



# Roof Coverings and Best Practices

## 8.1 Introduction

**D**uring storm events, a roof is expected to perform many functions—from preventing water intrusion to acting as a structural diaphragm in certain situations. As stated in the 2006 IBC, roofs must “serve to protect the building.” This requires roofs to resist high and low temperatures, rain, wind-driven rain, high winds, exposure to ultraviolet radiation, and (in some areas) snow, ice formation, and hail stones. In coastal areas, high winds and the hazards that often accompany high winds (such as windborne debris and wind-driven rain) can prove particularly problematic, as this is not specifically addressed by the codes (despite a few exceptions). Corrosion from salt-laden air can also be a factor in the performance of roof coverings as materials, systems, or fasteners can be weakened from extensive corrosion. Roof systems typically fail when winds produce forces greater than the roof’s strength. Winds can tear roof coverings from roof decks and can tear roof decks from framing. Roofs can also fail if punctured by wind-borne debris. In most cases, debris punctures are less of a problem on residential structures where the roof’s slope limits the amount of rain that can enter a puncture (unless the puncture occurs in a valley or other areas of the roof where water is channeled or collected). However, in buildings with flat or low sloped roofs, punctures from wind-borne debris can be devastating.

Roof systems (ranging from roof coverings to structural members) typically fail when winds produce forces greater than the capacity provided by the elements of the roof system. Winds can tear roof coverings from roof decks and can separate roof decks from framing. Roofs can also fail if punctured by windborne debris. In most cases, debris punctures pose less of a problem on residential structures, where a roof’s slope may limit the amount of rain that can enter a puncture (unless that puncture occurs in a valley or other area of the roof where water is channeled or collected). However, in buildings with flat or low sloped roofs, punctures from windborne debris can lead to extensive interior damage.

Historically, damage to roof coverings is the leading cause of building problems during hurricanes and other coastal storm events. High winds and windborne debris can damage the roof covering and rains that accompany those high winds can enter the building, soaking its contents and interior (Figures 8-1 and 8-2). After water enters a building, excess moisture becomes trapped within the building and mold can grow unchecked unless actions are taken quickly to secure and dry the building. Roof problems can occur in any area; in coastal environments that have higher wind speeds and greater potential for torrential rains, problems resulting from roof system damage and failures are more prevalent.



**Figure 8-1.**  
Instance where wind pressures exceeded the strength of the asphalt roofing. (Source: FEMA 549)

Roof systems can also fail if roof-mounted equipment is damaged or dislodged by high winds. During Hurricane Katrina, loss of mechanical equipment caused the majority of water damage that was observed in several buildings. In some of those buildings, structural roof damage itself was quite minimal yet the buildings experienced extensive water damage.



**Figure 8-2.**  
**GULFPORT, MISSISSIPPI:**  
Winds dislodged roof mounted equipment and created large openings in the roof system. (Source: FEMA 549)



There are many parameters to consider when good roof performance is desired. Although this process begins with the proper selection of the roof system for that particular environment, there are other important factors to consider, such as the roof covering, deck, ends, underlayment, flashing, and other components. Proper roof installation is achieved through experience and sound construction techniques, thorough inspections, and compliance with code requirements, standards, and manufacturer recommendations. Other steps can be taken to produce roofs that can perform better than code-mandated systems. Those steps, often called “best practices,” will be discussed in the following sections.

## 8.2 Roof Coverings – General Code Requirements

Building codes provide requirements for the design and installation of roof coverings. Roof coverings are addressed in Chapter 15 of the IBC and Chapter 9 of the IRC. Both codes provide requirements for roof coverings commonly used on high-sloped roofs (such as asphalt shingles, clay and concrete tile, wood shakes and shingles, and metal roofing) and for roof coverings typically used for low-slope applications (such as built-up roofing, thermoset single-ply roofing, thermoplastic single-ply roofing, sprayed polyurethane foam roofing, and liquid-applied coatings). Both codes also contain requirements for roof decks, underlayment, flashing, structural performance, and materials and testing criteria. Requirements for roof coverings installed in high-wind areas (i.e., where the basic wind speed is 110 mph or greater) are provided. Further, both codes contain provisions for re-roofing existing buildings, which will be discussed later in this chapter.

