Fact Sheet 3.3.1: Roof Systems—Sloped Roofs

The mitigation objective of this Fact Sheet is to improve the resilience of sloped roof systems to allow a building to continue to be used or quickly repaired following a hurricane, with an end goal of rapidly returning the building to full use.

Roof systems include all the building elements above the top of the wall system (wall systems are covered in Fact Sheet 3.2, *Walls and Openings*). Roof systems can be classified by roof shape and building size. As shown in Figure 3.3.1.11, gable and hip sloped roof systems include the following elements: framing, connectors and fasteners, sheathing, covering, edges and overhangs, roof vents, roof drainage, and openings, as well as roof-mounted equipment. Other roof shapes exist, including sawtooth roofs, mansard roofs, and round or dome-shaped roofs, and mitigation strategies for gable and hip sloped roof systems also apply to edge systems, rooftop equipment, gutters, etc., for these other roof shapes. Sloped roofs have a pitch of 3 feet vertical to 12 feet horizontal (3:12) or greater.

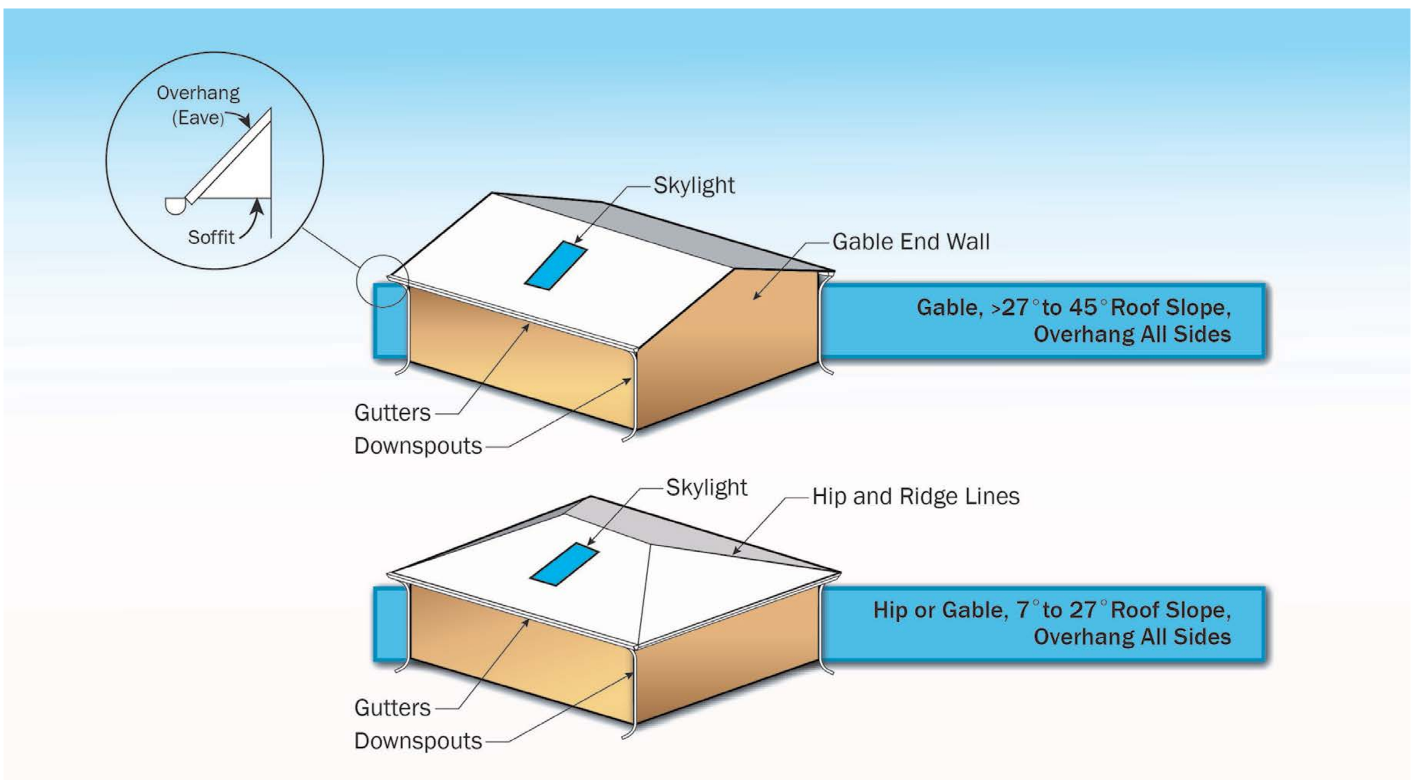


Figure 3.3.1.1. Basic elements of typical sloped roofs featuring gable-end roof system (top) and hip roof system (bottom).

DEFINITIONS

Elements of gable and hip sloped roof systems include the roof deck, roof covering, and edge materials. For this Fact Sheet, mitigation options also are provided for:

Framing—Provides the main structural support for the roof. Sloped-roof framing components include wood or metal trusses, wood rafters, or steel beams that form a gable end or hip roof shape.

Connectors and Fasteners—Link the roof framing to the wall system and hold elements of the roof system together. Sloped-roof connectors and fasteners may include hurricane straps or ties attached with nails or screws.

Sheathing—Covers the roof framing and provides additional structural strength to the wood or metal framing. Sloped-roof sheathing may include plywood, oriented strand board (OSB) or tongue-and-groove planks for wood-framed roofs, and metal decking or panels for steel-framed roofs.

Covering—Protects the roof framing and sheathing from rain, snow, wind and wind-driven rain. Sloped roof coverings may include asphalt or wood shingles, extruded concrete or clay tiles, slate or metal panels.

Edges and Overhangs—The roof border is frequently at risk of damage from wind uplift pressures and wind-driven rain entry than the rest of the roof. Sloped roof border elements typically include wood-framed overhangs (eaves) and soffits enclosed with wood, vinyl or aluminum panels, and fascia panels along roof rake edges (i.e., slanting edge of a gable roof at the end wall of the house). Roof edges also include edge metal systems such as eave flashing and drip edges.

Vents—Provide airflow in attic spaces to vent cooler air in the hotter months and vent warmer air in the cooler months to lower heating and cooling costs. Ventilation elements include soffit vents, ridge vents, gable-end vents, off-ridge vents, gable rake vents, turbines and standpipes.

Drainage—Removes water off the roof and away from the structure. Sloped roof drainage elements include gutters connected to downspouts.

