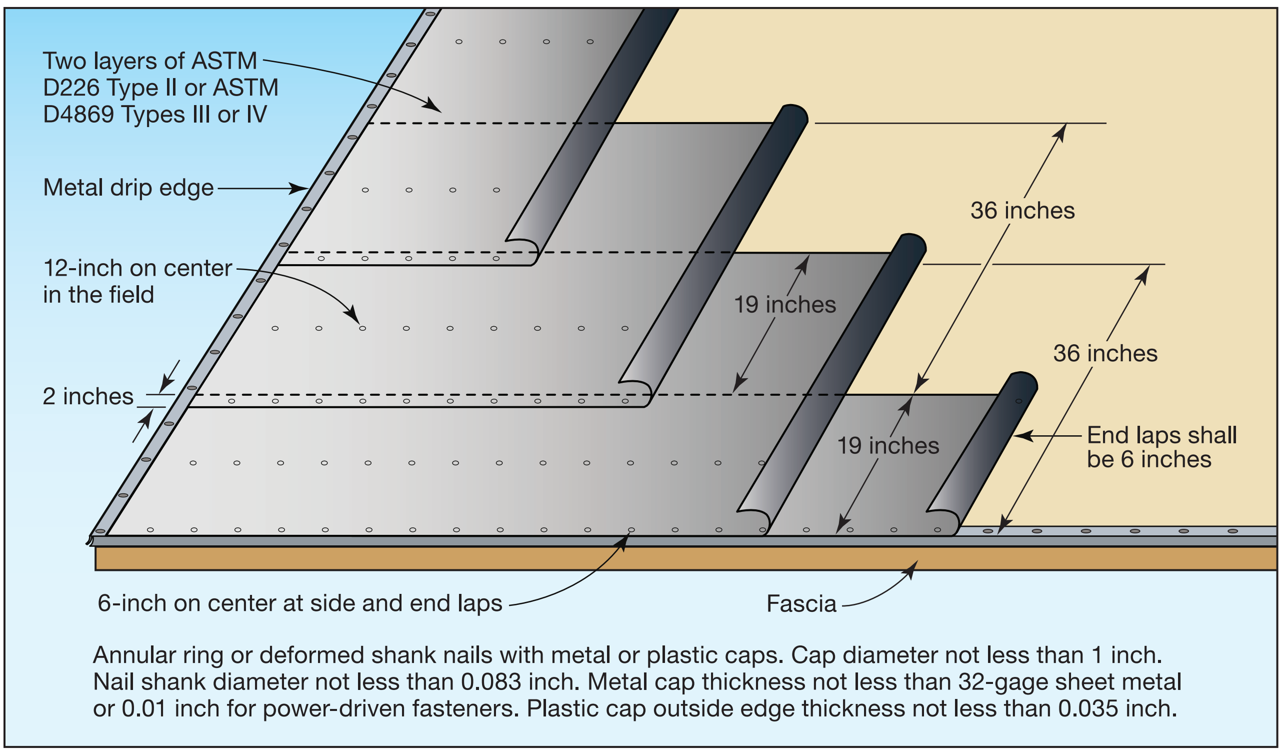


Figure 7: Option 3 for installing a sealed roof deck to reduce water infiltration through the roof

The benefits of a sealed roof deck were demonstrated in the residence shown in Figure 8. The metal roof covering of the home in the Panama City area was punctured by asphalt shingles that blew off an adjacent building during Hurricane Michael. Although the metal roof was damaged, the home had a sealed roof deck constructed in accordance with Option 1 shown in Figure 5 and did not suffer any interior water damage.

Example of a sealed roof deck that successfully protected a home during Hurricane Michael after wind-borne debris punctured the metal roof covering.

Figure 8:
Successful sealed roof deck (Panama City area)

Exterior Wall Coverings

Exterior wall coverings are commonly blown off walls or damaged by high winds, often resulting in water intrusion due to wind-driven rain. Keeping exterior wall coverings in place and intact is a significant protection against water infiltration. Typical exterior wall covering materials used include vinyl, fiber-cement, and brick veneer.

Wind Resistance

Exterior wall coverings have to be designed or tested for compliance with the applicable design wind loads.

Vinyl siding. Vinyl siding performance depends particularly on proper installation. The Hurricane Michael MAT observed widespread damage to vinyl siding wall coverings in the areas assessed. Table 6 provides guidance that will help improve the performance of vinyl siding in high-wind areas.