### NOTE

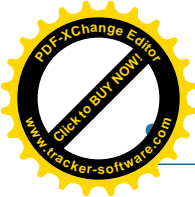
The FEMA MAT reports for hurricanes Charley (FEMA 488), Ivan (FEMA 489), and Katrina (FEMA 549), along with FEMA 499 provide extensive and updated examples of roof covering best practices originally presented by FEMA in the *Coastal Construction Manual* (FEMA 55).

Chapter 5 of SSTD 10 contains requirements for the installation of asphalt shingles and concrete roof tiles in high-wind areas. It is important to note that the requirements apply only to shingle and tile fastening and do not address underlayment, flashing, and other roof-covering components. Test standards such as ASTM D7158 are available to provide performance metrics for asphalt shingles. The new ICC-600 standard is the residential design standard for hurricane-resistant construction, replacing SSTD 10, and to reference the ASTM D7158 standard.

While the IRC is generally considered a prescriptive code, many of the roof-covering provisions are performance-based and mimic those contained in the IBC. The performance of more research has been recommended in recent FEMA MAT reports in order to understand and identify acceptable systems and appropriate (i.e., compliant) installation techniques for residential applications.

The technical nature of these roofing systems, and how they rely upon installation for code-compliance and warranty compliance, is often much more involved than other aspects of residential construction (such as wall and roof framing or foundation construction). The codes often rely upon the use of the manufacturer’s installation instructions to ensure proper installation. For many areas of construction, the codes state that “roof covering must be installed per the manufacturer’s installation instructions.” Instructions should be available onsite so that the proper installation of the roof covering can be achieved and verified. To facilitate the transfer of this information, it is common to see manufacturer’s installation requirements printed on the roof packaging itself.





## 8.2.1 IRC Roof Covering Requirements

**General.** The IRC addresses roof covering requirements in several areas. Fire resistance is covered in Section R902 and insulation is addressed in Section R906, but the majority of the requirements are presented in Section R903 and R904, which address weather protection and materials, respectively. Requirements for individual roof covering systems (e.g., asphalt shingles, clay or concrete tile, etc.) are listed in Section R905.

Load and pressure requirements are contained in Section R301. Section R301.2.1 requires that roof coverings resist the C&C loads listed in Table R301.2(2) as a function of basic wind speed and roof slope. Table R301.2(2) lists pressures for Exposure B conditions with mean roof heights of 30 feet or less. The pressures must be adjusted for other heights and exposures by factors listed in Table R301.2(3). This section provides the required loads that all components of a roof system (such as roof covering, roof deck, etc.) must be designed to resist the full C&C wind loads. Some exemptions exist for air permeable cladding and other roofing components, provided they have been certified by testing.

**Roof Decks and Underlayment.** The IRC generally requires roofing to be installed on continuous sheathing. Spaced sheathing is allowed for some metal roofing systems (specifically those listed for use on spaced sheathing) and for some wood and tile shingles (in areas where an ice barrier is not required). Building officials and builders should keep in mind that Chapter 9 of the IRC pertains to roof assemblies only and does not address structural system compliance for load-carrying systems such as diaphragms. While the use of spaced sheathing may be allowed beneath some roof covering systems, it may not satisfy structural diaphragm and bracing requirements contained elsewhere in the code. A conscious decision must also be made whether spaced sheathing is an appropriate system to use, based upon the roof slope.

When complying with the IRC, most roofing systems will require two layers of underlayment when the roof slope is between 2:12 and 4:12. Roof slopes greater than 4:12 require only one layer of underlayment. Underlayment in high-wind areas (i.e., where wind speeds are 110 mph or greater) must be secured with corrosion-resistant fasteners spaced no more than 36 inches apart.

As a best-practices approach, an augmented underlayment can provide an effective secondary roof barrier to reduce water penetration in the event that the primary roof is damaged by wind or windborne debris (see Figure 8-3). FEMA 499, Technical Fact Sheet No. 19: *Roof Underlayment for Asphalt Shingle Roofs*, provides guidance on improving the performance of roof systems by augmenting underlayment installations.

