Executive Summary

Hurricane Ivan made landfall on Thursday, September 16, 2004, just west of Gulf Shores, Alabama. The hurricane brought 1-minute sustained wind speeds (over open water) of 121 miles per hour (mph) (as estimated by the National Hurricane Center [NHC]), torrential rains, coastal storm surge flooding of 10 to 16 feet above normal high tide, and large and battering waves along the western Florida Panhandle and Alabama coastline. In its *Tropical Cyclone Report, Hurricane Ivan, 2-26 September 2004* (NHC, 16 December 2004, Revised 6 January 2005), the NHC categorized Hurricane Ivan as a Category 3 hurricane, as measured by the Saffir-Simpson Hurricane Scale. The National Weather Service reported that from September 15 through 16, Ivan spawned 23 tornadoes in Florida and produced as much as 10 to 15 inches of rainfall in some areas (National Weather Service Mobile – Pensacola, "Powerful Hurricane Ivan Slams the US Central Gulf Coast as Upper Category-3 Storm," www.srh.noaa.gov/mob/ivan_page/Ivan-main.htm). After landfall, Hurricane Ivan gradually weakened over the next week, moving northeastward over the Southeastern United States and eventually emerging off the Delmarva Peninsula as an extratropical low on September 19, 2004.

On September 18, 2005, the Federal Emergency Management Agency's (FEMA's) Mitigation Division deployed a Mitigation Assessment Team (MAT) to Alabama and Florida to evaluate building performance during Hurricane Ivan and the adequacy of current building codes, other construction requirements, and building practices and materials. This report presents the MAT's observations, conclusions, and recommendations as a result of those field investigations.

Several maps in Chapter 1 illustrate the path of the storm, the depth of storm surge along the path, and the wind field estimates. Hurricane Ivan approximated a design flood event on the barrier islands and exceeded design flood conditions in sound and back bay areas. This provided a good opportunity to assess the adequacy of National Flood Insurance Program (NFIP) floodplain management requirements as well as current construction practices in resisting storm surge and wave damage. FEMA was particularly interested in evaluating damages to buildings in coastal A Zones where V-Zone construction methods are not required.

Although the NHC categorized Hurricane Ivan as a Category 3 hurricane, surface observation sites throughout the coastal region provided data that indicate that most of the region impacted by the storm likely experienced Category 1 intensity winds with some areas near the Alabama-Florida border experiencing Category 2 intensity winds. None of the surface wind measurements for overland conditions correspond to Category 3 intensity winds. Although Hurricane Ivan was not a design wind event when analyzed with respect to the 2001 Florida Building Code (FBC) or the 2000/2003 International Building Code (IBC) and International Residential Code (IRC), it caused extensive wind-related damage to buildings constructed under earlier codes.

Floodplain Management Regulations in Alabama and Florida

All of the communities visited by the MAT participate in the NFIP and have adopted floodplain management regulations that meet or exceed minimum NFIP requirements. Up until 2000, these requirements generally were contained only in community floodplain management ordinances. Starting in 2000, however, flood-resistant provisions and floodplain management requirements began to be incorporated into model building codes used in the affected areas (e.g., the IBC, the IRC, and the FBC).

The MAT determined that the area flooded by Ivan exceeded the Special Flood Hazard Area (SFHA) shown on the effective Flood Insurance Rate Maps (FIRMs) for many communities, from Gulf Shores, Alabama, to Okaloosa County, Florida, and that flood elevations in many areas exceeded the 100-year Base Flood Elevations (BFEs) depicted on the FIRMs by 2 to 4 feet. The initial flood studies for these communities were completed in the mid 1970s and were based on National Oceanographic and Atmospheric Administration (NOAA) tide gauge frequency analyses. The next studies were completed in the mid 1980s and were based on FEMA's storm surge model. This second round of flood studies also mapped wave crest elevations (as opposed to stillwater elevations), due in large part to observed damages to new construction at the time of Hurricane Frederic (1979). For the most part, this second round of studies resulted in decreased BFEs and a smaller SFHA when compared to the studies completed in the 1970s. The most recent flood studies were completed in the late 1990s (after Hurricane Opal) and added wave setup and extended the V Zone to include the primary frontal dune. The most recent studies generally increased the BFEs and the SFHA when compared to the studies completed in the 1980s, but not to the extent of the studies from the 1970s. The coastal FIRM changes over time likely resulted in a variety of coastal construction practices over the years, as most buildings were constructed to the minimum regulatory requirements, and could have contributed to flood and erosion damages the MAT observed.

Building Codes and Standards in Alabama and Florida

Alabama adopts building codes on a statewide basis only for state-owned buildings, such as schools. Local jurisdictions determine the adoption of building codes for private buildings. All Alabama jurisdictions have traditionally adopted editions of the Standard Building Code (SBC) published by the Southern Building Code Congress International. The City of Orange Beach adopted the 2003 IBC in the summer of 2004, just prior to Hurricane Ivan. The City of Gulf Shores adopted the 2003 IBC as an emergency measure after Hurricane Ivan – to improve the quality of the reconstruction. Most other affected Alabama communities, such as those in unincorporated Baldwin County, were still enforcing the 1997 or 1999 SBC at the time of Hurricane Ivan.

