Structural Damage Due to Floods

By Craig D. Rogers, P.E.

The Federal Emergency Management Agency (FEMA) reports that each year approximately 90 percent of all disaster-related property damage results from flooding. Over the past decade, the average flood claim in the United States has been more than $46,000 with yearly totals averaging $3.5 billion per year. In addition to the damage to the interior contents and finish materials, as well as the damages to mechanical and electrical equipment, the forces associated with floodwaters can cause damage to the structural members of a building through several different means. Following the flood event, an engineer may be required to determine the origin and extent of damage, and prepare the scope of repairs required to restore the structure to its original (pre-flood) condition.

What's a Flood?

Under the National Flood Insurance Program (NFIP), a flood is defined as "A general and temporary condition of partial or complete inundation of two or more acres of normally dry land area or of two or more properties (at least one of which is the policyholder's property)." This inundation may include the overflow of inland or tidal waters, rapid accumulation of runoff, mudflow, or the collapse of land along a shore due to water that has exceeded anticipated cyclical levels. In plain English, a flood is generally described as excess water (or mud) on normally dry land. While floods are often thought of as being limited to coastal flooding or riverine flooding, they may also occur as a result of excess urban runoff, dam/levee breaches, landslides, ice dams, and even bursting city water mains. So long as the inundation that occurs meets the definition as prescribed by NFIP, the resulting damage would typically be considered the effects of flooding.

Coastal flooding is typically associated with storm surges. Within tropical weather systems, the storm surge is the rising water level that is primarily the result of wind forces pushing water towards the land. During a hurricane, the height of the storm surge is governed by the intensity of the hurricane and the slope of the continental shelf. Storm surges for hurricanes can exceed 25 feet, and are typically accompanied by dangerous, battering waves on top of the surge.

Riverine flooding is the overflow of rivers, streams, drains, and lakes due to excessive rainfall, rapid snow melt, or ice. The flooding occurs when the flow of runoff exceeds the capacity of the natural drainage system. The recurrence interval of the projected flooding event defines the severity of the flood. A 100-year flood is an event that has a 1 percent probability of occurring in a given year, while a 500-year flood has a 0.2 percent probability of occurring in a given year.

Urban flooding is a phenomenon that occurs where there has been man-made developments within the existing floodplains or drainage areas (e.g., new residential communities, retail establishments, commercial buildings, parking lots, etc). The changes may either increase the amount of runoff or reduce the capacity of the natural drainage channels. The addition of impermeable surfaces (such as asphalt or concrete pavement) increases the speed of drainage collection, overwhelming the drainage system. Changes to the shape, slope, or direction of the natural drainage channels to better suit development may reduce the capacity of the channel. An aspect of urban flooding that is typically not found in "natural flooding" is the potential of subrogation of legal damages against developers that modified the natural or original drainage system.

How do Floods Damage Structures?

Whether the flooding at a building results from storm surge, riverine flooding, or urban flooding, the physical forces of the floodwaters which act on the structure are generally divided into three load cases. These load cases are hydrostatic loads, hydrodynamic loads, and impact loads. These load cases can often be exacerbated by the effects of water scouring soil from around and below the foundation.

The hydrostatic loads are both lateral (pressures) and vertical (buoyant) in nature. The lateral forces result from differences in interior and exterior water surface elevations. As the floodwaters rise, the higher water on the exterior of the building acts inward against the walls of the building. Similarly though less common, a rapid drawdown of exterior floodwaters may result in outward pressures on the walls of a building as the retained indoor floodwater tried to escape.

Sufficient lateral pressures may cause permanent deflections and damage to structural elements within the building. Should a rapid rise or drawdown occur at a building that is relatively tightly constructed, there may be enough elevation difference between the interior and exterior water surfaces to damage the walls or foundation of the building. The lateral pressure associated with floodwaters is approximately 62 to 64 pounds per square foot for every foot of differential. So, if the outside water were to reach two feet above the floor of a building before any significant amount of water leaked into the building, the lower section of the wall would experience a maximum inward pressure of 128 pounds per square foot. However, once the water reaches the same level on the inside as the outside, this force is eliminated. So, in a "leaky" building there would be a low potential for damage in this manner. However, a problem sometimes is encountered when the rapid drawdown of basement water occurs due to mechanical means following a flood. On occasion, a local fire department or the nation guard unit, in an effort to be helpful, has used high capacity pumps to empty basements of floodwaters. A problem can occur if the soils near the property remained saturated. The lateral pressures associated with the saturated soils can possibly exceed the structural capacity of the basement walls. The result may be an inward collapse of the basement wall itself.

The buoyant forces are the vertical uplift of the structure due to the displacement of water, just as a boat displaces water causing it to float. These uplift forces may be the result of the actual building materials (the floating nature of wood products), or due to air on the interior of a tightly built structure. When the buoyant forces associated with the flood exceed the weight of the building components and the connections to the foundation system, the structure may float from its foundation. In a pier-and-beam or crawlspace foundation where there are few or no mechanical connections between the floor system and foundation, this would be most likely to occur. With interior-exterior water surface differentials of as little as one foot, a typical wood-framed residence can be lifted from its foundation. While it is unlikely that floating of a basement foundation would occur, buoyant forces can again become a problem when the basement is pumped and the soils remain saturated. The saturated soils below the floor of the basement can produce buoyancy pressure that acts upward on the basement floor system, and may induce cracking and movement of this floor.