### NOTE

ASTM D 3161 tests samples of asphalt roofing shingles for exposure to high winds. This is accomplished by conditioning the samples (in order to seal their self-sealing strips) and then exposing them to an air stream. The conditioning involves heating the samples between 135° F and 140° F for 16 hours. After conditioning, the samples are cooled to between 70° F and 80° F and are then exposed to air-stream testing for 2 hours. The test involves blowing a stream of air across the test sample from three different directions. Shingles that restrain tabs from lifting, disengaging, or being torn loose pass the test.

ASTM D 3161 lists two types of asphalt shingles (Type I and Type II) and three wind speeds (Class A, D, and F). Type I shingles have self-sealing tabs; Type II shingles have interlocking tabs. Class A shingles pass the ASTM test with a simulated wind speed of 60 mph, Class D shingles pass the test at 90 mph, and Class F shingles pass at 110 mph. While the IRC requires that shingles needing special fastening be considered Class F, the ASTM standard itself does not contain special fastening methods.



Figure 8-3.

Example of an augmented underlayment installation that helps provide a secondary barrier against water intrusion during a storm event. (Source: FEMA 488)

**Asphalt Shingles.** The IRC permits the installation of asphalt shingles on continuous sheathing for roofs with slopes as low as 2:12. When this covering is installed on roofs sloped between 2:12 and 4:12, two layers of underlayment are required. Roofs with slopes greater than 4:12 require only one layer of underlayment. Section R301.2.1 requires that asphalt shingles be designed in accordance with Section R905.2.6, which permits asphalt shingles classified using ASTM D 3161 to be installed in areas with basic wind speeds below 110 mph. Areas with wind speeds of 110 mph or higher require “special fastening methods.” Special fastening is also required for roof pitches greater than 20:12. Special fastening requires shingles that are classified using ASTM 3161 be considered Class F. Recommendations on the required special fasteners should be attained through the shingle manufacturer.

ASTM D 7158 is a relatively new standard for certifying asphalt shingles with self-sealing strips for uplift resistance. The test combines physical testing (similar to wind-tunnel testing) and an analytical approach to determine wind speed resistance ratings. During certification, shingles are provided with pressure “taps” that allow pressure measurements to be taken at selected locations. The taps are provided to measure pressures at exposed portions of the shingle as well as concealed portions of the shingle (i.e., at the underlayment). Exposed and concealed taps are placed both above and below the self-sealing strip. The shingle assembly is then exposed to relatively low wind speeds (approximately 35 mph) and pressure measurements to determine external pressures (those above the shingle) and internal pressures (those at the underlayment). These low-speed tests provide “external” and “internal” pressure coefficients that are combined into an “uplift coefficient.” The coefficients are used to determine the uplift force that each shingle tab will experience for a given wind speed. The shingles are then mechanically tested to determine their tab’s resistance to uplift. Shingles with tabs strong enough to resist the factored uplift force for a given wind speed are certified for that wind speed by class. ASTM D 7158 lists three classes of shingles:

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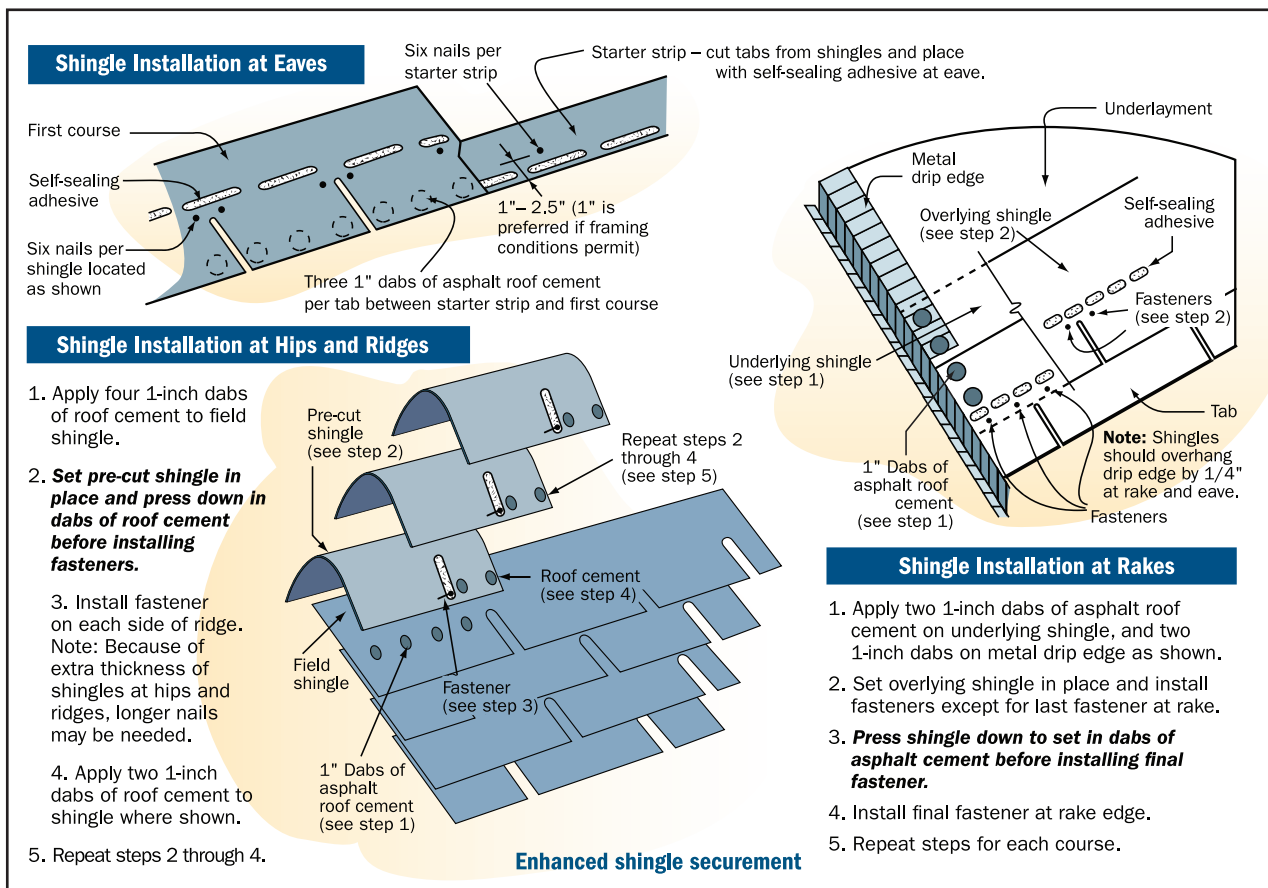
There are a few nuances of ASTM D 7158 that remain of interest to building officials, designers, and builders. These nuances include: building occupancy category (from ASCE 7-05 Table 1-1), topographic effects, and mean roof height. The tab uplift calculations used in ASTM D 7158 are appropriate for Category I and Category II buildings (i.e., non-critical and non-essential facilities) that are less than 60 feet tall and located in areas not exposed to topographic wind effects (i.e., the ASCE 7-05 Chapter 6 topographic effect factor  $K_{zt}$  equals 1.0). If asphalt shingles are to be used on Category III or Category IV buildings, buildings higher than 60 feet tall, or buildings exposed to topographic effects, the shingle certification must use higher uplift forces.

- Class D shingles pass tests with basic wind speeds up to and including 90 mph.
- Class G pass tests with basic wind speeds up to and including 120 mph.
- Class H pass tests with basic wind speeds up to and including 150 mph.

This new standard has yet to be referenced by the IRC or IBC, but is recognized by ICC-600. ASTM D 7158 cannot be used to certify Type II shingles (i.e., those with interlocking tabs). Type II shingles will need to be tested per current ASTM D 3161 tests.

As previously stated, manufacturer's installation instructions need to be followed to ensure proper installation and, in some instances, code compliance. Post-disaster MAT investigations have noted that two errors are often made in regard to the shingle installation technique. These two errors often result in the failure of the roof covering during high-wind events.