In the Florida Panhandle, the SBC – with local amendments – was used to regulate construction until early 2002 when the FBC 2001 Edition was adopted statewide. The FBC, administered by the Florida Building Commission, governs the design and construction of residential and non-residential (commercial, industrial, critical/essential, etc.) buildings in Florida. In December 2004, the Florida Building Commission completed the 2004 Edition of the FBC. However, additional changes to the 2004 Edition are being made in response to the 2004 hurricanes, and the 2004 Edition will not replace the earlier edition until fall 2005. Buildings constructed along Florida's Gulf of Mexico shoreline were also subject to the provisions of the state's Coastal Construction Control Line, which have been incorporated into the FBC.

Damage Assessment Observations

Flood

Because Hurricane Ivan approximated or exceeded a design flood event, the resultant storm damage provides valuable evidence about the adequacy of NFIP maps, floodplain management requirements, the reliability of the A-Zone delineation in coastal areas, building codes, and design practices. Flood levels from Hurricane Ivan exceeded the mapped BFEs throughout many bays and sounds by several feet. Flood levels along Gulf-front shorelines also exceeded the mapped BFEs but to a lesser extent, and the flooding extended beyond the SFHAs in most communities investigated. Many of the barrier islands were submerged and overwashed. Buildings constructed before the adoption of the NFIP and many buildings located outside the SFHA were severely impacted by the high storm-surge elevations and increased inundation area caused by Ivan.

Floodborne debris and wave damage (characteristic of V-Zone damage) was extensive in A Zones, especially along bay and sound shorelines. Floodborne debris from buildings, docks, and piers destroyed lower-level enclosures, stairs, and some buildings. Buildings that were not elevated above the wave crest elevation were damaged during Ivan not only by storm surge, but also by waves and floodborne debris.

Erosion was severe along the barrier islands of Alabama and Florida. Areas that had wide beaches and dunes before Ivan were less impacted than those with smaller, narrower beaches and dunes. Erosion along bay and sound shorelines was generally minimal, and structural damage there was predominantly due to storm surge, waves, and floodborne debris. The erosion along the barrier islands undermined shallow foundations and caused many buildings to collapse. Many areas had suffered beach and dune erosion during past coastal storm events, which made the buildings in those areas more vulnerable to flood and erosion impacts from Ivan.

Wind

Although structural system failures tend to be perceived by the public and the building industry as the dominant issue of concern, it is clear that for buildings built in accordance with the 2001 FBC or the 2000/2003 IBC, structural issues have, in general, been addressed by the codes. Now, the arena in which improvements can and must be made are those related to water intrusion and integrity of the building envelope. Protecting the integrity of the building envelope is important not only to minimize losses and damages to building contents, but also to prevent full internal pressurization and progressive failure of buildings.

Extensive damage to the building envelope with associated minor structural system damage was observed at many residential buildings even though Hurricane Ivan was not considered to be a design wind event when evaluating wind speeds and wind pressures from the 2001 FBC or the 2000/2003 IBC and IRC. However, in the areas around Gulf Shores, Orange Beach, and Pensacola Beach, existing building stock constructed to the 1979 to 1997 SBC can be said to have experienced a design wind event, and, thus, damage observed is related to the design parameters used at the times these codes were enforced.

Widespread building envelope damage was observed by the MAT throughout the affected area. Performance of building envelopes was generally poor and led to widespread damage to the interiors of residences, businesses, and critical/essential facilities.

Windborne debris damage was not widespread. ASCE 7 predicts that significant windborne debris damage will begin in the 120-mph range in inland areas and in the 110-mph range when buildings are within one mile of the coast. Since Ivan's gust speeds were generally below that level, it is expected that glazing damage during Ivan would be less common than in other more powerful storms such as Hurricane Charley. Given that the actual wind speeds were below current code level wind speeds, the occasional damage to the structural elements and the widespread damage to building envelopes can be characterized as wind-related damage caused by inadequate design, old construction methods, outdated design codes and methods, lack of maintenance, and/or poor construction/code enforcement. Wind damage to the contents of residential and commercial buildings, and critical/essential facilities due to these failures is preventable.

Recommendations

The recommendations in this report are based solely on the observations and conclusions of the MAT, and are intended to assist the State of Alabama, the State of Florida, local communities, businesses, and individuals in the reconstruction process and to help reduce damage and impact from future natural events similar to Hurricane Ivan. The report and recommendations also will help FEMA assess the adequacy of its flood hazard mapping and floodplain management requirements and determine whether changes are needed or additional guidance required. The general recommendations are presented in Sections 8.1 and 8.2. They relate to policies and education/outreach that are needed to ensure that designers, contractors, and building officials understand the requirements for disaster-resistant construction in hurricane-prone regions. Proposed changes to codes and standards are presented in Section 8.3.