Skylights—Provide an overhead source of natural light. Sloped roof opening elements include glass or clear polymer skylights.

Rooftop Equipment—On sloped roofs, roof-mounted equipment typically includes small equipment vents and fans, communications antennas and satellite dishes, solar panels and lightning rods.

Table 3.3.1.1 summarizes some common mitigation solutions that can improve the performance of sloped-roof systems. These strategies are discussed in the sections that follow.

Table 3.3.1.1. Mitigation Solutions for Sloped-Roof Systems

Solutions and Options	***Wind***	***Wind-Driven Rain***	***Rain***
Mitigation Solution: Strengthen or Improve			
Option 1: Install Gable End Bracing for Gable Roofs	✓		
Option 2: Strengthen Roof Framing and Connections	✓	✓	
Option 3: Upgrade Wood Sheathing	✓	✓	✓
Option 4: Improve Asphalt Shingles and Metal Roofing	✓	✓	✓
Option 5: Upgrade Vinyl and Aluminum Soffits	✓	✓	
Option 6: Improve Gutters and Downspouts	✓	✓	✓
Option 7: Strengthen Skylights	✓	✓	✓
Option 8: Strengthen Roof-Mounted Equipment and Connections	✓	✓	
Mitigation Solution: Add or Increase			
Option 1: Upgrade Underlayment to Shingle Roofs	✓	✓	✓
Option 2: Increase Roof Drainage	✓	✓	✓
Mitigation Solution: Secure or Eliminate			
Option 1: Secure or Eliminate Clay Tile Roofs	✓	✓	✓
Option 2: Secure, Minimize or Eliminate Roof Overhangs	✓	✓	
Option 3: Reduce or Eliminate Soffit Vents	✓	✓	
Option 4: Secure or Replace Ridge Vents and Turbines	✓	✓	✓
Option 5: Protect or Eliminate Gable Vents	✓	✓	✓

In addition to physical mitigation measures, it is important to create and follow a regular roof maintenance schedule. The roof should be inspected at least twice per year, generally in the spring and fall, to evaluate the condition and identify potential repair needs. Inspections also should be done after high wind events to assess if storm-related damage occurred. Needed repairs should be completed quickly after the inspection to help protect the roof.

Mitigation Solution: Strengthen or Improve

Strengthening or improving roofing systems involves upgrading elements of the existing roof system to help improve resistance to wind and wind-driven rain. A few mitigation options use this solution to protect various sloped roof system elements and maintain a continuous load path throughout the roof system.

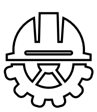
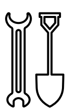
Option 1: Install Gable End Bracing for Gable Roofs

Gable end walls are at risk for damage in hurricanes because of their shape. Wind pressures can push or pull a gable end wall and cause it to collapse if it is not properly braced. A failed gable end wall can cause serious damage to the roof and allow wind and rain to get inside the building through openings and cracks that result from the failure. Installing gable-end bracing in gable roof shapes that are more than 4 feet tall protects against this problem. This retrofit builds on the Basic Mitigation Package item for strengthening overhangs at gable end walls (see FEMA P-804, *Wind Retrofit Guide for Residential Buildings*).

One way to retrofit gable end walls for mitigation involves:

1. Strengthening vertical framing members of the gable end using retrofit studs.
2. Bracing the top and bottom of the gable end with horizontal braces to transfer horizontal loads to the roof and ceiling.
3. Making connections between horizontal braces and retrofit studs using metal straps and fasteners.
4. Connecting the bottom of the gable end to the wall below using metal bracket connectors. Figure 3.3.1.2 shows a retrofit for a gable end wall without an overhang. Figure 3.3.1.3 shows a retrofit for a gable end wall with an overhang.

CONSIDERATIONS:

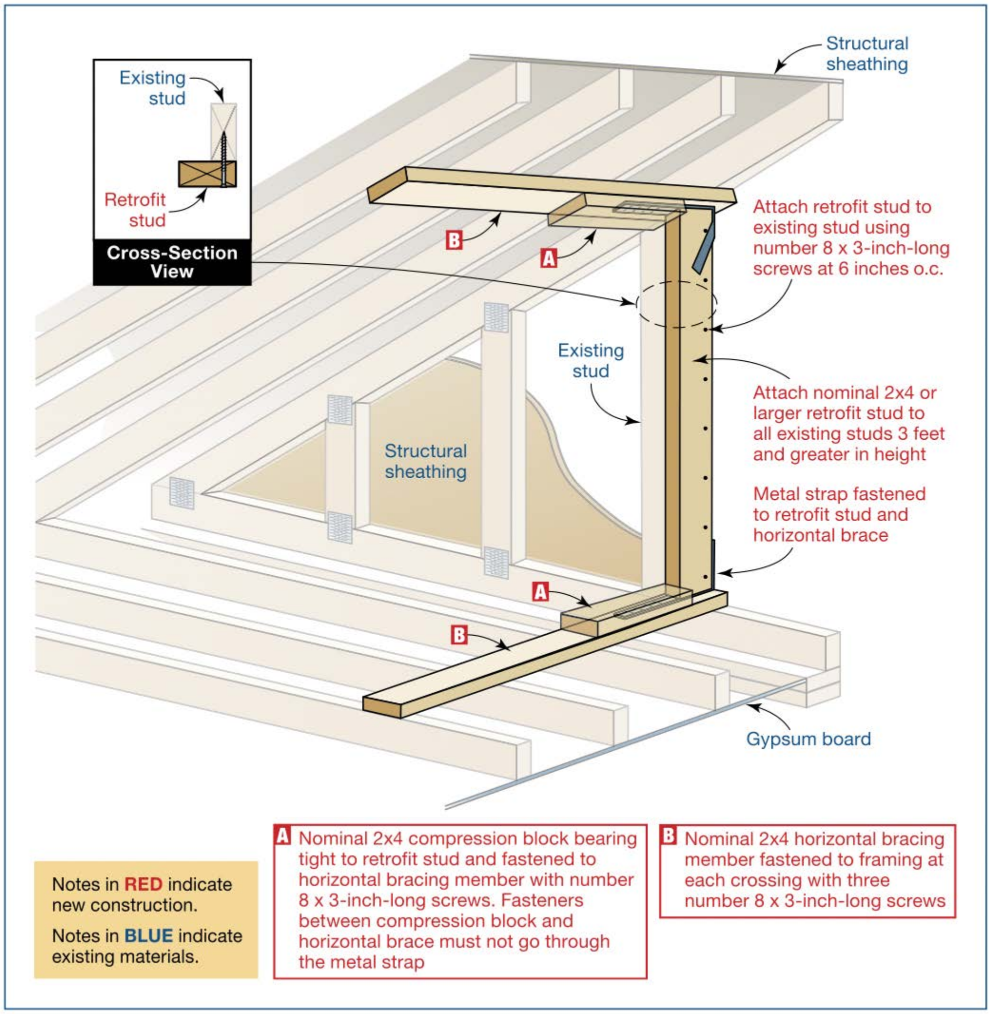


Figure 3.3.1.2. Conceptual gable end retrofit without overhangs.