The first common installation error concerns the improper installation of the starter strip (see Figure 8-5). For proper bonding of the self-sealing strips, the starter course must be rotated 180 degrees and the tabs must be cut off. If the tabs are not removed, they will prevent the self-sealing strip from functioning. Figure 8-4 is an example of proper shingle installation methods.



**Figure 8-4.**  
**Example of proper shingle installation. (Source: FEMA 499)**



The second common installation error occurs when shingles are installed in vertical sections. While this method allows roofers to traverse back and forth across the roof less, it may not allow for all of the shingles to be properly nailed. The ends of shingles installed after the first “column” of shingles can likely not be nailed without meticulously lifting the tabs of shingles that have already been fastened. This procedure, called “raking,” has been identified by MAT investigations in numerous failures involving asphalt shingle roofs during high-wind events and is attributed to the shingles having been damaged and improperly nailed. Figure 8-6 demonstrates an example of shingle failure attributed to raking. An example of improper shingle installation is also shown in Figure 8-7.

FEMA 499, Technical Fact Sheet No. 20: *Asphalt Shingle Roofing for High-Wind Regions*, provides guidance on asphalt shingle installations. Many of the recommendations presented are similar to those described in the installation instructions provided by many manufacturers.



**Figure 8-5.**  
Roof failures that resulted from improper starter-strip installation.  
(Source: FEMA 549)



**Figure 8-6.**  
Roof failures that resulted from asphalt shingles being installed in a raking fashion. (Source: FEMA 489)



**Figure 8-7.**  
Loss of asphalt shingle roofing along hip. Best Practices approaches contained in Technical Fact Sheet No. 20 help prevent this mode of failure. (Source: FEMA 489)

**Clay and Concrete Tile Roofing.** The IRC permits the installation of concrete or clay tile on roofs with slopes as low as 21/2:12. Tile-roofing underlayment requirements are similar to asphalt roofing surfaces; two layers of underlayment are required for low-slope applications and additional fastening for the underlayment is needed for areas with basic wind speeds of 110 mph or greater. Section 905.3.7 requires clay and concrete roof tiles to be installed per manufacturer instructions when used in areas where the basic wind speed is 100 mph or greater and in all areas where the tiles are installed more than 40 feet above grade.

FEMA (and other entities that have conducted post-disaster investigations since Hurricane Andrew struck Florida in 1992) have noted that tile roof coverings have not performed well during several high-wind events. Although performance of these roof covering systems has improved since Hurricane Andrew (due largely to better design and construction guidance from the manufacturers), roof covering systems still frequently fail during hurricanes. The performance of mortar-set tile roof systems continues to be very dependent upon the quality of the installation. This installation method has consistently been observed during MAT investigations to not perform as well as other tile installation methods. Tiles also remain vulnerable to being damaged by windborne debris because they are considered brittle coverings. When clay or concrete tiles are impacted by windborne debris, they commonly break and leave the underlayment exposed to high-wind forces it was not designed or constructed to resist (see Figures 8-8 and 8-9). This condition has been observed to lead to a progressive failure of the roof covering across the roof surface. Also, once damaged, it is important to note that the tile shards can become airborne, adding debris to the wind field. This debris may cause damage to the building itself as well as damage to downwind buildings.



**Figure 8-8.**  
Clay tile roof failure. The tiles were dislodged due to inadequate anchorage. (Source: FEMA 549)

Adequate design, testing, and installation can significantly reduce the potential for tiles to be dislodged, but vulnerability to debris damage remains. FEMA 499, Technical Fact Sheet No. 21: *Tile Roofing for High-Wind Areas*, provides guidance for installing tile roofing systems within coastal areas.





Figure 8-9.  
Storm damage to a tile roof system.  
(Source: FEMA 488)

**Wood Shingles and Shakes.** Sections 905.7 and 905.8 contain the requirements for wood shingle and shake coverings. Roofing can be installed on solid or spaced sheathing, but solid sheathing is required where ice dams or low temperatures require an ice shield. Wood shake installations differ from wood shingle installations particularly in their underlayment and rake installations. Due to the irregular surface of wood shakes, an interlayment layer of 30-pound roofing felt is required to improve weather tightness. This interlayment layer is applied between each course.

