

A satellite image of Hurricane Irma, showing its characteristic eye and spiral cloud bands. The hurricane is positioned over the Caribbean Sea, moving westward toward the coast of Cuba. The surrounding ocean is a deep blue, and the clouds are white and dense.

From Hurricanes Andrew to Michael:

Lessons Learned for Residential Roofing

By Michael Fischer

Figure 1 – Hurricane Irma moves westward toward Cuba on September 8, 2017. Courtesy of NOAA.

OVERVIEW

Hurricanes Irma (2017) and Michael (2018) left wide paths of destruction, especially in Florida, where Irma crossed directly over the Florida Keys and Michael made landfall in the Florida Panhandle. The storms combined to account for property losses of more than \$100 billion, which were partly attributed to damaged roof systems and accessories and the resultant water damage to structures and contents. The aftermath of the storms afforded opportunities to assess building performance and identify ways to improve construction methods and materials to reduce losses from future storms. The U.S. Federal Emergency Management Agency (FEMA) deployed Mitigation Assessment Teams (MATs) to investigate the effects of the wind, rain, and storm surge on buildings.

FEMA has released findings from Irma and recovery advisories from Michael. The FEMA MAT report for Hurricane Michael is being drafted and will add to the literature, providing additional data that can lead to continued improvements in construction methods. The FEMA publications, along with reports from other research efforts, provide significant information on how to improve roofing performance and resistance to damage from tropical storms and hurricanes.

HISTORY OF POST-DISASTER FINDINGS

The Asphalt Roofing Manufacturers Association (ARMA) has participated in field assessments with FEMA, the Insurance Institute for Business & Home Safety (IBHS), and the Roofing Industry Committee on Weather Issues (RICOWI) to lend professional assistance on asphalt roofing standards and product details. For roofing and other building products, field observations following significant wind events—including tropical storms and tornadoes—have been providing recommendations for new product development and enhanced product installation techniques for decades.

FEMA field investigations provide unique opportunities to look at failure modes, assess product performance and installation methods, and identify successful strategies. The IBHS and RICOWI have also led post-hurricane investigations; these efforts parallel research conducted by institutions such as the University of Florida. The availability of multiple investigations from differing perspectives, conducted in different areas hit by storms and at different time periods within the rebuilding process, provides complementary data to support consensus in recommendations to improve performance in future events. More importantly, the consensus findings help shape

work on product standards, installation and construction practices, and building code requirements. In fact, multiple code changes have resulted from hurricane investigations. This is a proven way to turn lessons learned into better buildings.

The FEMA MAT report from Hurricane Andrew, which devastated South Florida in 1992, included observations on roofing that bear little resemblance to today's shingle installation methods. The report noted that structures with minimal roof covering loss suffered from the penetration of wind-driven rain into the building interior, which "resulted in additional costly damage to the interiors and contents."

The Hurricane Andrew MAT report also addressed roof covering attachment. The report cited observed inadequacies in product and workmanship, noting torn and inadequately attached shingles and calling out staple quantity, location, and even orientation as contributing to shingle loss. Additionally, the report mentioned inadequate shingle strength and fastener pull-through resistance, as well as insufficient adhesive bonding strength.

The report also included a lengthy list of general and specific recommendations to improve building performance. Many of those recommendations resulted in the

development of more wind-resistant products, including windows, doors, garage doors, and roof cladding. The general recommendations called for attention to workmanship, enhanced building codes, and improved building inspections, including enlisting structural engineers or licensed design professionals for field inspections. The report also recommended that composition (asphalt) shingles be “manufactured and rated as satisfactory for high-wind areas,” as well as suggesting the installation of a water-resistant membrane to protect the structure from water penetration damage resulting with the loss of roof covering.

The observations and recommendations from the Andrew MAT report established the baseline for what have become common themes after subsequent storms: designing asphalt shingles to resist high winds with appropriate fastening and adhesives, ensuring that the shingles are properly attached to the roof deck, and utilizing enhanced underlayments to add a redundant layer of protection in the event of shingle loss.

Field investigations from post-Andrew storms—whether conducted by FEMA, RICOWI, IBHS, or others—have continued to highlight similar findings. For example, the FEMA MAT summary from Hurricane Katrina (2005) noted concerns about roof covering losses. In contrast to the Andrew findings, however, the team noted that the age of the product and the design standards in effect at the time of installation likely impacted the performance during Katrina.

