Roof Damage Issues in Hurricanes

Timothy P. Marshall, P.E.*
Haag Engineering Company

1. INTRODUCTION

There are a number of issues that arise in assessing roof damage after a hurricane. Roofs can have inherent deficiencies due to manufacturing, installation, and weathering. There are also myths and misconceptions regarding how hurricanes affect roofing systems. Thus, distinguishing between hurricane damage and pre-existing damage can be controversial. This paper addresses several issues regarding the assessment of roof damage from the author's inspection of thousands of roofs after more than a dozen hurricanes since 1980.

In order to conduct an accurate assessment of roof damage, it is important to have knowledge of the various roofing materials, installation procedures, weathering effects, as well as an understanding of how wind forces affect roofs. The National Roofing Contractors Association (NRCA, 1996) has published a manual showing the installation procedures for a number of roof systems. Roof installation manuals are also available from various trade organizations such as the Asphalt Roofing Manufacturers Association (1997), the Cedar Shingle Bureau (2001), and the Roof Tile Institute (2002). Obviously, the performance of a roof during a hurricane depends greatly on the type of product and how well it was installed. McCampbell (1991) presents a number of cases citing specific problems with roof design and installation. McDonald and Smith (1990, 1994) found specific modes of failure with various roofing systems after Hurricanes Hugo and Andrew.

2. ROOF STRUCTURE/DECK DEFICIENCIES

The roof structure must be capable of supporting dead loads from the weight of the roof as well as live loads from people walking on the roof, snow, and code-specified wind forces. However, the author has found many deficiencies with wood frame roof structures including inadequate bracing, poor joinery, absence of deck clips, and deck fasteners that missed the rafters. These deficiencies often are discovered after the storm and erroneously attributed to high winds, low barometric pressure, etc. Refer to Figure 1.

*_Corresponding author address:_ Timothy P. Marshall, Haag Engineering Co., 2455 S. McIver Dr., Carrollton, TX 75006. Email: timpmarshall@cs.com

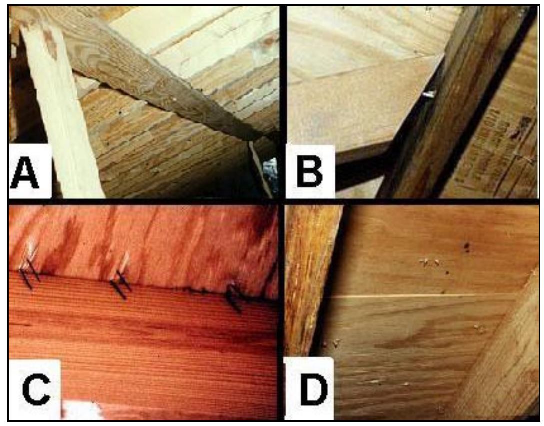

Figure 1. Inherent deficiencies in roof construction not related to wind: A) sagging of rafters due to inadequate support, B) gap between rafter and ridge beam from poor joinery, C) deck staples that missed the rafter, and D) wavy roof deck from lack of clips.

Wind flowing over a roof creates lift similar to that on an airplane wing. The lifting forces are not uniform but are greatest at windward edges, corners, eaves, and rakes. Thus it is not surprising to find that roof damage initiates at these locations. Additional uplift can occur to the roof if there is a breach on a windward side of the building causing internal positive pressures. Therefore, the roof structure must be anchored properly to the walls to resist wind uplift and braced to other trusses to transfer lateral loads. The author has observed numerous failures of gable ends on houses that resulted from the lack of lateral support and poor attachment of the roof deck, leading to substantial interior damage from water entry. Refer to Figure 2.

Figure 2. Examples of wind damage to the roof structure: A) removal of decking, B) failure of gable end, C) rotation of trusses, and D) shifting of a roof due to tree impact.

3. ASPHALT SHINGLE DAMAGE

Asphalt shingles are composed of a mat material that is either paper (organic) or glass-fiber (inorganic). The mat is saturated with an asphaltic mixture and topped with granules. Roof shingles come in a variety of shapes, sizes, and patterns including three-tab, strip, and dimensional, and they are fastened to the roof deck with nails or staples. It is important that the fasteners be installed properly and placed in the correct positions in order to achieve the greatest wind resistance.

As asphalt shingles age, the asphalt breaks down. The extent of aging depends upon many factors including the quality of the asphalt, shingle color, roof pitch, slope direction, and amount of attic ventilation. Common deficiencies inherent with aged asphalt shingles are blistering, flaking, cupping, clawing, and general granule loss. Refer to Figures 3 and 4. In many instances, these anomalies are not discovered until after the hurricane, however, this does not mean they were created or even aggravated by the storm.