The IRC does not contain prescriptive requirements for shingles and shakes used in high-wind regions. Although they are not specifically cited, shingles and shakes must satisfy the wind-loading requirements of Section R301.2.1. In order to verify proper installation techniques, users of these products should consult with the shingle or shake manufacturer or the Cedar Shake and Shingle Bureau for installation instructions required to satisfy the wind load requirements in areas where the basic wind speed exceeds 100 mph.

**Metal Shingles and Metal Roofing Panels.** Section R905.4 discusses metal roofing shingles and Section R905.10 covers metal roofing panels. The area exposed to weather distinguishes shingles from panels. Shingles offer less than 3 square feet of weather exposure per shingle; panels have exposures of 3 square feet or more.

Metal shingles and panels can be installed on solid sheathing, spaced sheathing, or purlins—except where the roof covering is designed for spaced supports. As previously stated, when roof coverings are installed upon decking that is not solid, the requirements of Chapter 9 of the IRC do not apply, as the IRC does not address roof diaphragms. Requirements for structural stability need to be checked for compliance with other portions of the code. For these systems, bracing will need to be installed to provide the code-required structural stability (described by engineers and designers as “diaphragm action”). An exception in the code is provided when the metal roof covering is designed to act as a structural diaphragm and when it is installed on spaced supports or spaced sheathing.



The IRC states that the minimum roof slope for metal shingles is 3:12. The minimum slope for metal panels depends upon the methods used to join the panels. Lapped, non-soldered panels have the same slope requirements as metal shingles and can be used on roof decks with slopes as low as 3:12. Lapped panels joined with an applied lap sealant can be used for slopes as low as 1:12. Standing-seam roofing can be used on roof surfaces with slopes as low as 1:12. Table R905.10.3(1) lists material requirements for metal roof panels (these requirements also apply to metal roof shingles).

The IBC does not include prescriptive fastening designs for metal shingles and metal roof panels. While the IRC does not specifically address the use of metal shingles and metal roof panels in high-wind areas, the manufacturer should be consulted to determine fastening and other installation requirements for basic wind speeds exceeding 100 mph. It is notable that MAT investigations from 1998 to 2008 continue to observe good performance of metal-panel roof systems.

**Roof Coverings for Low-Sloped (< 1:12) Roofs.** Modified bitumen roofing, thermoset, and thermoplastic single-ply are approved for nearly flat roofs. IRC Sections R905.11, R905.12, and R905.13 outline the requirements for these types of roof covering.

The requirements focus on material specifications and application of the roof covering. Modified bitumen membranes are typically fully adhered and, when installed on a properly constructed roof deck, can perform well during high-wind events. Single-ply systems, however, have been observed to perform poorly when exposed to high winds, particularly if these systems are not fully adhered. When used in areas where the basic wind speed exceeds 100 mph, single-ply systems should be fully adhered.

With all membrane systems, care must be taken along the edge and corner zones of the roof, where wind turbulence creates high localized uplift pressures. Post-event MAT assessments have determined that roofing failures commonly begin at the edges or corners of the roof, when insufficient attention is given to fastening, flashing, and coping.

### 8.2.2 IBC Roof Covering Requirements

The IBC requirements for roof coverings are similar to those included in the IRC. Like the IRC, much emphasis is given to weather protection. However, emphasis is also given to the fire ratings of roof coverings.

Section 1504.1 states that the roof coverings must be designed to resist the wind load requirements of Section 1504 and Chapter 16. Chapter 16 states that the wind load requirements for roof coverings unless specified otherwise are to comply with wind pressures based upon ASCE 7.

The requirements for installation of asphalt shingles in the IBC are the same requirements as those contained in the IRC. The IBC requirements are listed in Section 1540.1.1. Clay and concrete tiles are treated similarly but an alternative procedure for determining and certifying wind resistance is allowed by Section 1504.2. The alternative procedure is similar to the new procedures of ASTM D 7158, which are described earlier in this chapter and specified for self-sealing, asphalt shingles. Like the procedures of ASTM D 7158, the alternative procedure does not address critical or essential facilities and its applicability is limited to buildings 60 feet tall or lower.