This finding is especially significant due to the development of a new wind-resistant standard for asphalt shingles at ASTM International after Hurricane Andrew. ASTM D7158 was first published in 2005 and was subsequently adopted into the 2009 International Residential Code and the International Building Code. The ASTM standard, titled *Standard Test Method for Wind Resistance of Asphalt Shingles (Uplift Force/Uplift Resistance Method)*, shifted the evaluation of asphalt shingles from exposure to wind generated by a fan (using ASTM D3161) to this newer method that evaluates the uplift force resistance of asphalt shingle tabs using mechanical tests.

The intent of the test is to establish baseline uplift resistance of the shingle using the sealant bond, which plays a critical role in wind resistance of the shingle itself. It is noteworthy that the ASTM D7158 methodology approach is consistent with the Andrew MAT report findings, which mentioned adhe-

sive failure as a contributing factor in shingle loss. ASTM D7158 was not required by the building code in 2005, but the product research that led to its development likely contributed to improved performance of asphalt shingles prior to code adoption as manufacturers began to voluntarily test products.

The Katrina report also cited damage to roof accessories, including edge flashing, coping, and gutter systems, specifically noting the lack of appropriate test standards for these types of products. The detailed recommendations for asphalt shingles included, “Ensure manufacturers’ installation instructions are followed (i.e., starter strips and nail locations).”

The RICOWI investigation into Katrina damage was consistent with FEMA on the issues of improved codes and attention to installation methods, stating, “The main lesson learned in the Katrina investigation appears to be that roofs designed and detailed according to current codes and standards will perform satisfactorily. Older roofs constructed with little concern for the magnitude of the wind pressures at eaves and corners, and roofs installed with poor practices that lead to progressive failure of the roof membrane, were consistently the ones with significant damage.”

These findings from Katrina are consistent with data released from IBHS a year earlier after Hurricane Charley struck Southwest Florida. The IBHS summary of Charley, titled *The Benefits of Modern Wind-Resistant Building Codes on Hurricane Claim Frequency and Severity – A Summary Report*, was released in 2004. The detailed findings in this report were possible due to the permit data available from Charlotte County in Florida. By linking the storm path to permitting activity, IBHS was able to provide correlative data not available after any other event. The findings on roof coverings show how newer codes contribute to improved performance.

The IBHS report states that claims from homes constructed between 1996 and 2004 resulted in 44% fewer roof covering replacements compared to homes built prior to 1996, when construction under the SBCCI SSTD-10, *Standard for Hurricane-resistant Construction*, was implemented in Charlotte County and was followed by the development of the 2001 Florida Building Code. The report noted that homes built during this period most often required only partial roof replacements, compared to complete

replacements more common for homes built earlier. The effective date of the 2001 Florida Building Code was in mid-2002; that timeline was noted in the IBHS report as a key factor in roofing performance, as well as performance of garage doors and windows.

Hurricane Charley was part of the 2004 Atlantic hurricane season, which saw Florida struck by four storms: Charley, Frances, Ivan, and Jeanne. The combined impacts from these storms wreaked havoc in the Sunshine State—particularly in South Central Florida—where the paths of Charley, Frances, and Jeanne hit some of the same areas. Ivan made landfall in the western Florida Panhandle, thus sparing the main Florida peninsula from a fourth hit. The timing of Frances, Charley, and Jeanne made field assessments more difficult, because it was not always possible to determine which storm was responsible for the initial damage when some homes were hit by two or even three hurricanes.

Because of the overlapping damage from the 2004 season, FEMA issued the *Summary Report on Building Performance, 2004 Hurricane Season*, combining observations and recommendations from all four events and allowing for a more meaningful opportunity to look for potential improvements in building performance. The primary observations in the 2004 report addressed roof covering and soffit performance, as well as window and door failures. The report noted that roof covering loss allowed water to enter the building interior and, in some cases, led to structural damage; and that when soffit attachment failed at roof overhangs, “significant amounts of wind-driven rain” entered buildings that were otherwise undamaged.

In addition to building damage, the report highlighted successes and echoed the IBHS analysis of Charlotte County roofing data regarding newer construction codes:

Where design level winds were experienced, current building code provisions appeared to adequately address the design of the structural building systems, as there was overall little wind damage to these systems except to older buildings which were not constructed to current code.

The report also included dual impacts from fenestration damage—the water intrusion through failure of windows and doors, and the internal pressurization that resulted from broken windows and doors. That

pressurization can lead to catastrophic damage, including loss of roof decks. Interestingly, this phenomenon was noted in FEMA's Hurricane Andrew report; failure of garage doors was cited as a key factor in envelope breaches that caused blowoff of roof decks from internal pressure.