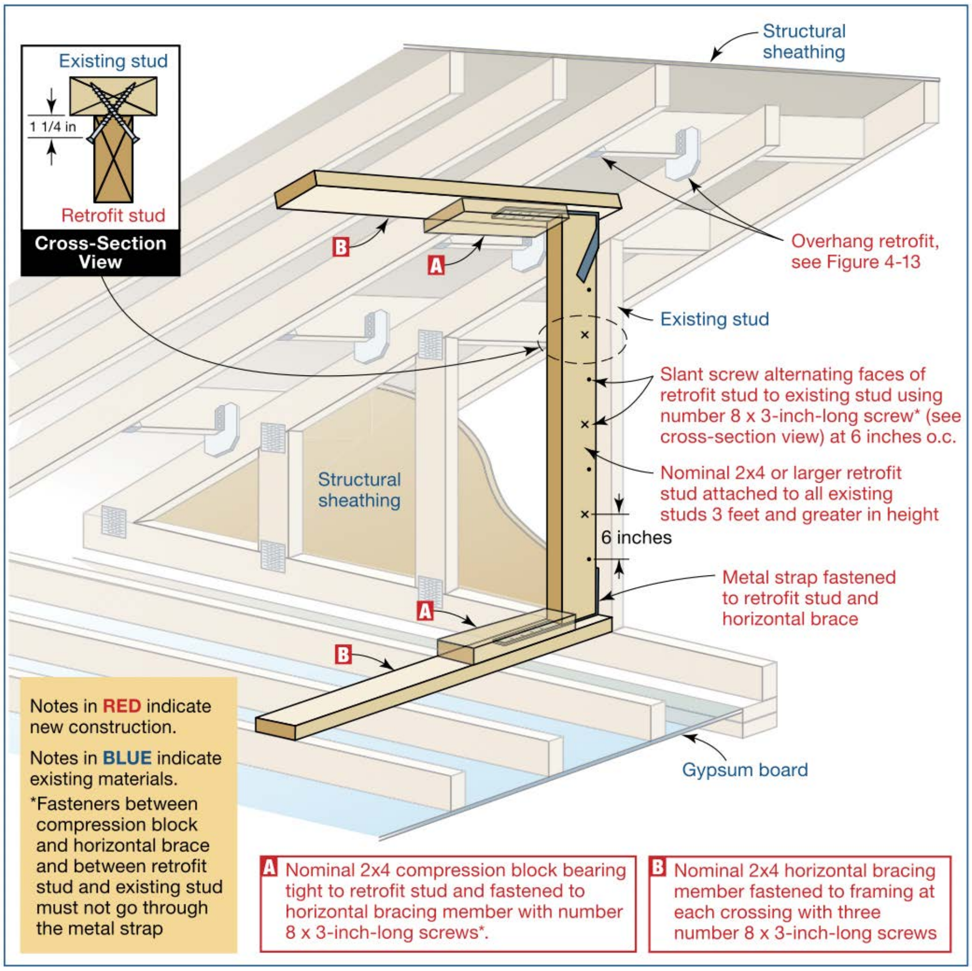


Figure 3.3.1.3. Conceptual gable end retrofit with overhangs.

Option 2: Strengthen Roof Framing and Connections

To make sure the roof framing and the connections between the roof and the wall framing are strong enough to withstand wind forces and wind uplift, use the following techniques to strengthen the roof framing and connections:

- Strengthen roof framing by using stronger or larger roof framing materials, adding ladder framing, and bracing the ends of gable roofs that are at risk of failing in high winds (see Option 1) according to FEMA P-55, *Coastal Construction Manual*.
- Strengthen connections by installing hurricane clips, anchors, straps, connectors and fasteners compatible with the roof system, as shown in Figure 3.3.1.4. As with wall framing connections discussed in Fact Sheet 3.2, *Wall Systems and Openings*, roof connectors and fasteners must be strong enough to resist the hurricane wind forces imposed on them.

