Repair and Replacement of Wood Residential Roof Covering Systems

Purpose and Intended Audience

The purpose of this Recovery Advisory is to identify best practices for repairing and replacing residential roof covering systems over wood framed structures and to provide a better understanding of the behavior of roof coverings during high wind events. Designing and constructing roof covering systems to the latest building codes and best practices to follow will reduce water leakage, improve the integrity of roof structures and roof coverings, and improve overall building performance during hurricanes and other wind events. The guidance is for residential one- and two-family dwellings and is primarily intended for engineers, architects, and contractors. However, it also provides helpful information to homeowners and building owners.

Key Issues

1. Prior to installation of a new roof covering system over an existing wood framed roof support structure, a wind vulnerability assessment should be performed by a licensed Professional Engineer or Architect. The assessor should verify the integrity of existing supporting framing structure (e.g., beams, joists, or trusses) and its connections to ensure adequate structural capacity for wind resistance. According to the International Code Council's 2018 *International Existing Building Code* (ICC IEBC, 2018b), if the existing roof support structure is not capable of resisting at least 75 percent of the wind loads derived from American Society of Civil Engineers *Minimum Design Loads and Associated Criteria for Buildings and Other Structures, 2016 Edition* (ASCE 7-16, 2017), the deficient structural members and connections should be replaced or strengthened to meet the current ASCE 7 wind loads.[1]
2. If existing wood sheathing occurs over the existing roof support structure, verify that the sheathing material, thickness, and attachment are sufficient and in serviceable condition. If the sheathing material is determined to be insufficient to transfer the load to the roof support system adequately, remove and replace the sheathing.
3. If sheathing is determined to be in acceptable condition, fasteners should be inspected and replaced, as needed, before replacing the roof covering. Additional fasteners may need to be added to meet code requirements for edge, ridge, and corner zones.
4. During construction, contractors should be supervised by a licensed Professional Engineer or Architect who can implement quality control and quality assurance procedures to ensure that that the recommended installation criteria are met.

This Recovery Advisory Addresses

- Building Codes
- Load Path
- Best Practices for Roof Covering System Repair and Replacement

[1] The 75 percent value is based on criteria in the 2018 IEBC.

This advisory addresses roof system components that are installed above a wood roof support structure (i.e., beams, joists, or trusses). It does not comprehensively address the design or installation of the roof support structure. Unless noted otherwise, all photos are from Mitigation Assessment Team observations in Puerto Rico following Hurricanes Irma and Maria in 2017.

Building Codes

The current governing code in Puerto Rico is the *Puerto Rico Building Code* (*PRBC,* 2011), which references the 2009 editions of the *International Building Code* (ICC IBC, 2009a), *International Existing Building Code* (ICC IEBC, 2009b), and *International Residential Code* (ICC IRC, 2009c), collectively the 2009 I-Codes. The applicable code adoption under the *PRBC* is the 2009 IEBC, which governs roof repair and roof replacement activities. Puerto Rico is expected to adopt the 2018 I-Codes in the summer of 2018. This advisory follows the 2018 IBC, IRC, and IEBC for repairing and replacing damaged or compromised roof covering systems.

Substantial Structural Damage

Depending upon the amount of damage to the roof structure below the roof covering system, the damage may be considered substantial structural damage (SSD). SSD is defined in the I-Codes. When a building is determined to have sustained SSD, the building official may require the roof structure and possibly other structural and building code upgrades to be undertaken during any repair effort. For more information on SSD, visit:

https://www.fema.gov/media-library/assets/documents/130384

Load Path

The load path describes how loads applied to a building are transmitted through a structure to the foundation. In the case of wind, loads are applied to the roof surface in the form of uplift pressures, and, in some cases, downward pressure, depending on roof geometry and wind direction. Wind pressures are transmitted from the roof covering to the wood sheathing below, through fasteners. Roof sheathing is the first structural component in the load path between the roof system and the foundation. The sheathing transmits the wind forces to the roof support members, through fasteners, ideally ring-shank nails, or screws. Ring shank nails are specially designed with ribs on the shank of the nail, providing higher withdrawal capacity compared to regular smooth shank nails. Failed or missed connections cause loads to travel through unintended load paths and can lead to system failure.