The performance of newer asphalt shingles was characterized as improved:

Although damage was observed on several new roofs, asphalt shingles installed within the past few years generally appeared to perform better than shingles installed prior to the mid-1990s. This was likely due to product improvements (adhesives) and less degradation of physical properties due to decreased weathering. On roofs with damaged shingles, almost all the shingle fasteners were located too high on the shingle.

FEMA thus captured two key takeaways in the 2004 report: improved performance based on new codes and changes in adhesives, and the importance of proper fastener location.

HURRICANE IRMA

Hurricane Irma struck the Florida Keys at 1 p.m. on September 10, 2017, making landfall at Cudjoe Key before crossing into the Gulf of Mexico and into Florida at Marco Island. At landfall, Irma was a Category 4 storm, with wind speeds in excess of 130 mph. Irma had a large wind field; gale-force winds extended to a diameter of 220 miles. The loss of life and property from Irma was catastrophic, with almost 100 deaths and over \$50 billion in damage attributed to the storm in the U.S. and its possessions alone. Irma was well organized, and its intensity at landfall was partially due to its track; as Irma crossed the Caribbean, it impacted the Leeward Islands, the British Virgin Islands, the southern Bahamas (Figure 1), and Cuba before turning to the north and the Florida Straits.

Despite the high winds and the large area of exposure, Irma was not a design-level event approaching the wind speeds in the Florida Building Code. Because the Florida Keys are accessible by land only by using U.S. 1, and due to the tremendous amount of debris that closed portions of the highway after the storm, the FEMA MAT deployment was delayed. A preliminary MAT was able to perform an initial assess-

ment 12 days after the storm, but it wasn't until December—three months after landfall—that the full MAT could conduct their investigation. The report noted that many damaged roofs were either covered in tarps or had already been repaired or replaced, making a complete assessment difficult.

HURRICANE IRMA OBSERVATIONS

The MAT was able to observe damage from a variety of roof covering systems, including asphalt shingles, metal panels, and concrete and clay roof tiles. The obser-

vations described varying levels of damage, but did not assess the market penetration of any specific roof covering in order to provide a weighted analysis of the damage likelihood based on material type. There were some common damage modes across all roof coverings, notably hip and ridge areas (Figures 2 and 3), edge and fascia details at rakes and eaves, and soffit loss. Soffit performance was not directly related to the type of roof covering, but is noted here because soffit failure can be connected directly to fascia materials at roof eaves.

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Figure 2 – Hip damage to tile roof. Courtesy of ARMA.



Figure 3 – Hip and ridge damage to asphalt shingle roof. Courtesy of ARMA.

On one noteworthy project, the installation of an architectural standing-seam panel roof on a convenience store was underway (Figure 4). This roof replacement project included new decking, as well as metal panels; it appeared during a visual inspection from floor level that the roof deck and panel attachment were not compliant with the Florida Building Code, based on the lack of fastener penetration through the wood deck.

HURRICANE IRMA RECOMMENDATIONS

The general recommendations in the Irma MAT report suggest that industry groups should study the causes of asphalt shingle roof covering losses in new construction. The report highlights the fact that Irma was a below-design-level event, showcasing the need to more thoroughly assess installed product performance. The recommendations bring roofing contractors and building inspectors into the mix, emphasizing

the need for proper installation, verified by roof installation inspections, for reroofing projects.

PROPOSED MONROE COUNTY ORDINANCE

In response to concerns about damaged roofs, the Monroe County Board of Commissioners considered an ordinance requiring all roofs installed in the county to be made of metal. The industry responded in public testimony by discussing the need for a more thorough assessment of roofing performance and product installation, as well as field inspections conducted by building department personnel.

Under Florida law, the Florida Building Commission is responsible for the evaluation of local amendments to the statewide code, and the law sets standards by which local amendments can be made. Those standards prohibit local ordinances that favor one product type over another, and require that performance requirements, such as wind or fire ratings, establish appropriate levels of code compliance. While the proposed Monroe County ordinance ultimately did not go forward, the response of a local government to perceived weaknesses in the code, and in product performance, should be noted.

HURRICANE MICHAEL

Hurricane Michael, which struck the Florida Panhandle in October of 2018, was the first Category 5 storm to make landfall in the U.S. since Andrew in 1992. Michael hit peak wind speeds of 160 mph just prior to landfall in Mexico Beach, Florida, and is the fourth strongest tropical cyclone to strike the U.S., falling right behind Andrew. In 2019, the National Hurricane Center reported that the total death toll from Hurricane Michael in Florida alone was 50.

The FEMA MAT deployed in the Florida Panhandle 88 days after landfall. During the intervening time, many structures had been repaired; many others were tarped and awaiting roof repair or replacement.