Table 6: Key Practices to Improve Wind Performance of Vinyl Siding

Item	Key Points	Source for Information/ Guidance
Testing and labeling	Use vinyl siding that complies with the 2017 edition of ASTM D3679 (2017) to achieve better performance. The 2017 edition increases the pressure equalization factor for vinyl siding products over previous editions.	• ASTM D3679 (2017 Edition)
	Verify that selected siding has a design wind pressure rating that equals or exceeds the required design wind pressure.	• ASTM D3679 (2017 Edition) • Technical Fact Sheet No. 5.3, *Siding Installation in High-Wind Regions* (in FEMA P-499, 2010)
	Design wind pressure ratings for vinyl siding vary by manufacturer and installation method. Typically, vinyl siding with a double or curled nail hem has the highest design wind pressure rating.	
Installation	Use vinyl siding installers certified by VSI.	• VSI: Certified Installer Program
	Installation pointers: • Install vinyl siding in accordance with recommended methods (see right-hand column) • Install vinyl siding over wood structural panel sheathing such as plywood or OSB • Use utility trim at top of walls and under windows where the nail hem has to be cut • Use proper starter strips at the first course of the siding	• Technical Fact Sheet No. 5.3, *Siding Installation in High-Wind Regions* (in FEMA P-499, 2010)

ASTM = ASTM International; FEMA = Federal Emergency Management Agency; VSI = Vinyl Siding Institute

Fiber-cement siding. The performance of fiber-cement siding varied in the areas assessed by the Hurricane Michael MAT. Table 7 provides guidance that will help improve the performance of fiber-cement siding in high-wind areas.

Table 7: Key Practices to Improve Wind Performance of Fiber-Cement Siding

Item	Key Points	Source for Information/ Guidance
Design	Verify that selected fiber cement siding is designed or tested to meet the design wind pressures in ASCE 7-16.	• ASCE 7-16
Installation	Although there are several installation techniques, face-nailing of fiber-cement siding is recommended in hurricane-prone regions.	• Technical Fact Sheet No. 5.3, *Siding Installation in High-Wind Regions* (specifically the face-nailing installation method) (in FEMA P-499, 2010)

ASCE = American Society of Civil Engineers; FEMA = Federal Emergency Management Agency

Brick veneer. When not adequately attached, brick veneer is frequently damaged from wind loading. Common failure modes include tie (anchor) corrosion, tie fastener pull-out, failure of masons to embed ties into the mortar, poor bonding between ties and mortar, and the use of poor quality mortar. While the Hurricane Michael MAT noted generally good performance of brick veneer on the buildings assessed, damage to brick veneer has been noted by previous MATs; Table 8 provides guidance that will help improve performance of brick veneer in high-wind areas.

Table 8: Key Practices to Improve Wind Performance of Brick Veneer

Item	Key Points	Source for Information/Guidance
Design	Improve wind performance by following appropriate guidance and criteria (see right-hand column).	• TMS 402 • Technical Fact Sheet No. 5.4, *Attachment of Brick Veneer in High-Wind Regions* (in FEMA P-499, 2010)
Installation	Improve wind performance by following appropriate guidance (see right-hand column).	• Technical Fact Sheet No. 5.4, *Attachment of Brick Veneer in High-Wind Regions* (in FEMA P-499, 2010)

FEMA = Federal Emergency Management Agency; TMS = The Masonry Society

Water Infiltration

The most effective way to reduce water intrusion through walls is for the exterior wall covering to remain in place. Currently, there is no guidance for a secondary water barrier for walls that would be comparable to the sealed roof deck. However, a water-resistant barrier or "housewrap" is required by code for many wall assemblies and may reduce water infiltration. Water-resistant barriers function to prevent airflow through a wall and to stop and drain water that has penetrated the exterior wall covering. Recommended installation methods for water-resistant barriers are provided in FEMA P-499 (Technical Fact Sheet No. 5.1).

Soffits

Soffits have historically performed poorly in hurricanes and are commonly damaged in high-wind events. When soffits fail, the result is often significant water intrusion. While water infiltration also occurs at soffit vents even when there is no failure, keeping the soffit in place reduces the amount of water infiltration. Typical soffit materials used include vinyl, wood structural panels, fiber-cement, and aluminum.

Wind Resistance

Until recently, building codes provided little guidance on designing soffits for wind loads. The 2007 FBC was revised to require that soffits be capable of resisting the same wind loads required for walls. Both the 2015 IRC and ASCE 7-10 were also revised to require that soffits be capable of resisting the wind loads specified for walls. The Hurricane Michael MAT observed widespread damage to soffits in the areas assessed.

