PERSPECTIVES

A Guide to Wind Versus Water Assessments for Property Damage Claims

Our perspectives feature the viewpoints of our subject matter experts on current topics and emerging trends.

INTRODUCTION

Since 2016, the United States has had at least one landfalling hurricane each year and a total of 19 landfalling hurricanes. According to the Insurance Information Institute, five of the top 10 costliest hurricanes have occurred in the past five years:

- #2 Hurricane Ida (2021)
- #4 Hurricane Harvey (2017)
- #5 Hurricane Irma (2017)
- #6 Hurricane Maria (2017)
- #10 Hurricane Michael (2018)

Property damage incurred by hurricanes occurs because of forces from wind, water, or a combination of both perils. While the source of water damage can be from overland flooding or precipitation that enters a building prior to accumulating on land, for the purpose of this publication, "water" damage will refer to property damage occurring as a result of flooding, including coastal (from the ocean), riverine (from a river), and pluvial (from precipitation) flooding.

In the aftermath of hurricanes, being able to determine whether damage to a structure was a result of wind or water is paramount, largely due to the way in which properties are insured. Typically, standard property insurance policies cover damage incurred by wind and provide an exclusion for damage resulting from flooding, and separate flood-specific insurance policies cover properties from damage due to flooding. As is the case for many coastal properties, hurricane damage can result in a combination of damage from both perils; therefore, damage is best categorized through extensive on-site investigations. The following information may be of particular interest to forensic engineers, design professionals, insurance industry personnel, building code officials, floodplain managers, and emergency managers.

UNDERSTANDING HURRICANE WIND DAMAGE

Hurricanes are tropical systems of low-pressure that rotate in a counterclockwise manner around a central eye and produce sustained wind speeds of at least 74 miles per hour (mph). Hurricanes are classified by the Saffir-Simpson scale, which is based upon the measured sustained wind speeds produced by a storm. The following table provides the range of wind speeds and typical damage from each hurricane category.[1]

CATEGORY	SUSTAINED WINDS	TYPES OF DAMAGE DUE TO HURRICANE WINDS
1	74-95 mph	Very dangerous winds will produce some damage: Well-constructed frame homes could have damage to roof, shingles, vinyl siding and gutters. Large branches of trees will snap and shalowly rooted trees may be toppled. Extensive damage to power lines and poles likely will result in power outages that could last a few to several days.
2	96-110 mph	Extremely dangerous winds will cause extensive damage: Well-constructed frame homes could sustain major roof and siding damage. Many shallowly rooted trees will be snapped or uprooted and block numerous roads. Near-total power loss is expected with outages that could last from several days to weeks.
3 (Major)	111-129 mph	Devastating damage will occur: Well-built framed homes may incur major damage or removal of roof decking and gable ends. Many trees will be snapped or uprooted, blocking numerous roads. Electricity and water will be unavailable for several days to weeks after the storm passes.

[1] National Hurricane Center website, https://www.nhc.noaa.gov/aboutsshws.php

CATEGORY	SUSTAINED WINDS	TYPES OF DAMAGE DUE TO HURRICANE WINDS
4 (Major)	130-156 mph	Catastrophic damage will occur: Well-built framed homes can sustain severe damage with loss of most of the roof structure and/or some exterior walls. Most trees will be snapped or uprooted and power poles downed. Fallen trees and power poles will isolate residential areas. Power outages will last weeks to possibly months. Most of the area will be uninhabitable for weeks or months.
5 (Major)	157 mph or higher	Catastrophic damage will occur: A high percentage of framed homes will be destroyed, with total roof failure and wall collapse. Fallen trees and power poles will isolate residential areas. Power outages will last for weeks to possibly months. Most of the area will be uninhabitable for weeks or months.

