Mitigation Assessment Team Report

Hurricane Ike in Texas and Louisiana

Building Performance Observations, Recommendations, and Technical Guidance

FEMA P-757 / April 2009

FEMA

MITIGATION ASSESSMENT TEAM REPORT

HURRICANE IKE IN TEXAS & LOUISIANA

In response to Hurricane Ike, the Federal Emergency Management Agency (FEMA) deployed a Mitigation Assessment Team (MAT) to evaluate and assess damage from the hurricane and provide observations, conclusions, and recommendations on the performance of buildings and other structures impacted by wind and flood forces. The MAT included FEMA Headquarters and Regional Office engineers, representatives from other Federal agencies and academia, and experts from the design and construction industry. The conclusions and recommendations of this Report are intended to provide decisionmakers with information and technical guidance that can be used to reduce future hurricane damage.

In this photo taken by the MAT on September 19, 2008, a lone house in the Gilchrist neighborhood on the Bolivar Peninsula in Texas, survived Hurricane Ike.

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FEMA P-757
Catalog No: 09035-1

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HURRICANE IKE IN TEXAS & LOUISIANA

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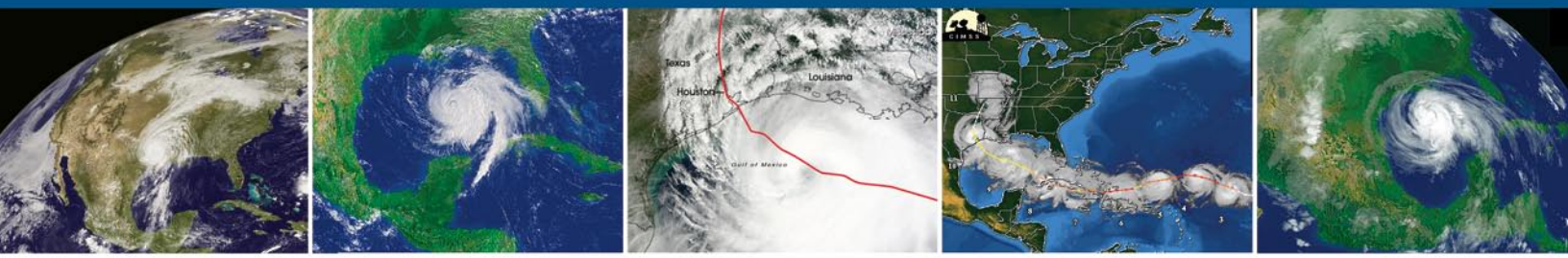

Eric Letvin

HURRICANE IKE IN TEXAS & LOUISIANA

Executive Summary

Hurricane Ike made landfall over Galveston, TX, on September 13, 2008 at 2:10 a.m. Central Daylight Time (CDT). Hurricane Ike was the ninth named storm during the 2008 hurricane season and the most significant of the three that hit Texas in 2008. It was the seventh storm of the season to hit the United States mainland. At one point in time, the tropical-force winds spanned 600 miles across the Gulf of Mexico as the hurricane approached Texas. It is estimated that the storm surge generated by Hurricane Ike affected an area of approximately 310 miles along the Gulf of Mexico coastline.

Hurricane Ike is likely to be one of the costliest and most destructive hurricanes in U.S. history. Although Hurricane Ike was only a Category 2 hurricane when it made landfall near Galveston, TX, the large wind field of Hurricane Ike and the timing of when it struck, which included a period of increased tides, led to storm surge levels more typically associated with a Category 4

hurricane. This disparity is due to the fact that the Saffir-Simpson hurricane scale is based on typical storm characteristics, and Ike was atypical. Ike was a very large hurricane (tropical-storm-force and hurricane-force winds extended approximately 275 miles and 120 miles from the storm center, respectively). A proposed new storm classification system (Integrated Kinetic Energy classification) would place Ike as high as 5.2 on a scale of 1 to 6.