When determining if a roof covering system can be repaired or should be replaced, it is essential to review the integrity of the roof sheathing and roof support structure. It is important to ensure that sheathing is capable of adequately transferring the load to the roof support structure to maintain continuity in the load path of the structure. Careful consideration should be given to fasteners that attach the roof covering to the roof sheathing and roof support structure. Additional roof fasteners may be required to ensure the roof sheathing is adequately connected to the support structure, particularly for edges, ridges, and corners.

Figure 1 illustrates an example of uplift load path for a standard wood roof covering system with wood sheathing. The uplift load path for corrugated metal panel roofs is similar when a plywood roof deck is present.

For corrugated metal panel roofs without wood sheathing, the load path is similar except that the metal panels are connected directly to the supporting rafters or trusses. In this case, the integrity of the roof is entirely dependent on the connection of the metal roof deck, fasteners, and roof support structure. The lack of redundancy in a metal roof deck without plywood sheathing makes this roof covering system susceptible to water leakage, damage from wind-borne debris, uplift due to high winds, and possibly structural damage.

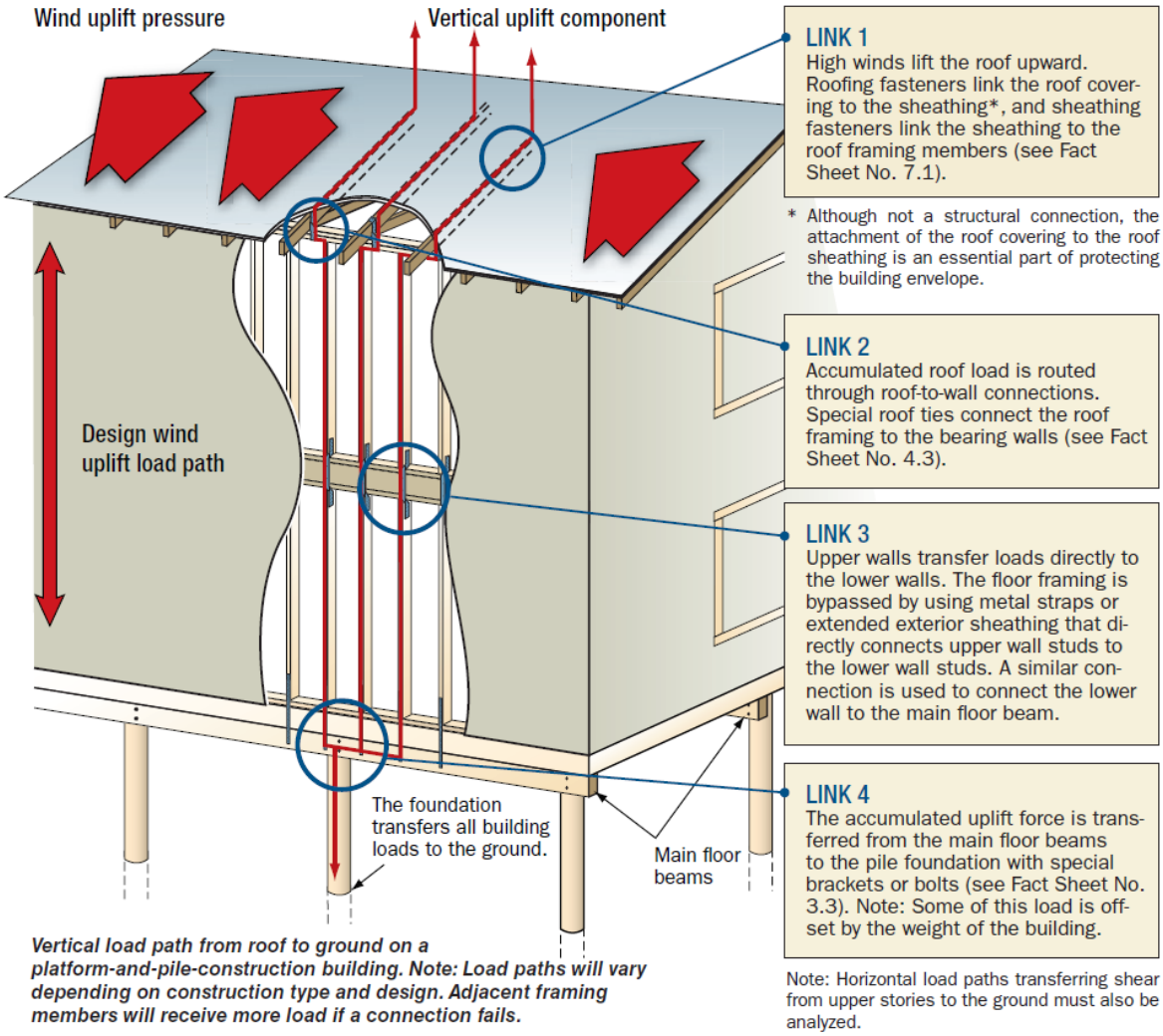

Figure 1. Illustration of a load path for a typical roof system. From Home Builder's Guide to Coastal Construction (FEMA P-499, 2010), Technical Fact Sheet 4.1.

Best Practices for Roof Covering System Repair and Replacement

In Puerto Rico, a common roof system failure mechanism observed was an insufficient attachment of the primary roof covering system to the roof framing structure. Another common failure was the collapse of the roof framing when the roof covering was lost, due to a lack of structural roof decking across the roof framing. This should ideally have been provided in the form of plywood or wood structural panel sheathing. Typically, minimum $\frac{5}{8}$ inch thick plywood sheathing is recommended in hurricane-prone regions, rather than oriented strand board (OSB). This sheathing provides higher nail head pull-through resistance to ensure the roof system remains intact when exposed to high wind uplift forces. See the *Home Builder's Guide to Coastal Construction* (FEMA P-499, 2010) for additional recommendations for sheathing selection and performance. The plywood also offers protection from windborne debris in hurricane-prone regions.

Two prevalent roof covering types (materials) observed in Puerto Rico on residential buildings with wood roof structural systems were corrugated metal panel roof coverings and tile roof coverings:

Metal Panel Roof Coverings

Metal roof panels can be a robust and durable roof covering system when designed and constructed correctly. It is important to select a roof panel that is thick enough to resist uplift forces. In Puerto Rico, thin corrugated metal roof panels frequently sustained wind and water leak damage under normal weather conditions. In Figure 2, note a portion of the roof structure missing due to high wind forces after hurricane Maria in 2017. The corrugated metal roof panels were screwed to 2 inch x 4 inch nailers, which were placed over plywood sheathing. The nailers and plywood were attached with nails, which provided insufficient uplift resistance.

Proper fastener size and spacing is critical to ensure that metal panels remain connected to the roof framing. Three-quarter inch T-1-11 structural sheathing or equivalent plywood deck under the roof panel is strongly recommended to provide load transfer to the roof framing, prevent water intrusion into the structure, and create a proper diaphragm. A robust underlayment system, such as #30 saturated roof felt, is strongly recommended to provide a secondary water barrier to further protect against water intrusion. If the new roof covering system were to be placed over such a roof support structure without strengthening it, the new roof covering system would be susceptible to future damage.

Figure 2. A damaged corrugated metal roof. The roof did not have plywood sheathing or adequate roof support framing or connections.

Tile Roof Coverings

Tile roof covering systems are not very common in Puerto Rico, but several communities on the island use tile as a primary roof covering system. In these cases, the tiles are aesthetic and placed atop a concrete roof deck. There are many types of tile roof styles, including clay, concrete, plastic, and even metal panels made to look like tile roof.

An ideal installation includes roof tile installed atop a solid concrete roof deck. A waterproof membrane is then installed, followed by battens. Tile roofs in hurricane regions must be anchored to the roof with fasteners, typically at battens. Fasteners used must be adequate to resist uplift from wind loads in accordance with the IBC. If fasteners are inadequate to hold roof tiles down on the roof, tiles can break away from the structure and become wind-borne debris. Roof tile missiles can be blown a considerable distance and can penetrate shutters and glazing, potentially causing injury. Roof tiles tend to be vulnerable to breakage from wind-borne debris, even when well attached, unless they are rated as impact resistant. Once roof tiles have been compromised and have broken away from the roof, the roof deck is susceptible to water intrusion. Many of the clay tiles blew off the house shown in Figure 3.