Table 1 *- Saffir-Simpson Hurricane Wind Scale.*

Note that the sustained wind speeds used for classification of hurricanes are recorded at 10 meters (~33 feet) above ground level. Wind speeds increase exponentially with height. As such, the maximum sustained winds reported during a hurricane are expected to be higher than the actual wind occurring near grade. Additionally, the location of a structure relative to the hurricane's eye and wind field, site topography, and building exposure each have effects on the wind forces acting on any given structure.

Damage to structures resulting from exposure to elevated wind forces manifests in a top-down progression, with the most severe damage typically occurring at or near the roof line, where wind speeds are the highest. On roofs, high wind regions—including the ridgeline, eaves, and rakes—are typically the first areas to incur damage from wind forces. Wind pressure on a building also varies on the windward and leeward sides of a structure, with the windward elevation experiencing direct positive wind pressures and the leeward elevation experiencing negative suction pressures. On exterior elevations, the top of the windward elevation is expected to show damage resulting from wind forces first, such as the removal of cladding materials or lightweight appurtenances.

Once a breach of the building envelope has occurred, such as a broken window, open door, or hole in the roof or wall, the internal pressure of a structure will also change as a result of wind forces. If the breach in the building envelope occurs on a windward elevation, the resultant internal pressure of the structure will be positive, essentially placing an additional outward force on the walls and roof. Conversely, if the breach in the building envelope occurs on a leeward elevation, the resultant internal pressure will be negative, creating a vacuum that will pull the walls inward. The resultant positive or negative internal pressure within a structure can vary from room to room throughout a building. The positive or negative internal pressures can either increase or decrease the net load on a building component dependent upon the directionality of the wind forces acting on the exterior of the structure. It is important to understand that the windward and leeward elevations of a structure can change as the hurricane moves along its track.

UNDERSTANDING FLOOD DAMAGE

During hurricanes, the source of flooding can be coastal, riverine, or pluvial. Coastal flooding during hurricanes occurs due to the central pressure, rotation, and wind speeds of the hurricane pushing the ocean onshore and inland through storm surge and wave action. Riverine flooding occurs as a result of a river exceeding its capacity and overflowing its banks. During a hurricane this can occur due to storm surge preventing a river from flowing downstream and excess water exiting the mouth of the river into the ocean. Riverine flooding can also occur due to excess stormwater from precipitation that runs off into the river faster than the discharge flowrate of the river, thus increasing the volume of water within the river. Pluvial flooding occurs as a result of precipitation that accumulates on the ground during a storm, does not percolate into the soil, is not collected by a stormwater system, or does not run off into a nearby body of water.

Damage to structures from flooding occurs as a result of several possible conditions: hydrostatic forces, hydrodynamic forces, impact forces, scour and erosion, earth movement, and/or saturation of non-flood damage resistant building materials. Hydrostatic and hydrodynamic forces are both generated by floodwater acting directly on a structure. Impact forces can include direct impacts from water, such as breaking waves, or impacts from flood-borne debris. Scour, erosion, and earth movement are all related to a change in the condition of the soils supporting a structure. Saturation of non-flood damage resistant building materials involves changes in the properties of building materials following prolonged exposure to floodwater. The FEMA definition and a brief description of each of these contributors is provided in the following paragraphs.