Table 9 provides guidance that will help improve performance of soffits in high-wind areas. Figure 9 illustrates proper installation for vinyl soffit panels.

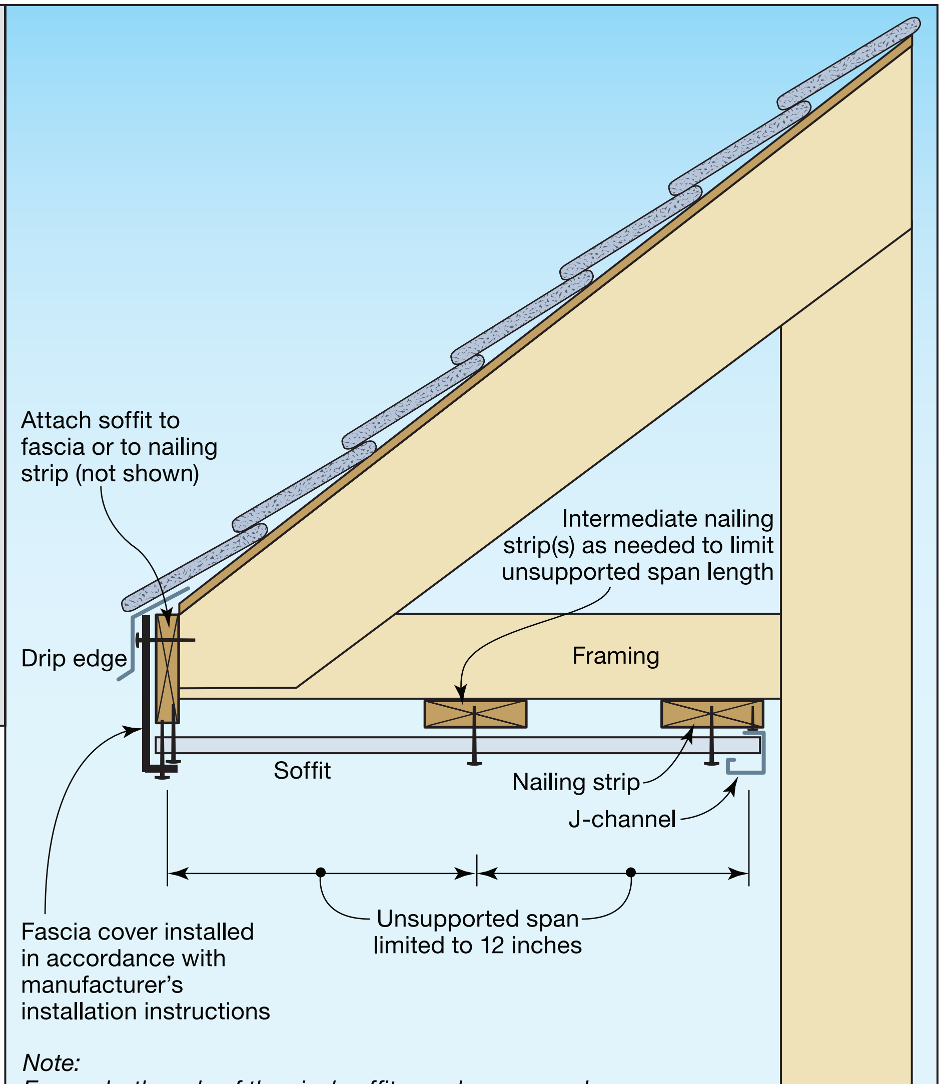
Table 9: Key Practices to Improve Wind Performance of Soffits

Item	Key Points	Source for Information / Guidance
Design	Determine the required wind loads. Use soffits that were designed or tested for wind loads specified for the adjacent walls. If appropriate, use a prescriptive option for wood structural panel soffits.	• Hurricane Irma in Florida Recovery Advisory 2, *Soffit Installation in Florida* (in FEMA P-2023, 2018)
Testing and labeling	To reduce water intrusion, verify that soffit vents are tested for resistance to wind and wind-driven rain.	• ICC: TAS 100(A)
Installation	At a minimum, fasten soffit panels at the wall and the fascia. Be sure to install fascia coverings in accordance with the manufacturers' installation instructions.	• Technical Fact Sheet No. 7.5, *Minimizing Water Intrusion Through Roof Vents in High-Wind Regions* (in FEMA P-499, 2010) • This advisory: Figure 9, "Vinyl soffit panel installation"

