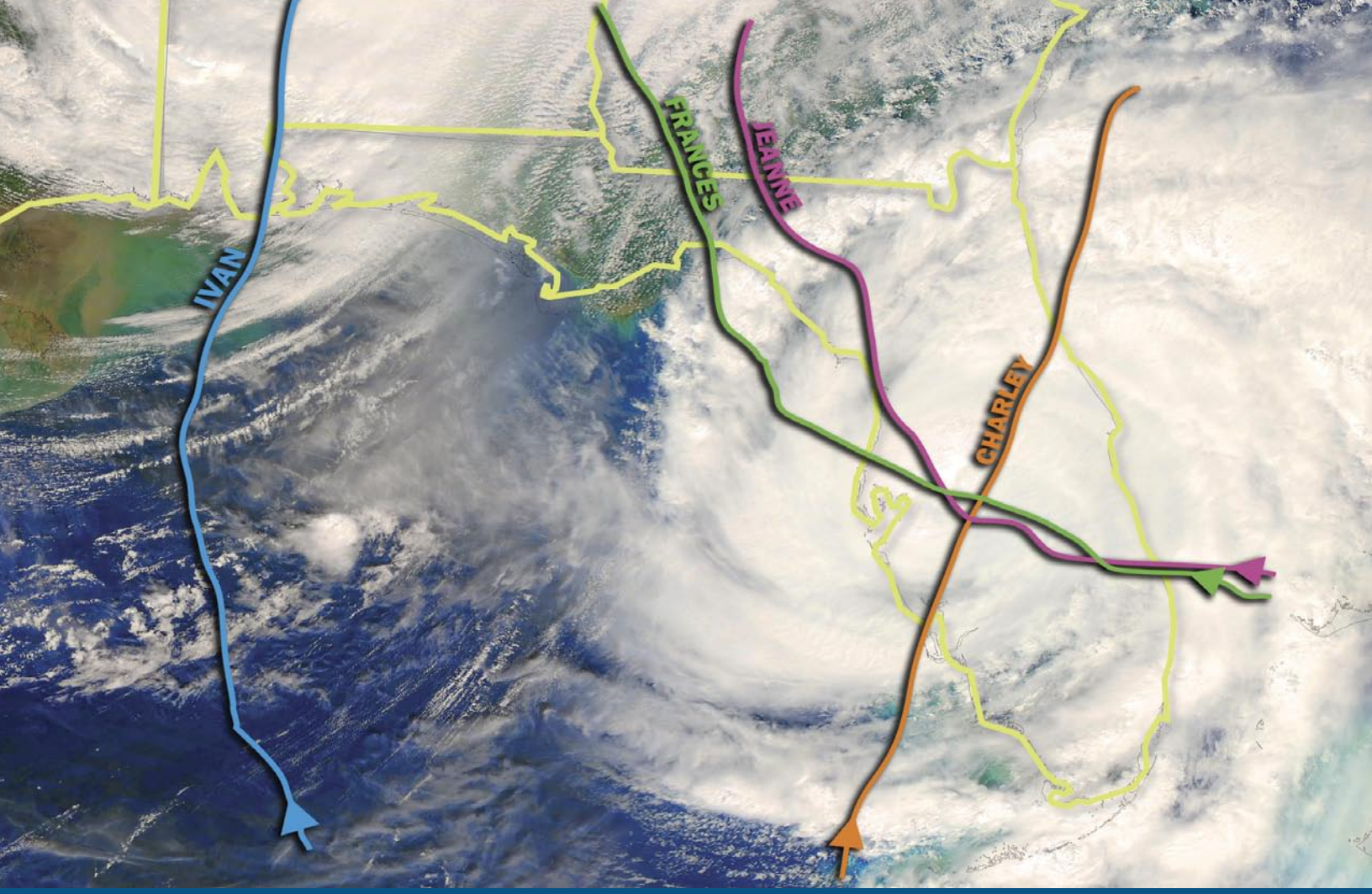

Summary Report on Building Performance

2004 Hurricane Season

FEMA 490 / March 2005

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Table of Contents

Executive Summary

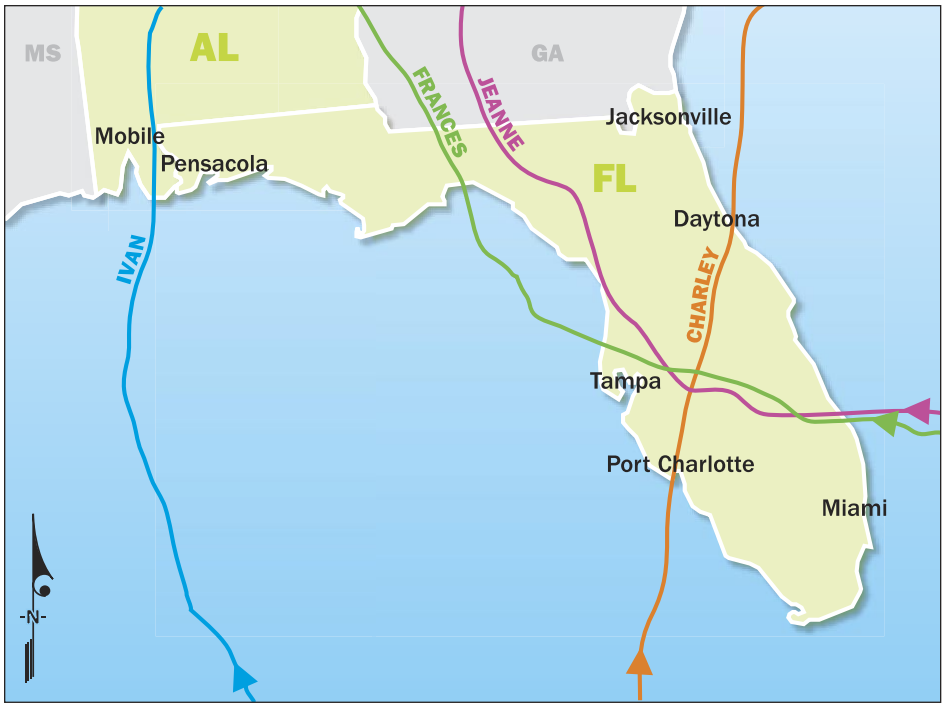
The nation will remember 2004 as a record-setting year in terms of presidential disaster declarations and administered disaster aid. In 2004, President Bush issued 68 disaster declarations of which 27 were due to hurricanes. Time and again the U.S. was impacted by hurricane force winds and waves that damaged cities and small towns in 15 states, Puerto Rico, and the U.S. Virgin Islands.

Of all the regions that endured the hurricane season, the State of Florida bore the brunt of the record-setting storms as Hurricanes Charley, Frances, Ivan, and Jeanne tested the federal and state fortitude in disaster response and recovery. Communities were devastated as wind and water damage from the four storms battered residential, commercial, industrial, and public facilities. Disaster assistance totaling more than $4.4 billion was approved for Floridians, and to date, 1.24 million storm victims have applied for federal and state assistance (FEMA 2005b). The financial impact of the season will likely exceed $20 billion, according to preliminary loss estimates from the Insurance Services Office's Property Claim Services (PCS).

The four hurricanes that struck Florida in 2004 were all significant events; however, the hurricanes were each distinctive in terms of their wind and water action and resulting damages. The first of these, Charley (designated a Category 4), was the first design level wind event to strike the U.S. mainland since Hurricane Andrew (1992) and caused more wind damage than flood damage. Frances (Category 2) and Jeanne (Category 3), while not as strong as Charley, were still very damaging hurricanes resulting in additional wind damage. Hurricane Ivan delivered not only strong winds (Category 3), but also caused significant flood damage to buildings and other structures, even those built above the 100-year flood elevation.