Special care should be taken to account for corners, hips, ridges, and perimeter tiles, to ensure these areas are correctly attached with clips or straps, as roof tiles in these zones are especially susceptible to blow-off. Figure 4 shows wind loading zones along a roof, from *Design Guide for Improving Critical Facility Safety from Flooding and High Winds: Providing Protection to People and buildings* (FEMA 543, 2007). At these zones, clips should be installed on roof tiles.

Figure 3. A damaged clay tile roof.

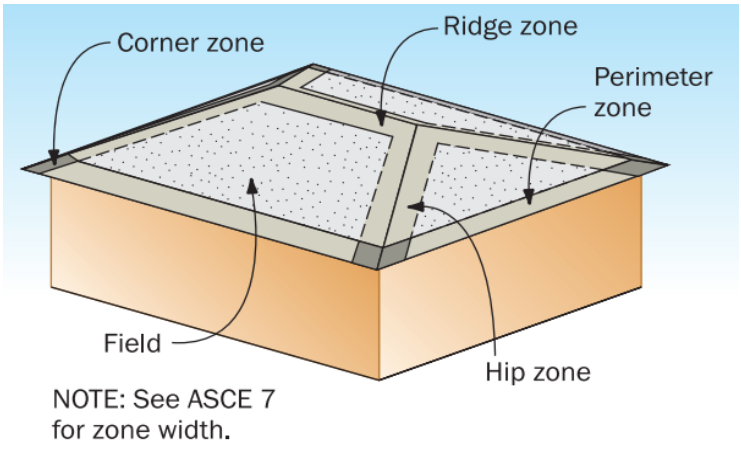

Figure 4. Zones where clips should be installed for roof tiles. From FEMA 543 (Technical Bulletin 7.4, Figure 1).

Underlayment for Tile and Metal Roofs

When used properly, underlayment provides additional protection to water infiltration and reduces water damage to the building's structure and contents at a limited additional cost. Underlayment was observed for many of the tile roof systems that were inspected in Puerto Rico but was not often found on other roof covering types despite being detailed in design guidance prepared by FEMA and others following Hurricane Georges in 1998.

During underlayment installation, proper starter, end, and side laps are required for the underlayment to perform optimally. Sealant should not be used as a substitute for proper lap lengths of the underlayment. See Figures 5 and 6 for examples of how underlayment should be installed and detailed to achieve additional protection against water infiltration through the roof system.