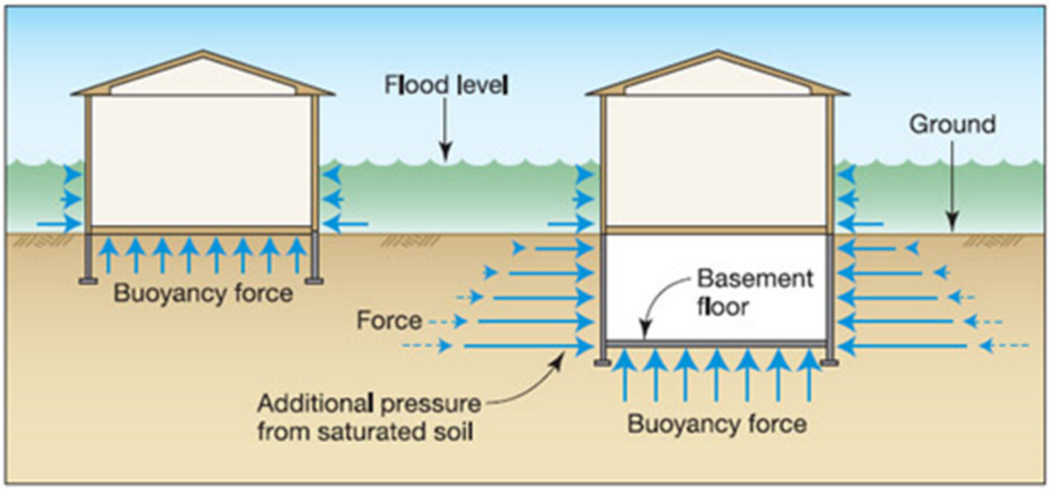

***Figure 1** - Hydrostatic forces acting against a foundation and exterior walls and floor surfaces (Source: FEMA https://emilms.fema.gov/is_0280/groups/154.html)*

Hydrostatic Forces

Hydrostatic forces are defined as "forces exerted by water at rest, including lateral pressure on walls and uplift (buoyancy) on floors." Differential hydrostatic pressure occurs when the elevation of the water acting on surface is not equal on both sides (see Figure 1). If the unequal hydrostatic pressure exceeds the capacity of the surface it is acting upon, damage such as displacement, rotation, or collapse of the surface can occur.

Hydrostatic pressure can act on the exterior or interior side of a structure. For example, a water-tight space will be inundated on the exterior and not the interior, resulting in differential hydrostatic forces acting on the exterior surface of a wall and pushing inward. Conversely, if floodwater inundates the interior of a structure and the exterior floodwaters recede faster than the floodwater trapped on the interior can escape the structure, the differential hydrostatic forces will be acting on the interior surface of a wall, pushing outward. Buoyancy is also considered a hydrostatic force which acts in the vertical orientation causing the upward displacement of a structure. Damage from this mechanism occurs when the buoyant forces exceed the capacity of the anchorage system of the structure or its components. Hydrostatic and buoyant forces can occur on below-grade surfaces, such as basement walls or floors, or retaining walls, due to an elevated water table or ground saturation from flooding, which can result in seepage through basement walls and floors, heaving of basement floors, cracking and bulging of basement walls, or collapse of basement walls.

Hydrodynamic Forces

Hydrodynamic forces are defined as "forces exerted by moving water; including positive frontal pressure against the structure, drag effect along the sides, and negative pressures on the downstream side." Several sources can contribute to the velocity of flow of floodwaters during a hurricane including topography of the land surrounding a structure and wind speeds. Hydrodynamic pressures typically produce a higher magnitude of force than hydrostatic pressures due to the additional velocity of the water acting on a surface compared to just the weight of the water. Wave action on a structure is also considered a hydrodynamic force and can affect the exterior walls of a structure or the underside of the floor on an elevated structure. Additionally, flood-borne debris in moving water can impact a structure and result in damage.

Scour, Erosion, and Earth Movement

Scour is defined as the "process by which flood waters remove soil around objects that obstruct flow, such as the foundation of a house," and erosion is defined as "the wearing away of soil by moving water." During a hurricane, the velocity of flow caused by storm surge and moving floodwater can result in scour and erosion of the soils supporting a structure, and the portions of the structure left unsupported can displace or collapse as a result.

Earth movement is different from scour and erosion in that the quantity of soil is unchanged, but saturation of the soil can result in expansion of expansive soils, consolidation of soils due to flood inundation settlement, or a reduction in the shear strength of the soils. These changes in the properties of soils supporting a structure can result in damage such as displacement, rotation, or cracks/fractures in structural elements (including, but not limited to, parts of a foundation and wall, floor, ceiling, and roof framing members).