The impact of the four hurricanes was intensified by their back-to-back occurrence; three of the hurricanes followed similar paths or had overlapping damage swaths (refer to Figure 1 Storm Track Map). Frances and Jeanne followed almost identical paths across Florida from the east coast (around Port St. Lucie) to the west coast (north of Tampa area). These two very wide storms crossed the path of Charley (which

Figure 1. Storm Track Map



traveled west to east) in central Florida creating an overlap of impacted areas in Orange, Osceola, Polk, and Hardee counties. As a result of these overlapping impact swaths, damage resulting from the later hurricanes (Frances and Jeanne) was difficult to distinguish from earlier damage caused by Charley. For instance, roofs that failed during Frances or Jeanne may have been weakened or damaged by Charley and more prone to failure. For this reason, most of the recommendations and conclusions contained in this report are based on observations made after Hurricanes Charley and Ivan and are supported by observations made after Hurricanes Frances and Jeanne.

Following Hurricanes Charley and Ivan, the FEMA Mitigation Assessment Teams (MATs) performed field observations to determine how well buildings in Florida and Alabama performed under stresses caused by the storms' wind and water impacts. A Rapid Response Data Collection Team performed field observations after Hurricane Frances that focused on critical and essential facilities; however an assessment was not performed after Jeanne, because Jeanne and Frances impacted a similar region. Overall, the MAT observed building performance success in structural systems designed and built after Hurricane Andrew. This Summary Report focuses on the ongoing need for improvement in building performance.

Primary Observations

Wind

- Most of the wind damage was preventable. The winds primarily damaged building envelope systems which, upon failure, allowed wind-driven rain to enter building interiors causing not only loss of function, but millions of dollars of damage to building contents due to the rain and subsequent mold growth. Based on observations of wind damage after Hurricanes Charley, Ivan, and Frances, the most consistent failures were:
    - **Roof covering failures** allowed water to penetrate throughout building interiors and in some cases led to structural failures.
    - **Mechanical and electrical equipment** failure left holes in roofs (allowing wind-driven rain into building interiors) and significantly impacted the function of the buildings (i.e., communications equipment needed for 911 response was blown off roof).
    - **Soffits,** which are architectural elements at roof overhangs, frequently failed and allowed significant amounts of wind-driven rain to enter otherwise undamaged buildings.
    - **Window and door** failure exposed buildings to the damaging effects of wind-driven rain. Broken windows and doors allowed internal building pressures to increase rapidly which sometimes led to structural roof and wall failures.
- 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.
- Many critical and essential facilities, including shelters, did not perform as well as intended. Significant loss of function occurred due to largely preventable failures in building envelope performance from high winds during Charley, Frances, and Ivan. For example, in Charlotte County, over a half-dozen fire stations, three hospitals, numerous police stations, and the County Emergency Operations Center (EOC) were badly damaged. Some of these facilities were unable to provide essential functions in the days, weeks, and

sometimes months following Hurricane Charley. Hurricanes Frances and Ivan, both of which had wind speeds below the design-event, caused significant damage to building envelopes of critical and essential facilities. Many of these failures were a result of the age of the facilities (not built to current standards) and lack of proper maintenance.

DESCRIPTION OF FLOOD ZONES

Zones X, B, and C. These zones identify areas outside of the Special Flood Hazard Area (SFHA). Zone B and shaded Zone X identify areas subject to inundation by the flood that has a 0.2-percent probability of being equaled or exceeded during any given year. This flood is often referred to as the 500-year flood. Zone C and unshaded Zone X identify areas above the level of the 500-year flood.