In addition to these hydrostatic loads, the water flowing around the building during a flood event creates hydrodynamic loads on the structure. These loads are the frontal impact loads from the upstream flow, the drag on the sides of the building, and the suction on the rear face of the building as the floodwaters flow around the structure. The magnitude of the hydrodynamic loads is dependent upon the velocity of the floodwaters and the shape of the structure. Like the hydrostatic pressures discussed earlier, these lateral pressures associated with the flowing water may be capable of collapsing structural walls or floor systems. In addition, the net downstream force against the building may shift the building from its foundation.

Further exacerbating the physical forces applied directly to the structure, rapidly flowing water may also scour the soils which support the foundation. While the rate and ease with which a soil will scour depends upon many factors, sandy and soft silty soils will generally be more prone to scour that stiff clay soils. As the soils are eroded from around and below a foundation system, the capacity of the foundation is reduced. Ultimately this may lead to a shifting of the building, a partial collapse of the structural system, or even a complete collapse of the structure.

Impact loads during flood events may be the direct forces associated with waves, as typically encountered during coastal flooding, or the impact of floating debris within the floodwaters. Impact loads can be especially destructive because the forces associated with them may be an order of magnitude higher than the hydrostatic and hydrodynamic forces during the flood event. In the FEMA publication *Building on Strong and Safe Foundations*, which considered the effects of Hurricanes Andrew, Hugo, Charley, Katrina, and Rita, it was reported that “post-storm damage inspections show that breaking wave loads have destroyed virtually all wood-frame or unreinforced masonry walls below the wave crest.” In addition, as debris travels downstream during a flood event, it exerts impact loads on structures it may encounter. This debris may include logs, building components, and even vehicles. Whether the impact loads against the structure occur as a result of waves or floating debris, the effects can be devastating as they apply large and/or concentrated loads to the structural elements of the building.

The Role of the Engineer

Following a flood event, there may be questions regarding the origin and extent of structural damage to a building. Often, the engineer’s role may be two-fold. First, he/she may need to serve as a forensic engineer to evaluate the origin of reported damage to a building. Then, he/she will likely be required to determine the extent of damage and provide a scope of repair for the structure.

As a forensic engineer, his/her investigation should determine the cause of the various reported instances of damage. When the results of flood damage are severe, the cause of damage can be quite obvious. However, from time-to-time, a building owner may identify conditions following a flood such as wall cracks, ceiling cracks, or tilted basement walls that may or may not be related to the flood event. Through proper forensic investigation and analysis, the engineer should be able to determine the cause of a particular condition, and whether or not it existed prior to the flood event. Once this portion of the investigation is completed, the claims adjuster will be able to better determine the extent of loss at a particular property.

From a structural standpoint, the engineer typically will determine if the foundation and superstructure of the building have been functionally damaged by the flood event. Functional damage occurs when the structural element is no longer capable of performing its intended purpose or the life expectancy of the structural element has been measurably reduced. The engineer often makes this determination by gauging the condition of the structural element against the appropriate performance or construction standard. For example, cracks and deflections within a masonry basement wall may be evaluated to determine if the wall still meets the standards and tolerances published by the Portland Cement Association.

Once the extent of damage has been determined, it may be necessary for the engineer to define a scope of repairs. Following a flood, these scopes of repairs will typically include the required work to restore the structure to its original (pre-flood) condition. From time-to-time, it may be necessary to note structural improvements needed to meet current code requirements or eliminate dangerous conditions. A claim adjuster should expect the scope of work to provide a general outline or guideline of the repairs to be performed. The goal of the scope of repairs is to assist the claim adjuster in determining the value of the loss. The scope of repairs is not intended to be an “engineered repair design.” In some cases the extent of damage or the complexity of the repair will necessitate that a professional engineer be hired to design and oversee the repairs. However, in most residential construction such oversight is typically not warranted.

The forensic engineer may also be helpful in identifying construction and/or design deficiencies that caused or contributed to flooding damage at a particular site. Examples of such deficiencies include improperly designed and constructed levies, under-designed masonry basement walls, under-sized storm retention systems, substandard building materials, etc. This information may be useful in identifying all relevant parties in a particular loss, which may lead to subrogation considerations.

Regardless of the outcome of a particular loss, the role of the forensic engineer is to uncover the facts and provide sound, substantiated and unbiased opinions. This information should be communicated by the engineer to others in a manner that is readily understood. In addition, it is the forensic engineer’s duty to identify dangerous structural conditions that exist at a particular site. Sometimes these hazardous conditions are not obvious, and the services of a competent forensic engineer are critical.

Craig D. Rogers, P.E. Is a Catastrophe Technical Manager, as well as a Central Division Assistant Property Manager, for Rimkus Consulting Group, Inc. He can be reached at cdrogers@rimkus.com or 888-474-6587. Rimkus Consulting Group, Inc. has 30 offices in the U.S. and overseas, and can be found on the internet at www.rimkus.com.