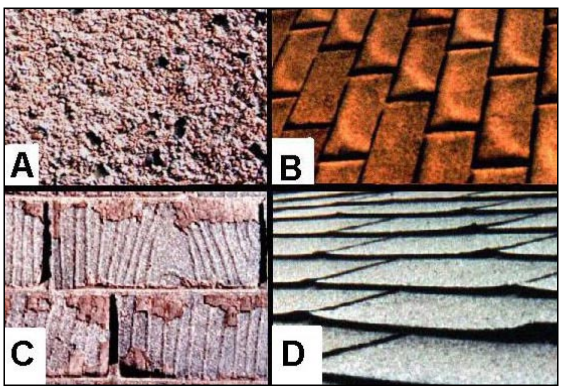

Figure 3. Asphalt shingle deficiencies not due to hurricane effects: A) blisters, B) clawing, C) granule flaking, and D) edge cupping.

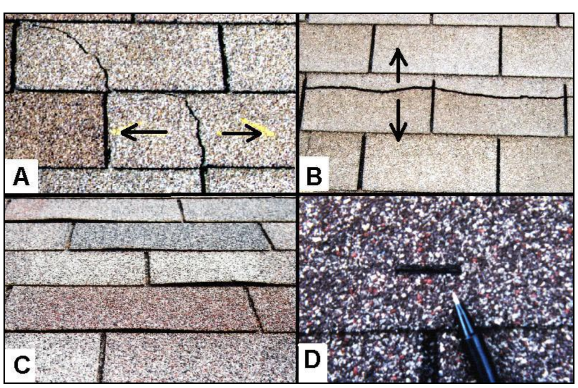

Figure 4. Additional shingle deficiencies not caused by hurricane effects: A) diagonal splitting, B) horizontal splitting, C) shingle buckling, and D) elevated or protruding fasteners.

Shingle blisters result from poor quality asphalt combined with excessive heat. Granule flaking stems from asphalt shrinkage and subsequent delamination from the mat. Cupping and clawing occurs from asphalt shrinkage on the top and bottom surfaces of the shingles, respectively. Diagonal and horizontal splitting results from asphalt shrinkage and low tensile strength of the mat. Elevated fasteners occur during the installation of the shingles and can buckle or protrude through the overlying shingles. None of these conditions are caused or aggravated by hurricane effects. In addition, the salt spray blown around by a hurricane is not detrimental to the asphalt.

Asphalt shingles are not damaged by granule loss from a hurricane. The quantity of granules lost from wind or rain during the storm is a very small fraction of the total amount of granules on the shingles and within normal tolerances. Generally, about one-third the weight of an asphalt shingle is granules such that the average residential roof has more than one ton of granules. Granule loss is expected from the moment shingles are manufactured, shipped, installed, and during the weathering process. Thus, more granules are initially placed on the shingles than are needed to cover the mat.

An asphalt shingle roof can leak water during a hurricane. Many steep roof coverings like asphalt shingles simply shed water and are not waterproof. As a result, wind-driven rain can be forced beneath the shingles and flashings causing interior damage without damaging the roof covering.

Wind uplift tends to remove asphalt shingles from the roof. This can lead to a combination of disbonding, creasing, and displacement of the shingles. Refer to Figure 5. Fasteners secured to the roof deck are usually stronger than the shingle. Therefore, shingles removed from a roof during high winds typically leave the fasteners in the roof deck. Windward eaves, corners, ridges, and rakes are the most susceptible areas for wind damage because of higher uplift pressures in these regions.

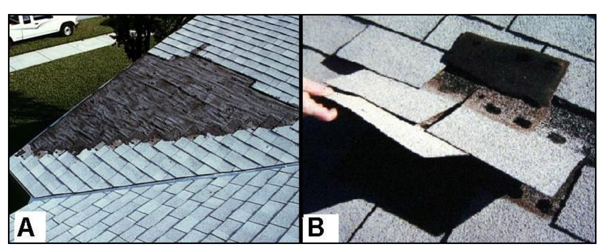

Figure 5. Wind damage to an asphalt shingle roof: A) shingles removed from windward rake, and B) shingles displaced from windward roof slope.

4. WOOD SHINGLE/SHAKE DAMAGE

Wood shingles and shakes usually are cut from Western Red Cedar trees. The roofing material comes in various grades and is nailed or stapled to the roof deck. Cedar shakes are cut thicker than shingles and are interlaced with roofing felt.

Wood shingles and shakes split and erode as they age. This is why the product is installed in layers only about one-third its length. Wood with distorted grain can cup and curl. Eventually, the metal fasteners corrode and wood pieces shed downslope. Fasteners should be hidden from the weather, otherwise the exposed fasteners can protrude from the wood when the wood swells when wetted. Therefore, wood roofs tend to require more maintenance than asphalt shingle roofs. Refer to Figure 6.