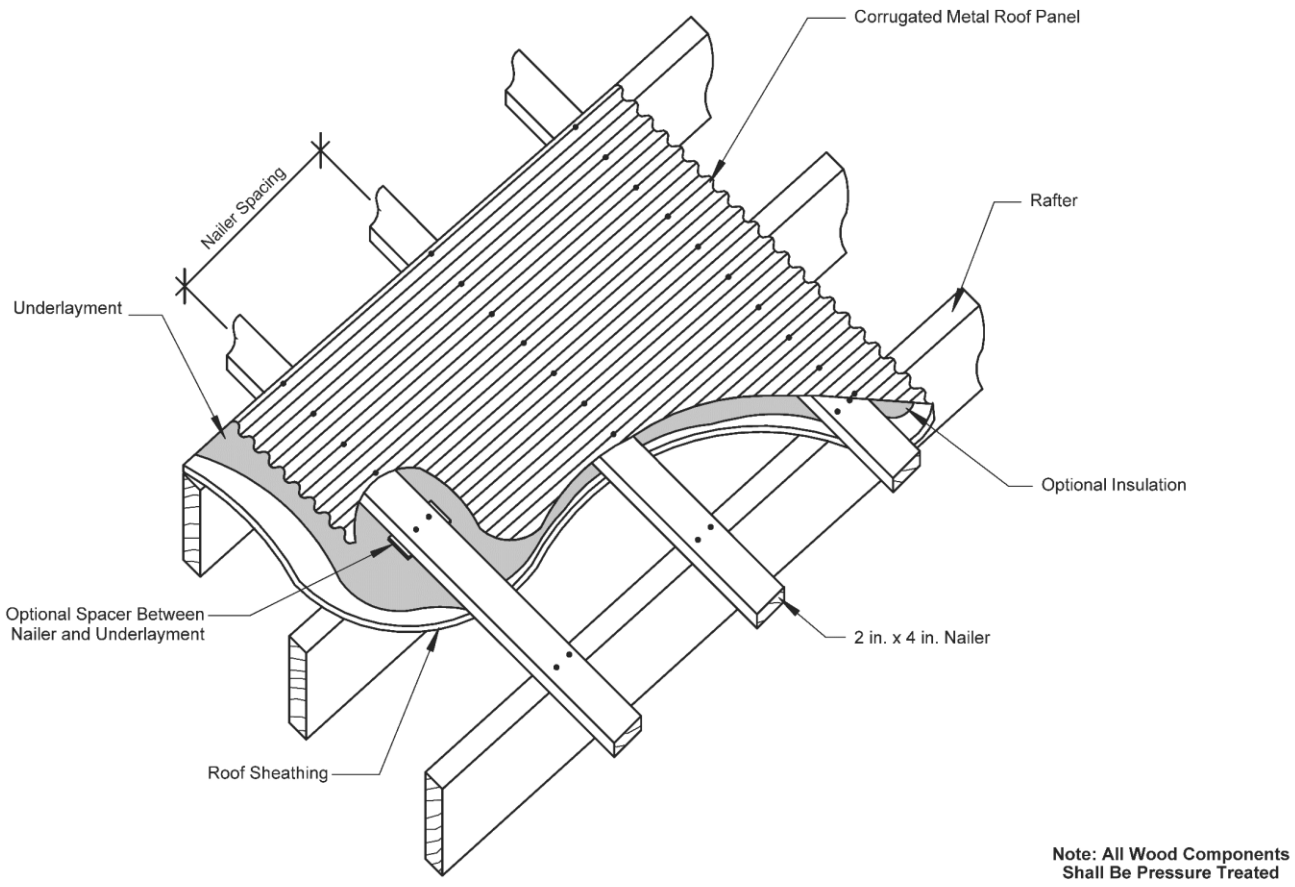

Figure 5. Typical underlayment installation. From Construction Information for a Stronger Home, 4th edition (U.S. Virgin Islands Department of Natural Resources, 2018), Sheet S-16.

Flashing and metal drip edges are important components for improving resistance to water intrusion and wind driven rain. Flashing should match the gauge of the metal roof covering or should be a vinyl equivalent. Aluminum flashing should be avoided because of the risk of corrosion from contact with treated wood products. Metal drip edges are required by code along eaves and gable ends. An example of underlayment and drip edge configuration is given below (Figure 6). Additional guidance on selecting and applying underlayment for roof covering systems is given in the 2018 IRC, Section R905, and 2018 IBC, Section 1507.

Materials and Installation

Table 1 provides best practice guidelines for materials and installation. Though written for the U.S. Virgin Islands, it is applicable to most areas in Puerto Rico. Table values are based on rafters spaced at 2 feet 0 inches on center (o.c.) and a basic wind speed of 165 mph for a building in Risk Category II. For areas in Puerto Rico with higher design wind speeds than 170 mph, a design professional should make final determination on roof components listed. Recommendations in Table 1 are based on the given exposure category, but the design may vary depending on the specific site location and the assumptions of the design professional.