Saturation of Building Materials

FEMA's *Technical Bulletin #2 Flood Damage-Resistant Materials Requirements* has tables that classify different building materials regarding the resistance to damage from prolonged contact (at least 72 hours) to floodwaters. Class 1, 2, and 3 materials are considered unacceptable to remain in place following prolonged exposure to floodwater due to their inability to survive the wetting and drying associated with floods without retaining their structural capacity or being affected by harmful pollutants. Class 4 and 5 materials are considered resistant to floodwater and are differentiated by their durability when exposed to moving flood water.

CONDUCTING WIND VERSUS WATER INVESTIGATIONS

A comprehensive wind versus water investigation includes a detailed physical site inspection to document conditions and obtain measurements; collect and analyze climatological and flood data; review topographic conditions; and perform engineering calculations (when necessary). The scope of a wind versus water investigation can vary between determining:

- The cause of a structural collapse or displacement.
- The cause of all damaged building components.
- The cause and origin of interior water (flooding versus water intrusion from precipitation through a storm-created opening).
- The "what, when, and how" of a structure where only the foundation remains.

The key factors in determining the origin of damage to a structure are the wind characteristics, flood characteristics, and the timing of each peril at the subject property. These factors can be determined through analysis of meteorological data obtained from a combination of publicly available government data sources, including the National Oceanic and Atmospheric Administration (NOAA), National Hurricane Center (NHC), and the U.S. Geological Survey (USGS) as well as information collected on site and through aerial imagery before and after the hurricane.

Collecting Background Information

During a site visit, an informal discussion should be conducted with the property owner or tenant. If the owner or tenant was present during the event, they may be able to provide information regarding the arrival timing of the wind and water, characteristics of the wind such as wind direction and duration, and characteristics of the flood waters such as the depth, velocity using descriptors such as fast or slow, direction, and duration. Additionally, the owner or tenant can provide information regarding any mitigation activities or repairs that were completed following the hurricane but prior to the inspection.

Documenting the Site

Next, the property should be sketched, with cardinal directions, topographic features, locations of trees, locations of obstructions such as ancillary or adjacent structures, and approximate locations and distance to any nearby bodies of water denoted. The cladding and finish materials, observed damage, and any other pertinent information should be documented by noting the locations on the sketch, providing any details or additional information in field notes, and photographed using both overview and close up shots.

Site Inspection

The subject structure and surrounding property should be inspected for evidence that a flood event occurred at the property, such as flood debris lines or water lines, mud accumulation or flood-borne debris on exterior grade, and/or browning vegetation. Attempts should be made to locate flood debris or water lines on both the exterior and interior of the structure to determine if an unequal inundation condition may have been present. Note that exterior and interior flood debris/water lines of a similar elevation above grade does not mean that a differential hydrostatic condition did not occur, as the rate of inundation depth may have been different on the interior and exterior of a building. All identified flood debris lines and water lines should be photographed with the elevation identified, such as the measurement from a tape measure visible in the photograph.

Sometimes flood debris lines are difficult to locate. In this event, it is important to check foundation elements in crawl spaces, utility closets, nearby utility poles, stop signs, trees, etc. If flood debris lines cannot be located at the property, the USGS Flood Event Viewer website is a reliable resource to check for field-measured flood debris/water lines following a hurricane. If nearby debris/water lines are obtained from the USGS website, the elevation above sea level at the location of the USGS data reference point must be compared to the elevation above sea level of the subject property in order to approximate the inundation depth at the site. Additionally, the location of the subject property relative to the USGS reference property, nearby bodies of water, and hurricane's eye and approximate path must be considered in order to infer accurate inundation data. Determination of the inundation depth at a property is pertinent in wind versus water investigations because forces associated with wind do not affect areas under water and forces associated with water do not cause damage to areas above the flood line without damage occurring below the flood line.