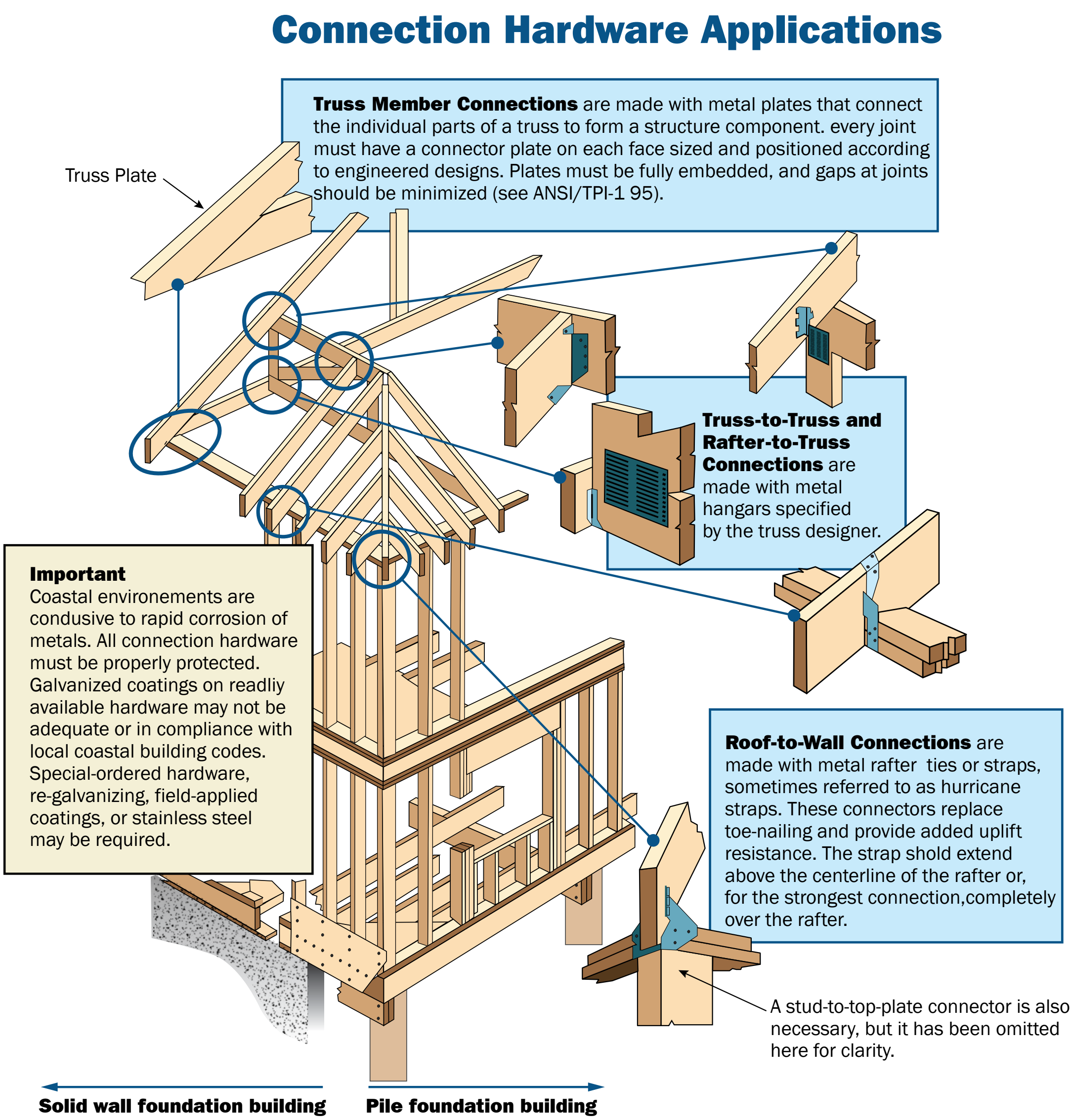


Figure 3.3.1.4. Examples of proper roof connectors and fasteners for a wood-framed truss.

- Connection hardware used in coastal areas must meet building code requirements to resist corrosion. Standard hardware available in local stores may not meet these building code requirements; special-ordered hardware, field-applied coatings, re-galvanizing or stainless steel may be required. As part of these solutions, note that NFIP Technical Bulletin 8, *Corrosion Protection of Metal Connectors in Coastal Areas*, recommends all exposed roof connectors and fasteners within 3,000 feet of the coastline to be either hot-dipped galvanized steel or stainless steel to resist salt spray and corrosion.

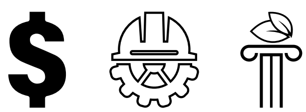
CONSIDERATIONS:

Option 3: Upgrade Wood Sheathing

Lightweight wood sheathing can be at risk for wind uplift and damage from wind-borne debris. Upgrading wood roof sheathing can improve its performance during hurricanes. This can be done to replace roof sheathing damaged after a storm or as a retrofit. When evaluating this mitigation option, consider the following:

- Wood sheathing panels made of plywood or OSB are recommended for high wind regions. The panels should be rated for high wind and usually are designated as “Exposure 1” or better. Building codes require more specific materials in the High-Velocity Hurricane Zone (HVHZ) specific to Miami-Dade and Broward Counties in Florida.
- Sheathing layouts for gable-end and hip roofs should be installed to match APA—The Engineered Wood Association recommendations as shown in Figure 3.3.1.5.
- Improved sheathing connections should use full round head deformed-shank nails, ring shank nails or screws; staples should not be used in high-wind areas.
- Decrease nail spacing for sheathing systems that do not meet current wind load requirements.
- Adding closed cell spray foam to connect roof decking to rafters/trusses improves roof performance by strengthening areas where there may not be enough nails between the roof deck and the rafters/trusses.

CONSIDERATIONS:



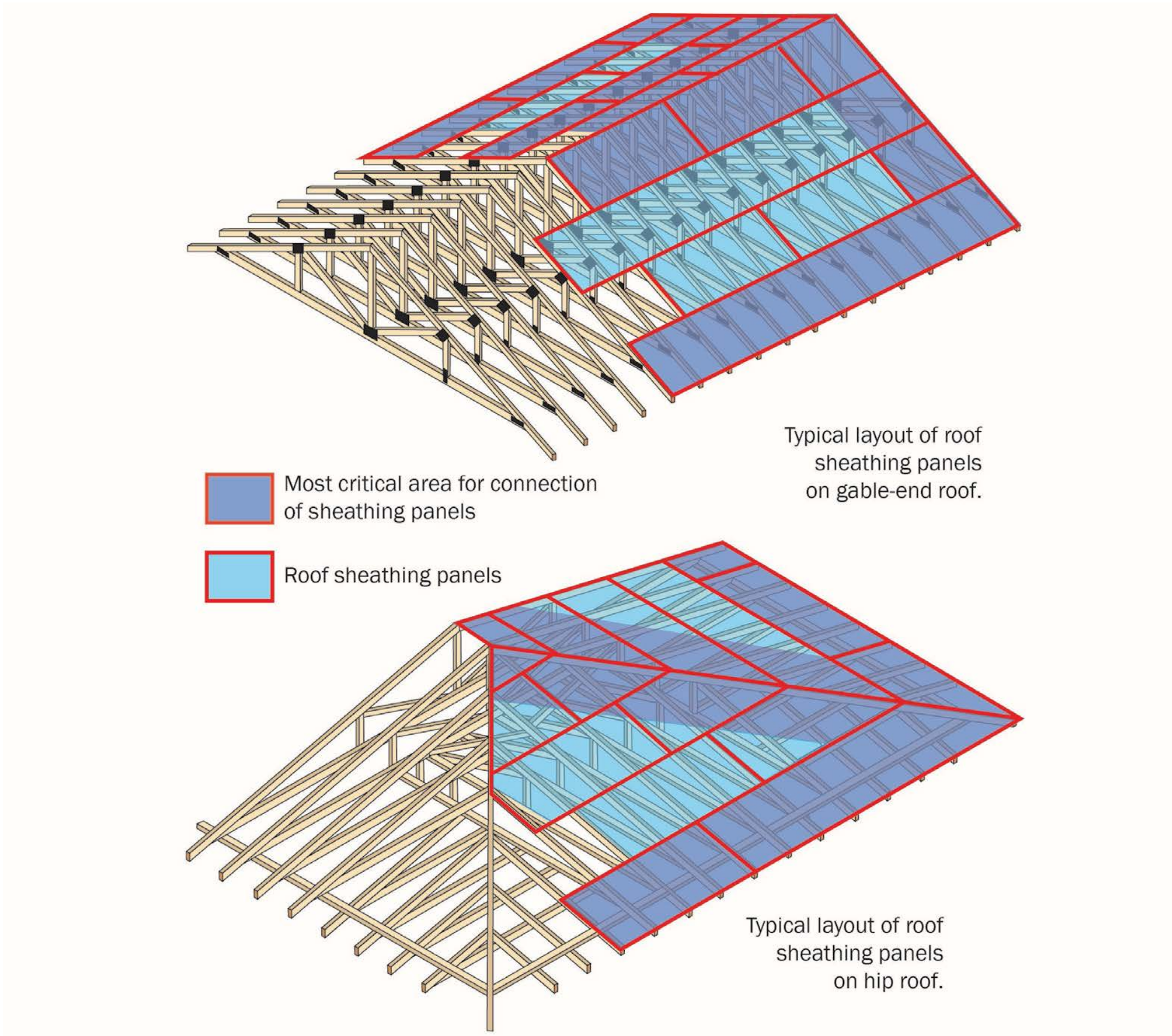


Figure 3.3.1.5. Examples of proper sheathing panel layouts for gable-end roof (top) and hip roofs (bottom)

Option 4: Improve Asphalt Shingles and Metal Roofing

Improve the performance of asphalt shingles and metal roofing by following best practices for materials, installation and connections, as noted below:

- Use ring shank nails for all wood nailing.
- Consider replacing loose or damaged shingles as needed with ASTM-rated shingles that meet the area's local code regulations and wind requirements or International Building Code requirements, whichever is stricter.
- If it is determined the entire roof covering should be removed and replaced, install an upgraded underlayment to the roof sheathing (Figure 3.3.1.6) before installing the new roof covering. The upgraded underlayment provides an additional layer of water resistance to the roof system.

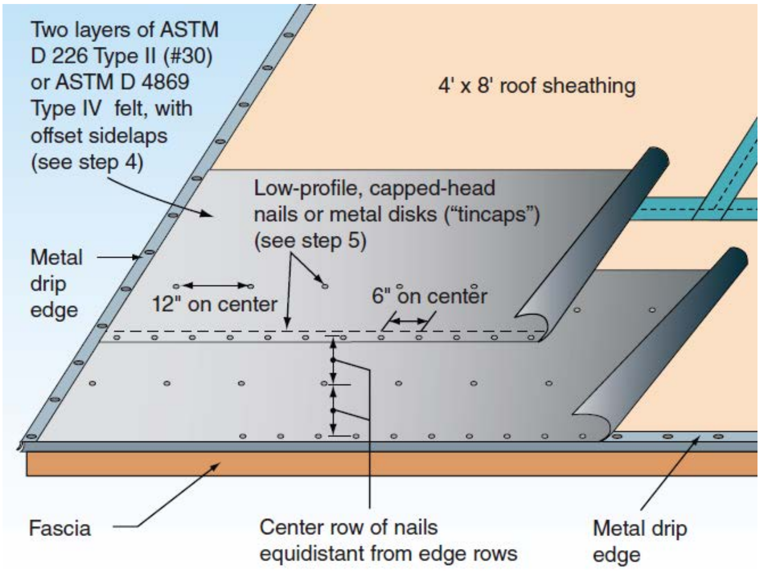
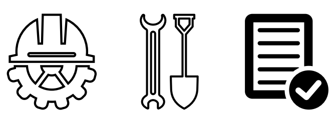
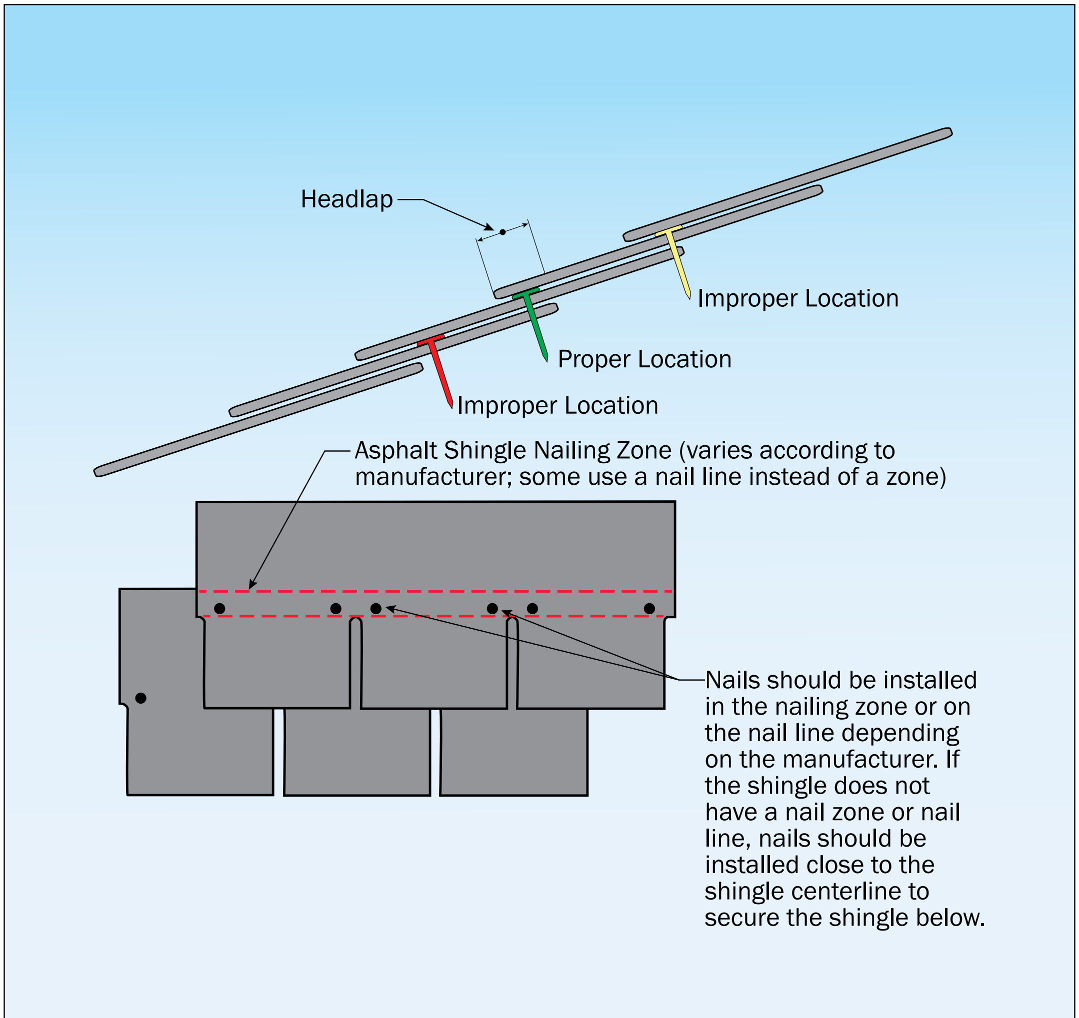


Figure 3.3.1.6. Strong underlayment installation details applied to asphalt shingle roof sheathing in high-wind regions.