FEMA = Federal Emergency Management Agency; ICC = International Code Council; TAS = Testing Application Standard

Key Recommendations for Improved Performance of Vinyl Soffit Panels

- Only use a vinyl soffit panel that has a test report, or for the State of Florida, make sure the vinyl soffit panel has a product approval indicating the soffit and installation instructions meet the required wind loads.
- Secure the fascia cover adequately. When the fascia cover is lost, the end of the vinyl soffit panel is exposed to additional wind loads and wind-driven rain.
- Ensure both ends of the vinyl soffit panel are securely fastened to framing or a nailing strip. Do not float (leave unattached) vinyl soffit panels in channels, as this installation method offers poor wind resistance.
- Limit the unsupported span of vinyl soffit panels to 12 inches.



Note:
Ensure both ends of the vinyl soffit panel are securely fastened to framing or a nailing strip.

Figure 9: Vinyl soffit panel installation

Water Infiltration

The failure of soffits can expose the interior of the building to significant water intrusion due to wind-driven rain. Even when soffits do not fail, water infiltration can occur during high-wind events through soffits and soffit vents. However, keeping the soffit in place significantly reduces the amount of water infiltration through the soffit area. One method to reduce water infiltration through soffits is to place filter fabric (such as is used for HVAC system filters) above the vent openings. However, this approach must be custom designed (see Technical Fact Sheet No. 7.5, *Minimizing Water Intrusion Through Roof Vents in High-Wind Regions* [in FEMA P-499. 2010]).

Glazed Openings and Doors

Glazed openings include windows, skylights, and doors with glass. Doors include entry and garage doors. In addition to high wind pressures, windows and doors are exposed to wind-driven rain and impacts from wind-borne debris.

Wind Resistance

Wind damage can occur from both high wind pressures and wind-borne debris impacting the glazing. This type of damage was observed after Hurricane Michael, as well as past hurricanes.

Windows, skylights, and doors. The most critical factor for improving the wind resistance of exterior glazing and doors is to use products that have been tested, certified, and labeled for the applicable wind loads to indicate compliance. Product labeling, including the certification program to which the product is listed under, ensures that wind-resistance testing has been performed as required. Windows, skylights and doors should be tested and labeled in accordance with the following:

- Exterior windows, skylights, and sliding glass doors: AAMA/WDMA/CSA 101/I.S.2/A440, *North American Fenestration Standard (NAFS)/Specification for windows, doors, and skylights*
- Side-swinging doors: ASTM E330
- Garage doors: ANSI/DASMA 108

Additional recommendations for testing of exterior windows and doors are provided in Sections 11.2.1.1 and 11.3.1.1 of FEMA P-55 (2011).

Protection from wind-borne debris. When a glazed opening (windows and doors with glass) is not impact-resistant or not protected with an impact-protective device, wind-borne debris can impact the glazing and create a large opening in the building envelope, resulting in higher internal wind pressures and significant water intrusion. This type of wind-borne debris damage was observed after Hurricane Michael, and is a common observation made after many hurricanes. Table 10 provides guidance that can help reduce damage to glazed openings from wind-borne debris.

Table 10: Key Practices for Glazed Openings in Wind-Borne Debris Regions

Item	Key Points	Source for Information/ Guidance
Code requirement	Glazed openings in wind-borne debris regions* must be impact-resistant or be protected with an impact-protective device such as a shutter.	2017 FBCR/2018 IRC: Sections R202 and R301.2.1.2
Testing and labeling	Use recommended impact-resistant products that are tested and properly installed.	Technical Fact Sheet No. 6.2, *Protection of Openings – Shutters and Glazing* (in FEMA P-499, 2010) FEMA P-55 (2011): Sections 11.2.1.2 and 11.3.1.3

* For information about wind-borne debris regions, see the text box in this advisory.

FBRC = Florida Building Code, Residential; FEMA = Federal Emergency Management Agency; IRC = International Residential Code

FBC Wind-Borne Debris Region

Wind-Borne Debris Regions are defined in Chapter 2 of the FBCR as follows:

"Areas within hurricane-prone regions located in accordance with one of the following:

- Within 1 mile (1.61 km) of the coastal mean high water line where the ultimate design wind speed, Vult' is 130 mph (58 m/s) or greater
- In areas where the ultimate design wind speed, Vult' is 140 mph (64.6 m/s) or greater; or Hawaii."