The combination of surge and high waves was particularly destructive in areas along the Gulf of Mexico coast and parts of the Galveston Bay shoreline, particularly the Bolivar Peninsula, where preliminary numbers show that out of 5,900 buildings standing before Ike, approximately 3,600 were destroyed, 400 sustained major damage (substantially damaged), 1,800 sustained some damage but were not substantially damaged, and 100 were undamaged or sustained only minimal damage. Flooding also damaged many homes and businesses in the City of Galveston; in communities surrounding Galveston Bay; in the Bridge City, TX, area; and in low-lying southwest Louisiana.

In January 2009, the Property Claim Services (PCS) of the Insurance Services Office revised its estimated insured losses to $10.655 billion from its original estimates of $8.1 billion. Based on the revised estimated insured losses, total losses are estimated at $21.3 billion, which would make Hurricane Ike one of the top five costliest U.S. hurricanes of all time.

Mitigation Assessment Team (MAT)

For the past 25 years, the Federal Emergency Management Agency (FEMA) has studied the performance of buildings affected by disasters of national significance. Disasters of national significance provide opportunities for research on how hazards affect the built environment and also an opportunity to research the performance of current building codes and practices. This work is accomplished by the FEMA Mitigation Assessment Team (MAT). Often, recommendations from these findings have been adopted as statutes in model building codes, or just as importantly, as guidance for better and stronger construction practices.

These broad-minded studies are driven by a core mission of FEMA's Mitigation Directorate: to reduce damages from future disasters. They support an integral part of the Stafford Act, which is to reduce the loss of life and property that can occur from disasters. The ongoing study of the effects of these significant disasters and the documentation of findings will help in developing recommendations to enhance building performance. Improving building performance will reduce the vulnerability of population centers and critical infrastructure to natural hazards. This can be accomplished by exploiting the science and technology developed today, and imparting this knowledge to local communities through guidance and education.

In response to a request for technical support from FEMA's Joint Field Office in Austin, TX, and the Transitional Recovery Office in New Orleans, LA, FEMA's Mitigation Directorate deployed a MAT to Texas and Louisiana in October 2008 to evaluate both building performance during Hurricane Ike and the adequacy of current building codes, other construction requirements, and building practices and materials. The MAT set out to investigate the following

issues and make appropriate conclusions and recommendations based on their observations of Hurricane Ike damage:

- Performance of new construction, especially foundation performance and performance against floodborne debris
- Performance of critical facilities (e.g., schools, hospitals, and first responder facilities)
- Performance of high-rise buildings in downtown Houston
- Performance of hurricane-resistant homes on Bolivar Peninsula
- Performance of beach nourishment and reinforced dune projects in reducing flood damage
- Performance of FEMA-funded mitigation projects
- Sustainable design considerations in hurricane-prone areas

Assessment Observations

In localized areas in Texas, the flood levels for Hurricane Ike exceeded the current design flood event (i.e., 100-year base flood event) illustrated on the FEMA Flood Insurance Rate Maps (FIRMs). The wind speeds from Hurricane Ike were less than the design speeds prescribed in American Society of Civil Engineers (ASCE) 7-05, *Minimum Design Loads for Buildings and Other Structures.*

Flood Damage

All the Texas and Louisiana communities visited by the MAT participate in the National Flood Insurance Program (NFIP) and have adopted floodplain management regulations that meet or exceed minimum NFIP requirements. Most of the communities have also adopted model building codes. However, unincorporated areas of Texas are not required to complete plan review, residential building design review, or building inspection by a State or county building official. One of the goals of the MAT was to investigate building failures in mapped flood zones. The MAT determined that some of the communities visited have adopted design and construction requirements more stringent than required by the NFIP for these zones, and that structural damage to newer buildings in these communities was generally less than in communities that have not adopted higher standards.

Compliance with NFIP design and construction provisions was lacking at some buildings and in some Louisiana communities. Problems were observed at residential and commercial buildings, and at critical facilities. Compliance issues seemed to be more frequent at older structures, but some problems were also noted at newer structures.

A preliminary review of pre- and post-Ike aerial photographs suggests that 100 to 200 feet of dunes and vegetation were lost during Ike along much of the Gulf of Mexico shoreline. This loss occurred in areas with natural dunes and in areas where eroded dunes had been rebuilt

and reinforced with geotextile tubes. The MAT observed significant levels of erosion and scour around buildings situated near the Gulf. Erosion was widespread along the Gulf shoreline of Follets Island, Galveston Island, Bolivar Peninsula, and portions of southwest Louisiana. The MAT did not observe any significant erosion and scour along the bay shorelines, although there may have been some locations where such erosion and scour occurred.