- Ensure shingles are attached correctly, as shown in Figure 3.3.1.7. Ensure nails are adequately driven as shown in Figure 3.3.1.8.
- Apply dabs or continuous lines of asphalt roof cement beneath shingles along eaves, rakes, hips and ridges to better attach shingles.
- Make sure flashing is installed correctly around plumbing vents, chimneys, exhaust vent caps, dormers and skylights. Flashing must be integrated with the shingles and roof underlayment to prevent water from entering.
- Consider using metal roof panels that have been tested to meet the local code regulations and wind load requirements of the area and installing them per site-specific analysis requirements.

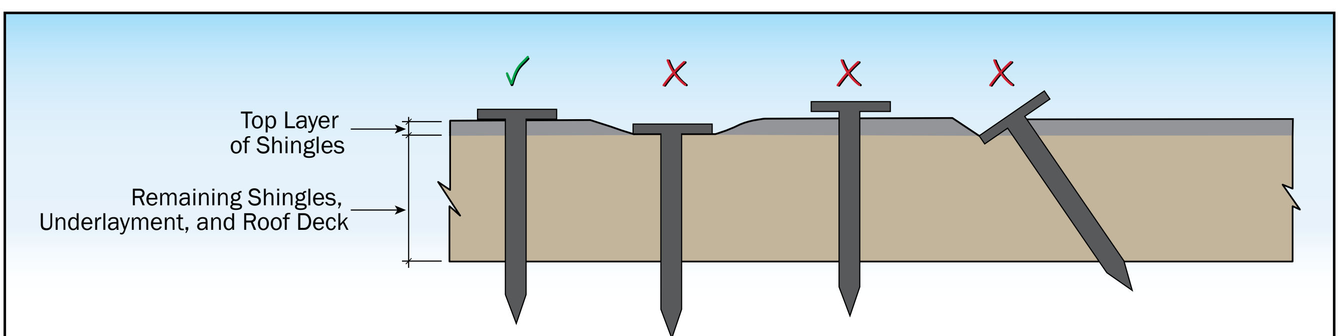
CONSIDERATIONS:





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

Figure 3.3.1.7. Proper and improper locations of shingle fasteners.



“The Good, the Bad, and the Ugly” - Properly Driving Roofing Nails

Figure 3.3.1.8. The Dos and Don’ts of driving roof nails through asphalt shingles.

Option 5: Upgrade Vinyl and Aluminum Soffits

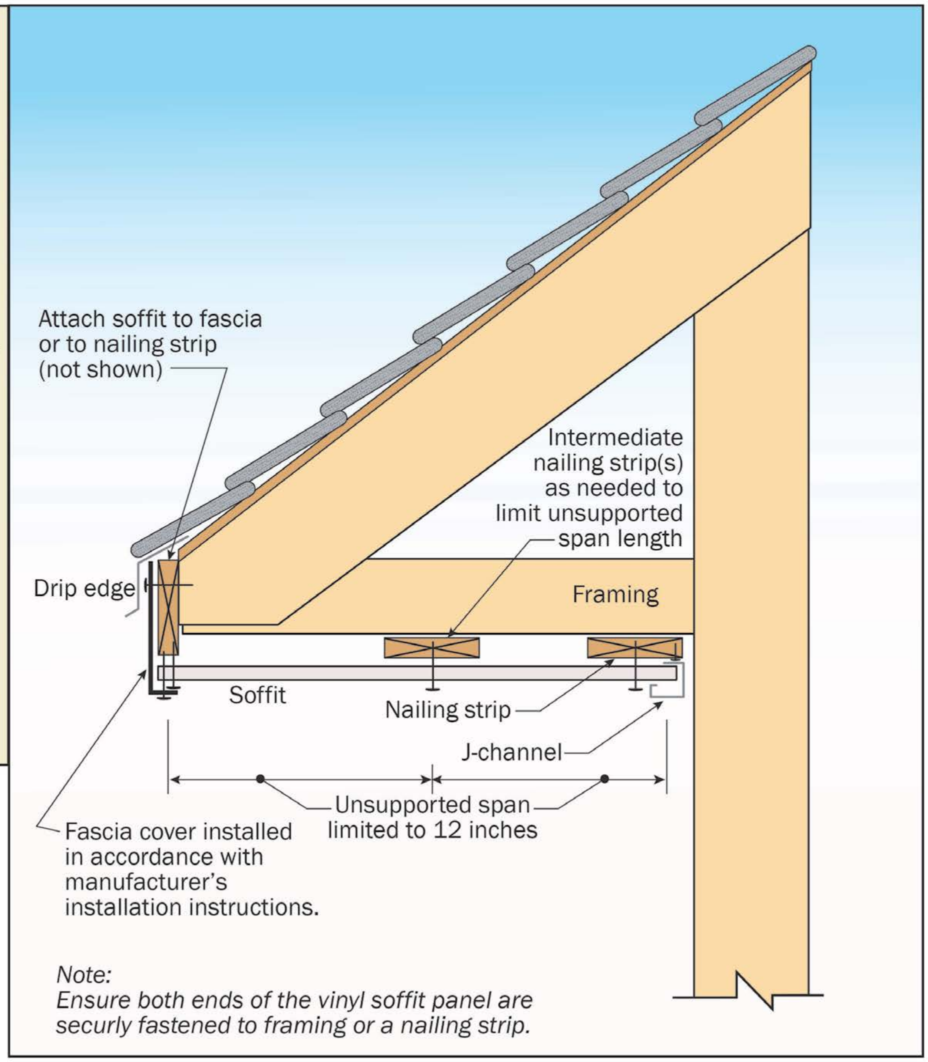
Vinyl and aluminum soffit panels that are commonly used to enclose the underside of sloped roof overhangs (eaves) are vulnerable to damage from wind and wind-driven rain. The following upgrades to vinyl and aluminum soffits can address this issue:

- Replace vinyl or aluminum soffits with plywood soffits that tend to be more rigid and well anchored to the wall and roof framing (Figure 3.3.1.9).
- Replace poorly connected tracks with nailing strips and intermediate framing and connections to reduce bending of soffits in roof overhangs greater than 12 inches.
- Seal soffits:
    - Clean the surfaces first to ensure proper bonding.
    - Apply beads of sealant along the bottom edge of the wall channel to adhere it to the wall surface below.
    - Also, apply beads of sealant in indentations between the soffit panels and the wall channel at one end and the fascia flashing at the other end.
    - Install screws to tie the soffit panels to both the fascia flashing and the wall channel.
- Soffit upgrades should be done simultaneously as changes are made to reduce or eliminate soffit vents, as shown in Figure 3.3.1.9.
    - Use soffits designed or tested for the same wind loads as the attached walls.
    - To reduce water intrusion, verify soffit vents are tested for resistance to wind and wind-driven rain.
    - Fasten soffit panels directly at the wall and the fascia rather than in tracks to prevent them from failing in high winds.

CONSIDERATIONS:

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.



Vinyl Soffit Panel Installation

Figure 3.3.1.9. Improving soffits can decrease wind damage to sloped roofs.

Option 6: Improve Gutters and Downspouts

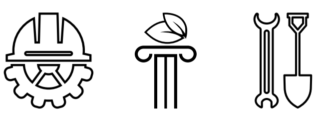
Gutters and downspouts carry water away from the roof and the building. If they become clogged or damaged, they cannot perform their function and leave the roof exposed to potential wind and water damage. FEMA P-55, *Coastal Construction Manual*, recommends the following measures to protect gutters and downspouts from wind damage and make sure they provide sufficient storm runoff capacity:

- Use gutter materials and connectors designed to resist wind, water and ice loads as per ANSI/SPRI GD-1, *Structural Design Standard for Gutter Systems Used on Low-Sloped Roofs*, for both low- and steep-slope roofs, as shown in Figure 3.3.1.10.

Figure 3.3.1.10. Sheet metal straps (circled) attached to an existing gutter to increase wind uplift resistance.

- Upgrade and lengthen downspouts to direct water farther away from the building to reduce the risk of interior or basement water damage.
- Maintain gutters and downspouts using routine inspections to clean them of vegetation and other debris and to tighten loose connections. Trim back tree limbs surrounding the building, so they do not extend over the rooftops.

CONSIDERATIONS:



Option 7: Strengthen Skylights

While skylights can provide added light to a room, they can also be a point of entry for water and wind if they are not rated for the wind zone in the area where the building is located, or if they are not properly sealed. Consider using skylight systems that have product approval or have been tested using approved methods and meet the site-specific wind requirements for the area. (The online ASCE 7 Hazard Tool and ATC Hazards by Location tool contain information about wind requirements by location.) Strengthen skylights to help reduce damage to the interiors of public buildings as follows:

- Upgrade older plastic skylights with wired glass or other impact-resistant glazing materials with thicker seals and frames.
- Use skylight installation and performance standards found in ASTM E 2112 and ASTM E330.
- Replace hinged skylights with closed skylights to further reduce the risk of wind-driven rain penetration and increase security.

- Install a protection device such as a shutter to protect a skylight from debris impact.
- Ensure the skylight frame is adequately flashed and sealed to prevent water entry.

CONSIDERATIONS:

Option 8: Strengthen Roof-Mounted Equipment and Connections

Sloped roofs may have heating/ventilation/air conditioning (HVAC) and communication systems mounted on them, including satellite dishes, antennas, solar panels and vents. Mounting HVAC and communications systems components on the roof can make it vulnerable to wind and wind-borne debris damage. Equipment that collapses or is torn off the roof by wind can damage the roof covering and sheathing, allowing rain to enter the building.

Improve the performance of rooftop-mounted equipment by doing the following:

- Follow specific design guidance found in *Calculating Wind Loads and Anchorage Requirements for Rooftop Equipment* published by the American Society for Heating, Refrigeration and Air Conditioning Engineers (ASHRAE); FEMA P-424, *Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds*; and FEMA P-543, *Design Guide for Improving Critical Facility Safety from Flooding and High Winds*.
- Ensure antennas and communications masts are designed for the wind loads in the geographic region where they are located. If they support equipment such as satellite dishes, make sure they are designed for the additional wind load that could be transferred from the equipment.
- Make sure antennas and communications masts are well attached to the roof using mechanical anchors instead of ballast material.
- Make sure the uplift rating of roof-mounted solar panels is enough to handle the potential wind loads during a storm. The uplift rating may be in the manufacturer's specifications for the panels; otherwise, contact the manufacturer for wind uplift rating.
- Evaluate the parts used to make connections between the photovoltaic modules and the framing system, such as mechanical fasteners, panel clips, snap-fit couplings and adhesive. Tighten loose connections and replace corroded or otherwise inadequate parts with corrosion-resistant connectors.

CONSIDERATIONS:

Mitigation Solution: Add or Increase

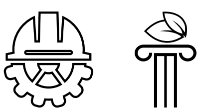
Roofs can be particularly vulnerable to wind and rain during a hurricane. Adding an element or increasing the size or quantity of an existing roof system component can help protect it from hurricane damage caused by wind, wind-driven rain and rain hazards. This solution can help improve the performance of roof sheathing and roof drainage components.

Option 1: Upgrade Underlayment to Shingle Roofs

Strong winds can blow coverings off roofs and wind-driven rain can get underneath shingles, exposing the underlying roof material and increasing the potential of water and debris damage. Sealing the roof deck by upgrading the underlayment can help protect the roof from rain and debris impacts if the covering is lost or damaged. An upgraded underlayment to the roof sheathing will provide a significant secondary water and impact barrier.

- Ensure the underlayment is rated and labeled according to ASTM standards and matches the wind ratings for the area.
- Ensure the underlayment is securely fastened to the roof deck in accordance with the manufacturer's specifications, through the use of button cap nails orinstall a fully adhered underlayment.
- Install drip edges at eaves above the underlayment to reduce water entry from wind-driven rain.
- See Figure 3.3.1.6 for more information about installing an underlayment on a shingle roof.