Specific recommendations for improving the performance of the building structural system and envelope, and the protection of critical and essential facilities (to prevent loss of function) are provided in Chapter 8. Implementing these specific recommendations, in combination with the general recommendations of Section 8.1 and 8.2 and the code and standard recommendations of Section 8.3, will significantly improve the ability of buildings to resist damage from hurricanes. Recommendations specific to structural issues, building envelope issues, critical and essential facilities, and education and outreach have also been provided.

As the people of Alabama and Florida rebuild their lives, homes, and businesses, there are a number of ways they can minimize the effects of future hurricanes, including:

Flood-related

- Elevate all new construction (including substantially improved structures and replacement of substantially damaged structures) in coastal A Zones with the bottom of the lowest horizontal supporting member above the base flood level.
- Require freeboard for all structures in all flood hazard zones with the amount varying with building importance (see ASCE 7-05 and ASCE 24-05 for building importance classification and freeboard requirements) and anticipated exposure to wave effects.
- Require V-Zone design and construction for new construction in coastal A Zones subject to erosion, scour, velocity flow, and/or wave heights greater than 1.5 feet.
- Use a deep pile and/or column foundation anywhere on a barrier island, if erosion/or scour are possible.
- For sites near bay or sound shorelines, foundation selection should be based on several factors: erodibility of the soil; exposure to “damaging” waves (> 1.5 ft high); potential for velocity flow; potential for floodborne debris; and required resistance to lateral flood and wind forces.

- Use pier foundations only where soil characteristics and flood conditions permit. If there are any doubts as to the appropriate foundation to use near bay and sound shorelines, elevate the building at least one story above grade on piles or another deeply embedded open foundation, and leave the area below free of obstructions or enclose it with breakaway walls.
- Design foundations and structures to withstand loads from floodborne debris during a base flood event (100-year).
- For barrier island sites outside the V Zone, the ground level floor of a multi-story building (typically used for vehicle parking and building access) should either: 1) use a lowest floor slab or floor system that will not collapse and can support all design loads, if undermined, or 2) use a slab or floor system that will collapse and break into small pieces if undermined.
- Elevate heating, ventilation, and air conditioning equipment above the BFE, and preferably to the same elevation as the lowest floor of a building. The equipment should be supported to prevent damage from flooding and fastened to resist blow-off from high winds. The preferred approach is a cantilevered platform.
- Ensure that breakaway walls are designed and built to break away cleanly and do not cause additional damage to the building. Minimize the size of any enclosure to the amount necessary for parking and building access.
- Either elevate pools above the BFE on a pile foundation (and design the pool without side support from soil), or install a frangible (breakaway) pool at grade level and consider it expendable. Do not rely on a bulkhead to protect the pool during a severe storm.
- Subject to local and state regulations for coastal armoring, assume that only heavy walls will provide protection during a severe storm, and note that even those may be overtopped by surge and waves. Consider lightweight bulkheads as temporary structures that may provide protection during minor storms, but which will likely fail during a major storm.

Wind-related

- Design and construct facilities to at least the minimum design requirements in the 2003 IBC in Alabama and the 2001 FBC and the 2004 FBC (after it becomes effective in the fall of 2005) in Florida.

- When renovating or remodeling for structural or building envelope improvements (both residential and commercial), involve a structural engineer/design professional/licensed contractor in the design and planning.
- Assure code compliance through increased enforcement of construction inspection requirements such as the Florida Threshold Inspection Law or the IBC Special Inspections Provisions.
- Perform follow-up inspections after a hurricane to look for moisture that may affect the structure or building envelope.
- Use the necessity of roof repairs to damaged buildings as an opportunity to significantly increase the future wind resistance of the structure.

The following recommendations are specifically provided for state and Federal government agencies:

- Re-evaluate the methodology to determine flood zones and flood elevations in coastal areas to address the inconsistencies between observed flood elevations (and damages) and BFEs (and anticipated damages).
- Re-evaluate the storm surge data and modeling procedures that served as the basis for the effective FIRMs.
- Use Hurricane Ivan tide levels, inundation limits, and areas subject to wave effects as proxies for reconstruction guidance until such time as new, up-to-date regulatory studies and maps can be prepared and adopted.
- Allocate resources to hardening, providing backup power and data storage to NOAA/NWS's surface weather monitoring systems, including the Automated Surface Observing System (ASOS) located in hurricane-prone regions.
- Continue to fund the development of several different tools for estimating and mapping wind fields associated with hurricanes and for making these products available to the public as quickly as possible after a hurricane strikes.

Additional recommendations and mitigation measures for design professionals, building officials, contractors, homeowners, and business owners are presented in Chapter 8, including:

- Improving the performance of building structural and envelope systems through proper design of the continuous load path

- Improving quality control and inspections
- Retrofitting existing residential and commercial buildings from the roof decks to the foundations
- Improving the performance of critical and essential facilities (including shelters)
- Improving design and construction guidance
- Improving public education and outreach

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