The entire building structure should be inspected for evidence of damage, with particular attention paid to areas where changes in geometry or reductions in cross-sectional areas of a wall are present, such as corners, door and window openings, penetrations, or appurtenances. These areas are typically the first areas to show evidence of damage or distress from loads applied by wind or water forces. Further, openings through which water could penetrate into the interior of the structure should be identified, including construction deficiencies that result in openings in the building envelope, such as gaps below doors, and storm-created openings, such as failed doors, windows, or roof systems. On the interior of the structure, the locations of observed water stains should be identified to help determine the source and approximate path of travel of the water. Structural elements should be assessed for evidence of damage or distress such as displacement, rotation, or fractures in members. The location and orientation of any such damage or distress should be documented. For example, if a wall section is displaced and out of plumb, it should be noted if the displacement occurred along the top, bottom, or middle of the wall, and the direction of the wall's rotation should be noted to determine the location and orientation of the forces that caused the failure. All observed damage to the structure should be documented via photographs that show an overview of the damaged area and close-ups of the damage. Additionally, all observed damage should be denoted on a sketch of the structure to identify the locations where such observations were made. It is also important to photograph locations where no damage was observed to provide evidence of the lack of relevant damage following a hurricane.

Flood Debris Zone

A flood debris zone should be located through physical exploration of the impacted region or through aerial imagery of the impacted region following the hurricane. The flood debris zone is usually denoted by a visible inland line approximately perpendicular to the edge of a body of water where debris carried by the moving floodwaters is deposited at the approximate inland extents of the flood. In a coastal region following a hurricane, the flood debris zone will indicate the area where storm surge was present along the coast. The structures exposed to both storm surge and wind forces are expected to have more extensive damage than those exposed to just wind forces. The remaining structures just beyond the flood debris zone will provide a general idea of the extent of damage caused by wind, since the wind speeds within the flood debris zone and just outside of the flood debris zone will be approximately the same. Figure 1 provides aerial imagery of Mexico Beach, Florida following Hurricane Michael (2018) where buildings within the flood debris zone were all completely removed by the storm and buildings beyond the flood debris zone were damaged but still standing.

Figure 2 *- Aerial imagery showing flood debris zone in Mexico Beach, Florida following Hurricane Michael (Source: National Oceanic and Atmospheric Association https://storms.ngs.noaa.gov/storms/michael/index.html#17/29.95110/-85.42426).*

Climatological Data Analysis

The wind characteristics, inundation characteristics, and the timing of each peril during the hurricane must be determined through analysis of climatological data, flooding data, and damage models. Climatological data obtained from NOAA and the NHC provide incremental wind data that includes sustained wind speeds and wind direction. Flooding data obtained from NOAA, NHC, and USGS provide incremental tidal and inundation data. The incremental nature of these data points provides valuable information that can be used to determine the time that the peak wind speeds occurred and/or the peak inundation occurred, and the magnitude of each peril at any given time throughout the progression of the hurricane.

CONCLUSION

Comprehensive wind versus water assessments include the following: an in-depth analysis of on-site observations; climatological and flood data analysis; an understanding of the damage signatures related to wind and water; and engineering calculations, when necessary. The damage signatures associated with wind are different from those associated with floodwaters. Wind damage manifests in a top-down progression, for instance, while flood damage follows a bottom-up progression. The forces of wind and water cannot impact the same location on an element simultaneously; however, they can impact the same location of an element at different times or different portions of the same element at the same time. Understanding the timing of the wind and water impacts during a hurricane are critical in determining the cause of damage or progression of a structural failure experienced during a hurricane.

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Erin Roberts is a Senior Engineer and Certified Floodplain Manager in J.S. Held's Forensic Architecture and Engineering Practice. Erin has over seven years of experience in the industry. Erin's expertise is in structural damage assessments, cause and origin determinations, hazard mitigation, and building code interpretation with regards to

code-required upgrades to existing structures. Throughout her career, she has conducted investigations on over 700 structures damaged by wind and/or water.

Contact Erin Roberts at eroberts@jsheld.com or
+1 470 287 3931.

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