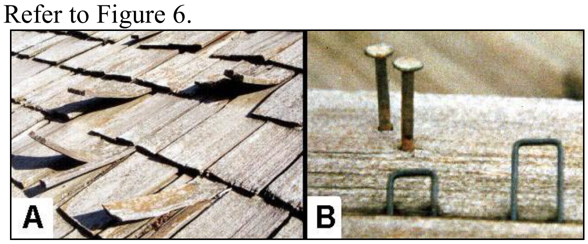

Figure 6. Wood roof deficiencies not caused by hurricane effects: A) weathered splitting and cupping, and B) rusting, protruding fasteners.

Hurricane winds can dislodge or remove wood shingles and shakes especially if the roofs are weathered. Windward eaves, corners, ridges, and rakes are the most susceptible areas for wind damage. Recently displaced shingles or shakes leave unweathered areas on the underlying wood. Freshly exposed wood usually turns grey (oxidizes) within six to twelve months of exposure to the weather. Refer to Figure 7.

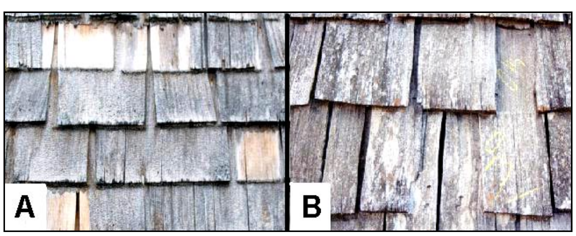

Figure 7. Wind damage to wood roofs: A) recent damage, B) old damage.

5. TILE ROOF DAMAGE

Roofing tiles are made from clay or concrete and come in various profiles, most commonly: flat, S-shaped, or barrel shaped. Tiles usually are anchored to the roof by fasteners or adhesive. However, in some areas of the country the tiles are attached with mortar patties. The author has found the mortar attachment method inadequate to resist the strong uplift winds during hurricanes. Tiles have had an insufficient amount of mortar to secure them to the roof. Also, mortar generally does not bond well to the tiles unless the tiles are initially wetted. As a result, the roof tiles either separate from the mortar or tear the underlayment when displaced by the wind.

There are certain crack patterns in tiles not caused by wind. A single horizontal crack extending across the middle of the tile occurs when persons walk improperly across the roof. It is important to step near the bottom edge of the tile where the tile bears against the underlying tile. Some tile roofs are simply too brittle to walk on without the use of a "chicken" ladder.

Single, curved fractures on the right corners of interlocking concrete tiles are due to lateral expansion of the tile and can be aggravated by foot traffic. Proper installation of the tile is crucial to reduce corner cracking. Tiles should be installed with maximum clearance and with straight joints to avoid uneven bearing against the adjacent tiles.

Clay tiles are prone to pitting and spalling due to freeze-thaw effects especially if they are soft and deteriorated. The small voids absorb moisture that expands during freezing conditions. Occasionally, rough areas or gouges are formed on tile surfaces when tiles are manufactured. Refer to Figure 8.

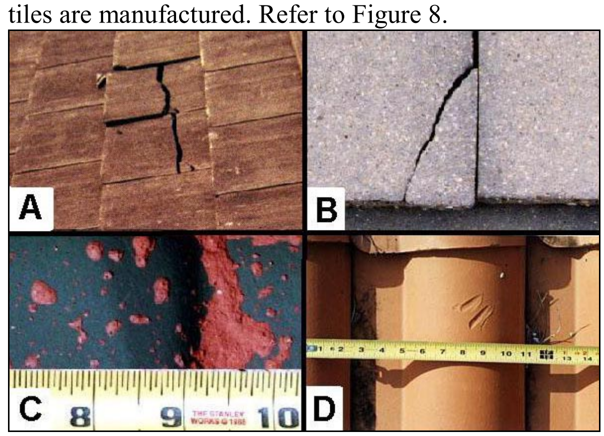

Figure 8. Tile damage not caused by a hurricane: A) foot broken tiles, B) right corner cracks from thermal expansion, C) pitting and erosion, D) manufacturing defect.

Wind damage to a tile roof typically begins with the removal of ridge and rake tiles especially where they are not well anchored. Field tiles are susceptible to being displaced along windward eaves, rakes, and corners. Refer to Figure 9. Tiles that are not fastened or bonded to the roof are most prone to being uplifted by wind. Wind does not just unbond the tiles and leave them in place, as loose tiles would become displaced.