CONSIDERATIONS:

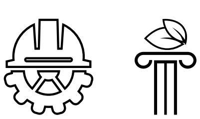


Option 2: Increase Roof Drainage

Gutters and downspouts typically are sized to handle regular rainfall events and often are poorly maintained. As a result, they quickly can become overwhelmed or clogged with vegetation or debris during extreme rainfall events. This increases the risk of water ponding on roofs and on the ground around the building, which can leak in and cause damage. To address these issues:

- Increase the capacity of gutters and downspouts by using larger elements positioned for positive drainage that can collect and carry more rainwater away from the roof and building.
- Larger gutters and downspouts will require stronger connectors and fasteners to attach to roof and wall systems (see Figure 3.3.1.10).

CCONSIDERATIONS:



Mitigation Solution: Secure or Eliminate

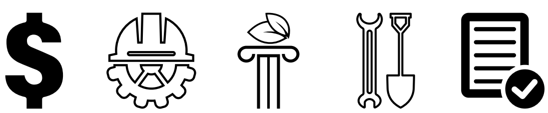
Secure a vulnerable component or eliminate it from the roof system to reduce or end wind and wind-driven rain damage. In particular, wind pressure can damage roof coverings, overhangs and vents, making them susceptible to wind-driven rain entry.

Option 1: Secure or Eliminate Clay Tile Roofs

Clay tile roofs on public buildings in high wind regions should be attached using a tested and approved assembly based on site-specific analysis for the area. Tile roof attachments should meet local code regulations. When evaluating mitigation of clay tile roofs, consider the following:

- Determine the wind loads for the geographic area and make sure the tiles are rated to withstand those wind loads.
- Install clay tiles as per the most current guidance from the Tile Roofing Institute.
- To improve performance, use the attachment designed for the corner area throughout the entire roof area.
- For roofs within 3,000 feet of the ocean, straps, fasteners and clips should be hot-dipped galvanized or stainless steel to resist corrosion.

CONSIDERATIONS:

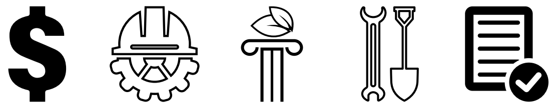


Option 2: Secure, Minimize or Eliminate Roof Overhangs

Roof overhangs on sloped roofs (eaves) can become a major source of uplift failure for the roof system, allowing wind-driven rain to damage the building's interior. The following mitigation options can be used to address at-risk overhangs on buildings subject to high winds:

- Use stronger materials, connectors and fasteners to attach moderately sized overhangs (12 inches to 16 inches) to resist uplift forces and wind-driven rain penetration. See the *Wood Frame Construction Manual for additional information*.
- Large overhanging roofs covering porches and other areas connected to the main building should be designed as either a single-roof structure to resist the maximum uplift forces or as a separate roof structure not attached to the main building.
- For new construction or existing buildings with large roof overhangs that are damaged and need to be replaced, consider redesigning the roof system to minimize or strengthen roof covering attachments and strengthen roof-to-wall connections.
- New or reconfigured roofs should be designed by a licensed engineer.

CONSIDERATIONS:

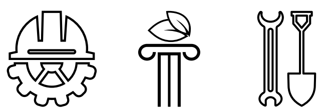


Option 3: Reduce or Eliminate Soffit Vents

Soffit vents provide ventilation of the attic space from the underside of sloped-roof overhangs (eaves), but they can be a point of failure unless the weak vinyl and aluminum soffit panels that cover most soffit vents are upgraded. Currently, there is no suitable test method to evaluate the potential for wind-driven rain to enter the attic through soffit vents. Designers should consider the following options:

- Reduce the size of existing soffit vents by custom designing a filter fabric (such as those used in HVAC system filters) above the vent openings.
- Eliminate soffit vents by designing a different airflow route into the attic or design for an unvented attic.

CONSIDERATIONS:



Option 4: Secure or Replace Ridge Vents and Turbines

For public buildings with sloped roofs, ridge vents placed along the crown of the roof and/or off-ridge vents placed along the edges of the roof near the crown can provide air flow into attic spaces. Turbines that use wind power to pull humid air out of attic spaces can be mounted on top of short standpipes and installed on sloped roofs. Ridge vents, off-ridge vents, and turbines often are poorly attached to the roof and can bend or dislodge during hurricanes, allowing entry of wind-driven rain into the building. Consider the following mitigation recommendations:

- For ridge vents, replace ordinary roofing nail connectors with gasketed stainless steel wood screws.
- Consider replacing the existing ridge vents with vents that have passed the Florida Building Code Testing Application Standard (TAS) 100(A), *Test Procedure for Wind and Wind Driven Rain Resistance and/or Increased Windspeed Resistance of Soffit Ventilation Strip and Continuous Intermittent Ventilation System Installed at the Ridge Area*, for wind-driven water.
- For off-ridge vents, check existing connectors and consider adding vent covers that can be installed from inside the attic, but avoid simply adding nails or screws that can damage roof coverings.

- Turbines can be securely anchored to the roof sheathing and framing with straps, and the turbine head should be connected to the standpipe with sheet metal screws. Consider temporarily removing the turbine head before a hurricane and plugging the top of the standpipe to prevent rain entry. Even high wind-rated turbines will rotate at above-design speeds and can be damaged easily by wind-borne debris.

CONSIDERATIONS:

Option 5: Protect or Eliminate Gable Vents

Gable end vents placed in the center of gable end walls near the roof line create air flow into the attic space of gable roofs. Gable rake vents may use porous soffit panels or screen vents on the bottom surface of gable end roof overhangs bigger than 12 inches and are supported by outriggers (2-inch by 4-inch boards running perpendicular to the gable truss that extend into the gable overhang). Gable end and rake vents are susceptible to wind-driven rain. The following mitigation measures for gable vents, as shown in Figure 3.3.1.11, include:

- Add shutters to gable end vents. This is an active mitigation measure that requires manual installation before a hurricane and removal after a hurricane.
- Plug gable rake vents when not needed using metal flashing or pre-cut pieces of wood that can be anchored to

Figure 3.3.1.11. Protecting gable end vents using shutters (left) and sealing gable rake vents using metal plugs as indicated by red arrows (right).

CONSIDERATIONS:

REFERENCES:

Detailed technical information on hurricane mitigation of sloped roofs can be found in these publications. Much of the residential information also applies to non-residential buildings.

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