V Zone. The portion of the SFHA that extends from offshore to the inland limit of a primary frontal dune along an open coast, and any other area subject to high-velocity wave action from storms or seismic sources. The Flood Insurance Rate Maps (FIRMs) use Zones VE, V1-30 to designate these Coastal High Hazard Areas. The SFHA are subjected to inundation to the flood that has a 1% chance of being equaled or exceeded during any given year. This flood is referred to as the 100-year flood.

Coastal A Zone. The portion of the SFHA landward of a V Zone in which the principal source of flooding is storm surge, not riverine sources. Coastal A Zones may therefore be subject to wave effects, velocity flows, erosion, scour, or combinations of these forces. The forces in Coastal A Zones are not as severe as those in V Zones but are still capable of damaging or destroying buildings or inadequate foundations. A Zone areas are subject to breaking waves with heights less than 3 feet and wave run-up with depths less than 3 feet. It is important to note that FIRMs use Zones AE, A1-30, AO, and A to designate both coastal and non-coastal SFHAs. The SFHA are subjected to inundation to the flood that has a 1% chance of being equaled or exceeded during any given year. This flood is referred to as the 100-year flood.

For NFIP flood zone definitions, refer to 44 CFR 64.3.

- Lack of a continuous load path in the structural systems of older buildings led to structural failures. Un-reinforced masonry (URM) load bearing wall buildings performed poorly, as did older wood frame buildings, because neither building type had adequate connections between structural members to transfer wind loads from the roof system to the foundation.

Flood

- Flooding associated with Hurricane Ivan significantly damaged structures including those built above the regulatory 100-year flood elevation, especially in back bay areas.
- Damage caused by significant wave action, which is typically anticipated and experienced in V Zones, also occurred in Coastal A Zones.
- Multi-family residential structures located in areas outside the 100-year floodplain (as designated on the FIRMs in Zones B, C, and X and which are not required to have deep foundations) were severely impacted by erosion, causing the shallow foundations to fail, resulting in total collapse of the buildings.
- Flooding and wave action significantly damaged utilities, enclosures, stairs, and accessory structures located under the first floor of elevated buildings.
- Walkway sections and piles from docks and marine structures, along with other damaged materials, added to the debris

in high flood levels causing severe damage throughout the inland bays.

- Buildings with first floor elevations lower than required by current minimum standards were observed to sustain more damage from wave action, debris impact, and flood waters than buildings built beyond the standards.

Primary Recommendations

Wind

1. The performance of building envelope systems in high wind events requires attention. Design guidance and code changes are needed as described in this report.
2. The performance of critical and essential facilities/shelters in high wind events must be improved. The MATs proposed stricter design requirements, as outlined in this document. Communities and states need to develop and implement mitigation retrofit programs and take advantage of FEMA's mitigation programs: the Pre-Disaster Mitigation and the Hazard Mitigation Grant Program.
3. Emphasize best practices for schools and shelters as described in FEMA 424, *Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds*, FEMA 361, *Design and Construction Guidance for Community Shelters,* and in the latest codes and standards governing wind resistant designs.

Flood

The primary recommendations based on damages observed after Ivan are:

1. Re-evaluate the hazard identification/mapping approaches in Coastal A/V Zones.
2. Re-evaluate the storm surge modeling methodology.
3. Require V Zone foundations for new construction in Coastal A Zones subject to erosion and/or wave heights greater than 1.5 feet. Require deep pile or column foundations in coastal areas mapped as Zone B, C, or X, where erosion is possible.
4. Elevate the bottom of the lowest horizontal structural member above the Base Flood Elevation (BFE) in Coastal A Zones, as is currently required in V Zones.

5. Emphasize best practices as described in FEMA 55, *Coastal Construction Manual* and in the latest codes and standards governing flood resistant design.
6. Use Hurricane Ivan tide levels, inundation limits, and areas subject to wave effects as proxies for reconstruction guidance.
7. Use flood and corrosion resistant materials below the BFE as recommended by American Society of Civil Engineers (ASCE) 24-05 and the *Coastal Construction Manual* (FEMA 55).