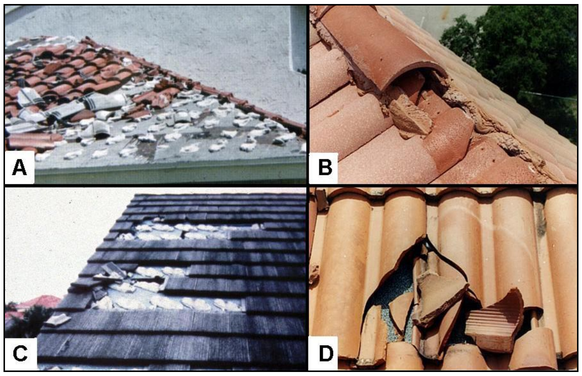

Figure 9. Wind damage to tile roofs: A) at a roof corner, B) at a ridge, C) at a rake, and D) from the impact of other tiles.

6. BUILT-UP ROOF DAMAGE

Built-up roofs are comprised of overlapping layers of rolled roofing felt bonded together with asphalt. Sometimes the built-up roof is flooded with asphalt and covered with rock or coated with aluminum paint. Roofing membranes are three feet wide and usually applied with 11-inch (three-ply) or 17-inch (two-ply) exposures between side edges. There are a number of deficiencies that can occur during the installation of a built-up roof. Refer to Figure 10.

It is important to keep the roofing membrane straight to avoid wrinkles. Asphalt must be applied solidly between each membrane layer to develop a monolithic structure. Membrane blisters are common with built-up roofs. The blisters form between or underneath the membrane when there is a void of entrapped air and water vapor that expands when heated. The void is created during installation of the roof when not enough asphalt was applied between the roofing membranes, or when the membranes simply were not bonded together because the interply asphalt had boiled or cooled. Korhonen and Charest (1995) indicate that blisters grow from breathing action driven by thermal cycling. Hurricane winds and low barometric pressure effects do not cause or aggravate membrane wrinkles or blisters.

Heavily applied areas of asphalt will slowly shrink and undergo craze cracking or "alligatoring" as volatile components of the asphalt evaporate or are washed away by periodic rains. Hurricane effects do not cause asphalt alligatoring.

Occasionally, deficiencies are found in parapet flashings. Vertical gaps in membrane seams are usually the result of poor installation. Horizontal gaps occur from shrinkage and long term expansion and contraction effects between the roof and parapet.

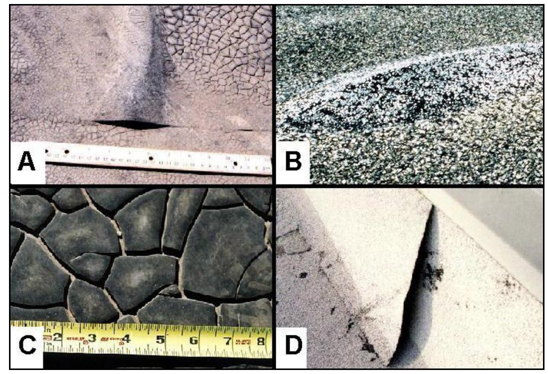

Figure 10. Built-up roof deficiencies not caused by hurricane effects: A) wrinkled felt, B) blisters, C) alligatoring, and D) poorly applied parapet flashing.

Wind damage to a built-up roof typically initiates at the windward roof edge when metal flashing is uplifted. Once the flashing has been compromised, it is easier for the damage to progress into the field of the roof. Built-up roofs with loose gravel can be subjected to scouring effects especially along the windward roof edges or corners. Refer to Figure 11. Wardlaw and Kind (1984) have conducted wind tunnel tests and found that roof gravel can be displaced in winds as little as 60 mph when there is no parapet.

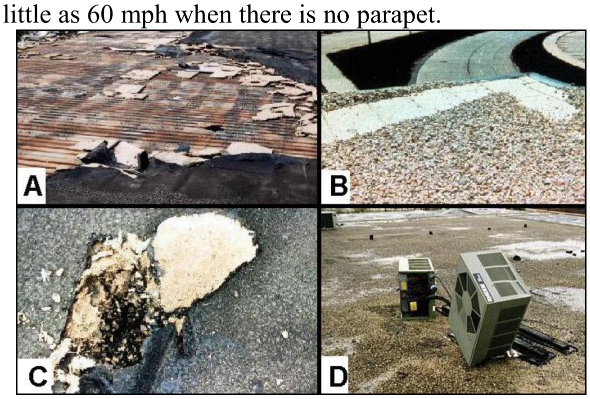

Figure 11. Wind damage to built-up roofs: A) displacement of membrane and insulation, B) scouring of loose gravel, C) impact by flying debris, and D) flipped air conditioners.

7. REPAIRABILITY

Another issue has to do with the repairability of the roof damage caused by a hurricane. Roof repairability depends on a number of factors including the extent of damage to the roof as well as roof age and condition along with availability of materials. Marshall and Herzog (1999) have developed a procedure by which to calculate the repair cost of a roof if the damage is not too severe.

8. REFERENCES (available upon request)