HURRICANE MICHAEL OBSERVATIONS

The FEMA MAT noted significant performance differences between structures built prior to and after the adoption of the Florida Building Code. In fact, the team was able to investigate the performance of homes built to different codes and located in the same neighborhoods, where they would be exposed to very similar wind, rain, and storm surge conditions. This provided the team with a unique opportunity to assess differences in construction methods and



Figure 4 – Damaged architectural standing-seam roof on convenience store.

look for best practices.

Despite the improved structural performance noted by FEMA after Michael, roof coverings from older as well as newer installations exhibited damage. As with Irma, damage to hip and ridge shingles and ridge vents appeared to be widespread; these observations are not unexpected due to higher pressures typically generated at these locations on roofs during wind events. Because the roof decks at ridge vents are installed with a gap, loss of the roof covering at these locations can provide an easier point of entry for water.

While many damaged roofs had already been replaced prior to the MAT deployments, a significant amount of debris, including roof coverings that had either blown off the roof or been removed during reroofing, remained

in the areas. By examining the debris, the team was able to identify some significant issues related to product installation.

The examination of asphalt shingles in the debris pile highlighted two areas of concern from FEMA's perspective; the first is a widespread occurrence of improperly located fasteners (Figure 5). If nails are not properly located, the shingle is unlikely to perform as intended. The Florida Building Code requires that the shingles be installed in accordance with the manufacturer's installation instructions. The second observation is the absence of roofing cement on hip and ridge shingles in the debris pile. While this application method is not required outside of the High-Velocity Hurricane Zone (HVHZ) in Florida, FEMA recommends its use.

HURRICANE MICHAEL RECOMMENDATIONS

The Hurricane Michael MAT report has not yet been released and is still in draft form, but FEMA has released a Recovery Advisory titled "Best Practices for Minimizing Wind and Water Infiltration Damage." The Recovery Advisory includes the following:

- There was widespread wind damage to enclosure components (roof coverings, wall coverings, roof ventilation components, and windows and doors) that 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



Figure 5 – Damaged asphalt shingle showing incorrect fastener location. Courtesy of ARMA.



Figure 6 – Reroofing project using fully adhered underlayment. Courtesy of ARMA.

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 great deal 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.

The recommendations arising from the Hurricane Michael MAT report will likely echo those from Hurricane Irma, and they suggest that additional study should


be undertaken by building experts and the industry to address opportunities to improve performance of installed roof coverings. One of the recent efforts to strengthen codes has been the introduction of a secondary water barrier under the roof covering through the use of double layers of underlayments, or by employing a sealed roof deck. Applying a layer of self-adhered underlayment on the entire deck (Figure 6) can help reduce water penetration if the roof covering is compromised.

CLOSING

ARMA will continue to collaborate with FEMA, IIBEC, the National Roofing Contractors Association (NRCA), the Florida Roofing and Sheet Metal Association (FRSA), and IBHS to seek ways to improve roofing performance. ARMA supports efforts to increase the number and effectiveness of field inspections of new roof systems by building departments and independent inspectors, as well as enhanced training of

roofers through programs being developed by NRCA.

On the codes and standards front, ARMA has collaborated with all interested parties, including IBHS, on myriad issues related to asphalt shingle performance, including underlayment attachment, sealed roof deck provisions, updates to the HVHZ protocols, and improvements to the requirements for reroofing in existing buildings.

Considering the evolution of post-disaster investigations from Hurricane Andrew through Hurricane Michael, the emphasis has clearly shifted from the development of product test standards to a focus on enhanced underlayment application, proper shingle attachment, and appropriate verification of the installed system by building inspectors and roof observers. ARMA remains committed to participating in discussions with all stakeholders and helping reduce future losses from high wind events. 



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than 35 years, holding executive positions in association leadership, regulatory affairs, sales, and marketing. His involvement in codes, standards, and legislative and regulatory affairs within the industry provides a comprehensive background to deliver responsible advocacy and leadership for his clients.

WALMART SUES TESLA OVER ROOFTOP FIRES

Walmart filed suit August 20 against Tesla Energy Operations for breach of contract, gross negligence, and failure to live up to industry standards. The suit alleges that seven rooftop fires between 2012 and 2018 at Walmart's stores were the result of problems with solar panels installed by Solar City, a company that is now owned by Tesla. The panels were disconnected by Tesla in 2018 at Walmart's insistence, but an additional fire occurred thereafter. Tesla purchased SolarCity in 2016 for around \$2.6 billion. Walmart has more than 240 stores with Tesla solar systems.

Tesla is now offering rental of its solar rooftop systems without a contract. A \$1,500 fee is charged to remove panels and restore the customer's roof if the rental is cancelled.

— CNBC