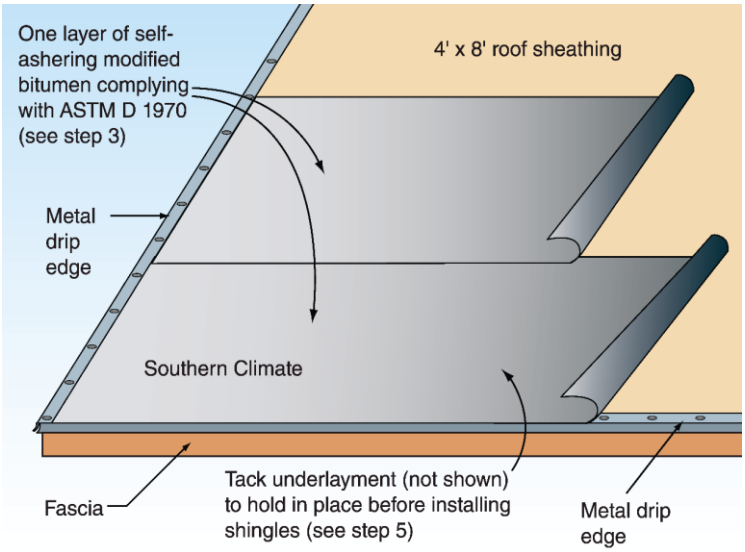

Figure 6. Typical underlayment and drip edge installation. From FEMA P-499 (Technical Fact Sheet 7.2).

Table 1. Roof Sheathing, Nailer, and Attachments. From Construction Information for a Stronger Home, 4th Edition (Sheet S-15).

Roof Component Designs	Wind Exposure B on Upper Half of a Hill, Ridge, or Escarpment or Near the Crest of an Escarpment	Wind Exposure B	Wind Exposure D
Metal Roof Panel Fasteners Spacing Along Nailer	5 ⅓ in. o.c. (Every Other Corrugation)	10 ⅔ in. o.c. (Every 4th Corrugation)	8 in. o.c. (Every 3rd Corrugation)
Nailer Spacing	See Roof Plans	See Roof Plans	See Roof Plans
Nailer Fasteners into Outlookers at Overhangs	#14 x 5 in. Long Stainless Steel Wood Screw at 6 in. o.c.	#12 x 4 ½ in. Long Stainless Steel Wood Screw at 12 in. o.c.	#14 x 5 in. Long Stainless Steel Wood Screw at 6 in. o.c.
Nailer Fasteners at Each Rafter Intersection	Two #14 x 5 in. Long Stainless Steel Wood Screws	Two #12 x 4 ½ in. Long Stainless Steel Wood Screws	Two #14 x 5 in. Long Stainless Steel Wood Screws
Blocking for Sheathing	Blocking Shall Be Installed Under the Unsupported Edge of All Roof Sheathing Which Has a Liquid Applied Membrane	Blocking Shall Be Installed Under the Unsupported Edge of All Roof Sheathing Which Has a Liquid Applied Membrane	Blocking Shall Be Installed Under the Unsupported Edge of All Roof Sheathing Which Has a Liquid Applied Membrane
Sheathing Size Thickness May Be Decreased by ⅛ in. if Textured Plywood is Replaced with Regular Plywood. However, Minimum Thickness Shall Not Be Less than ⅝ in.	Structural 1 Type ⅞ in. Textured Plywood with 48/24 Span Rating	Structural 1 Type 23/32 in. Textured Plywood with 32/16 Span Rating	Structural 1 Type ¾ in. Textured Plywood with 40/20 Span Rating
Sheathing Fasteners	#14 x 3 ½ in. Long Stainless Steel Wood Screws at 3 in. o.c. at All Support Members	#12 x 3 in. Long Stainless Steel Wood Screws at 5 in. o.c. at All Support Members	#14 x 3 ½ in. Long Stainless Steel Wood Screws at 3 in. o.c. at All Support Members

Note: Table based upon rafters which are spaced at 2 feet 0 inches (o.c.) maximum.

References and Useful Links

References

American Wood Council. 2018. *Wood Frame Construction Manual for One- and Two-Family Dwellings*. http://www.awc.org/codes-standards/publications/wfcm-2018.

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Puerto Rico Permits Management Office. 2011. *Puerto Rico Building Code*. *PRBC* 2011.

U.S. Virgin Islands Department of Natural Resources. 2018. *Construction Information for a Stronger Home, 4th Edition*. (Expected date of publication April 2018).

Useful Links

FEMA. 2011. *Coastal Construction Manual: Principles and Practices of Planning, Siting, Designing, Constructing, and Maintaining Residential Buildings in Coastal Areas, 4th Edition*. FEMA P-55. https://www.fema.gov/media-library/assets/documents/3293.

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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