Note: The definition of Wind-Borne Debris Region in the FBC is consistent with ASCE 7, the IBC, and the IRC. The definition is used with permission: Chapter 2, Excerpted from the 2017 Florida Building Code-Residential 6th Edition; Copyright 2017; Washington, D.C.: International Code Council. Reproduced with permission. All rights reserved. www.ICCSAFE.org.

Water Infiltration

Water infiltration in and around windows and doors can occur during the high winds and heavy rain that typically accompany hurricanes, and was observed after Hurricane Michael. Flashing and sealing methods are often used to mitigate the effect of water intrusion, but each method presents challenges.

Windows and sliding and hinged glass doors have to comply with AAMA/WDMA/CSA 101/I.S.2/A440 (see Table 11), which also includes a water infiltration test at 15 percent or 20 percent of the required positive design pressure rating depending on the product class. Products complying with AAMA/WDMA/CSA 101/I.S.2/A440 are assigned a Performance Grade (PG) rating correlating to the required design pressure based on the product's performance under structural design pressure, water infiltration, and air leakage. For example, a PG40 window has a design pressure rating of ± 40 pounds per square foot (psf) and was tested for water infiltration at 6 psf (15 percent of 40 psf). The PG rating should be identified on the product label.

Table 11 provides guidance that will help reduce water infiltration in glazed openings and doors in high-wind areas.

Table 11: Key Practices to Reduce Water Infiltration at Glazed Openings and Doors

Item	Key Points	Source for Information/ Guidance
Testing and labeling	Review product labels to confirm that windows have a Performance Grade equal to or greater than the required design wind pressure.	• AAMA/WDMA/CSA 101/I.S.2/A440: *North American Fenestration Standard/Specification for windows, doors, and skylights*
Installation	Follow recommended installation and flashing methods for windows and doors.	• Technical Fact Sheet No. 6.1, *Window and Door Installation* (in FEMA P-499, 2010) • FEMA P-55 (2011): Sections 11.2.1.4 and 11.3.1.4

AAMA = American Architectural Manufacturers Association; CSA = Canadian Standards Association; FEMA = Federal Emergency Management Agency; WDMA = Window & Door Manufacturers Association

References

AAMA/WDMA/CSA (American Architectural Manufacturers Association / Window & Door Manufacturers Association / Canadian Standards Association). 2017. *North American Fenestration Standard/Specification for windows, doors, and skylights*. AAMA/WDMA/CSA 101/I.S.2/A440-17. https://aamanet.org/news/latest-north-american-fenestration-standard-published.

ANSI/DASMA (American National Standards Institute / Door & Access Systems Manufacturers' Association, International). 2017. *Standard Method for Testing Sectional Garage Doors and Rolling Doors: Determination of Structural Performance Under Uniform Static Air Pressure Difference.* ANSI/DASMA 108. Cleveland, OH. https://www.dasma.com/dasma-pages/D-AS-standards.asp.

ANSI/FM. 2004. *American National Standard for Evaluation of Simulated Wind Uplift Resistance of Roof Assemblies Using Static Positive and/or Negative Differential Pressures*. FM Approvals. ANSI FM 4474 (R2010). https://law.resource.org/pub/us/code/bsc.ca.gov/sibr/com.fmglobal.4474ansi.pdf.

ASCE (American Society of Civil Engineers). 2016. *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*. ASCE 7. https://www.asce.org/asce-7/.

ASTM International. West Conshohocken, PA. https://www.astm.org/.
- ASTM E330 (2014). *Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights and Curtain Walls by Uniform Static Air Pressure Difference.*
- ASTM D3679 (2017a). *Standard Specification for Rigid Poly (Vinyl Chloride) (PVC) Siding.*
- ASTM E1592 (2017b). Standard Test Method for Structural Performance of Sheet Metal Roof and Siding Systems by Uniform Static Air Pressure Difference.
- ASTM D7158 (2019). Standard Test Method for Wind Resistance of Asphalt Shingles (Uplift Force/Uplift Resistance Method)

FEMA. 2010. *Homebuilders Guide to Coastal Construction*. FEMA P-499. https://www.fema.gov/media-library/assets/documents/6131.

Technical Fact Sheets: https://www.fema.gov/media-library/assets/documents/6131.
- No. 5.2, *Roof-to-Wall and Deck-to-Wall Flashing*
- No. 5.3, *Siding Installation in High-Wind Regions*
- No. 5.4, *Attachment of Brick Veneer in High-Wind Regions*
- No. 6.1, *Window and Door Installation*
- No. 6.2, *Protection of Openings – Shutters and Glazing*
- No. 7.2, *Roof Underlayment for Asphalt Shingle Roofs*
- No. 7.4, *Tile Roofing for High Wind Regions*
- No. 7.5, *Minimizing Water Intrusion Through Roof Vents in High-Wind Regions*
- No. 7.6, *Metal Roof Systems in High-Wind Regions*

FEMA. 2011. *Coastal Construction Manual.* FEMA P-55. https://www.fema.gov/media-library/assets/documents/3293.

FEMA. 2018a. *Mitigation Assessment Team Report: Hurricane Irma in Florida.* FEMA P-2023. https://www.fema.gov/media-library/assets/documents/176315.

Hurricane Irma in Florida Recovery Advisories: https://www.fema.gov/media-library/assets/documents/158123.
- FL-RA 1, *Dry Floodproofing: Operational Considerations*
- FL-RA 2, *Soffit Installation in Florida*
- FL-RA 3, *Mitigation Triggers for Roof Repair and Replacement*

FEMA. 2018b. *Mitigation Assessment Team Report: Hurricanes Irma and Maria in the U.S. Virgin Islands.* FEMA P-2021. https://www.fema.gov/media-library/assets/documents/170486.

Hurricanes Irma and Maria in the U.S. Virgin Islands Recovery Advisories: https://www.fema.gov/media-library/assets/documents/170486.
- USVI-RA 3, *Installation of Residential Corrugated Metal Roof Systems*

FEMA. 2019a. *Mitigation Assessment Team Report: Hurricane Harvey in Texas*. FEMA P-2022. https://www.fema.gov/media-library/assets/documents/177700.

Hurricane Harvey in Texas Recovery Advisories: https://www.fema.gov/media-library/assets/documents/177700.
- TX-RA 1, *Dry Floodproofing: Planning and Design Considerations*
- TX-RA 2, *Asphalt Shingle Roofing for High-Wind Regions*

FEMA. [to be published 2019]. *Mitigation Assessment Team Report: Hurricane Michael.* FEMA P-[TBD].

FRSA/TRI (Florida Roofing, Sheet Metal & Air Conditioning Contractor's Association / Tile and Roofing Institute). 2012. *Florida High Wind Concrete and Clay Roof Tile Installation Manual.* 5th Edition. Revised. https://tileroofing.org/revised-5th-edition-florida-manual-approved-available/.

ICC™ (International Code Council). 2014. *Test Procedure for Wind and Wind Driven Rain Resistance and/or Increased Windspeed Resistance of Soffit Ventilation Strip and Continuous or Intermittent Ventilation System Installed at the Ridge Area*. Testing Application Standard (TAS) No. 100(A)-95. https://codes.iccsafe.org/content/FLTP2014/testing-application-standard-tas-no-100-a-95-test-procedure-for-wind-and-wind-driven-rain-resistance-and-or-increased-windspeed-resistance-of-soffit-ventilation-strip-and-continuous-or-intermittent-ventilation-system-installed-at-the-ridge-area.

ICC. 2017. *Florida Building Code – Test Protocols for High Velocity Hurricane Zone,* Sixth Edition. https://codes.iccsafe.org/content/FTPC2017.

Masters, Forrest J., Craig R. Dixon, David O. Prevatt, and Kurtis R. Gurley. 2013. *Phase II Report: Investigation of the Wind Resistance of Asphalt Shingle Roof Coverings*. Southeast Region Research Initiative. https://www.teamcomplete.com/wp-content/uploads/2015/12/SERRI-Report-Phase-II-90100-02.pdf.

TMS (The Masonry Society). 2016. *Building Code Requirements and Specification for Masonry Structures.* TMS 402/602. https://masonrysociety.org/product/tms-402-602-2016/.

TRI/WSRCA (Tile Roofing Institute / Western States Roofing Contractors Association). 2015. *Concrete and Clay Roof Tile Installation Manual.* https://tileroofing.org/resources/installation-guides/.

UL LLC. https://standardscatalog.ul.com/standards/en/.

- UL 580 (2006). *Standard for Tests for Uplift Resistance of Roof Assemblies.* https://standardscatalog.ul.com/standards/en/standard_580.
- UL 1897 (2015). *Standard for Uplift Tests for Roof Covering Systems*. https://standardscatalog.ul.com/standards/en/standard_1897.

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