Overall, the damage observed by the MAT was consistent with typical wave damage patterns: damage to properly designed and constructed elevated homes was generally minor until the waves reached above the elevated floor system, at which point the damage increased dramatically with increasing water level and wave height. Performance of residential building foundations to coastal and near-coastal hazards depended primarily on the residence having adequate elevation, proper construction, and proper foundation selection. If any of these criteria were not satisfied, performance suffered. Several of the houses the MAT evaluated performed well, particularly where the foundations elevated the houses above flood levels, where the foundations were adequately constructed to resist the imposed forces, and where the foundations were founded deeply enough to resist scour and erosion.

Wind Damage

Though Hurricane Ike's estimated wind speeds were less than the design wind speeds given in the current building code, the MAT observed widespread wind damage in the areas that were investigated. Although a very large number of buildings (including residential, commercial, and critical facilities) were damaged, much of the damage was light to moderate. Most of the wind damage was to building envelopes (primarily roof coverings, rooftop equipment, and wall coverings). Wind damage was most pronounced along the Bolivar Peninsula, the eastern portion of Galveston Island, and the areas bordering Galveston Bay.

The MAT observed various types of building envelope damage at several buildings in downtown Houston. A few high-rise buildings in downtown Houston had extensive glazing damage. According to the current building code, the basic wind speed for downtown Houston is approximately 108 mph. The estimated maximum speed during Hurricane Ike was approximately 94 mph. Several failure mechanisms were observed for building envelopes, specifically glazing damage.

The wind speeds in Louisiana were even less than those in Texas, and were also less than the design wind speeds given in the current building codes. Estimated wind speeds ranged from 80 mph near the Texas/Louisiana border, to 50 mph in Vermilion Parish. East of Vermilion Parish, estimated wind speeds were less than 50 mph. Although wind damage did occur in Louisiana, it was not as significant as the damage in Texas. As is frequently observed during MAT investigations, damage to buildings and other structures is routinely produced by less than design wind speeds due to the following: lack of understanding and execution of basic wind-resistant design and construction practices; insufficient codes and standards at the time of construction; insufficient or lack of design guides and/or test methods at the time of construction; and improper or non-compliant building modifications or lack of maintenance by the property owners.

Critical Facilities Damage

Several critical facilities, such as Emergency Operations Centers (EOCs), fire and police stations, hospitals, nursing homes, and schools were evaluated by the MAT in order to document building performance, as well as loss of function from Hurricane Ike. Critical facilities generally performed as expected. Those that were elevated higher and on stronger foundations sustained less damage. Those that were constructed in a manner similar to nearby, minimally compliant residential and commercial buildings sustained more damage.

Critical facilities with equipment and utilities in basements or at ground level tended to sustain flood damage to these support systems that either prohibited post-Ike resumption of operations, or delayed or reduced operational capabilities. At least one critical facility destroyed by Hurricane Rita and rebuilt prior to Ike appeared to have insufficient elevation, and will likely be flooded again. While Ike flooding did not enter the building, the below-floor utilities were damaged by Ike, and facility function was lost for a period of time. Critical facilities such as this should be elevated several feet above the base flood elevation (BFE) to reduce the likelihood of future flood damage.

All of the critical facilities exposed to Hurricane Ike were subjected to wind speeds that were less than the design wind speeds given in the current building codes. Hence, while most of the critical facilities observed by the MAT experienced relatively little or no wind damage, the MAT observed issues indicating that if Hurricane Ike had delivered code design wind speeds, damage from poor wind performance would have been expected at many of these facilities.

Recommendations

A few of the main recommendations based on observed building performance related to Hurricane Ike are provided below, as well as specific recommendations for improving wind- and flood-resistance of critical facilities.

Flood

a. Until new flood maps are available and adopted, require the following freeboard above the Effective BFEs for new construction, substantial improvements, and repair of substantial damage: freeboard specified by the ASCE 24-05, *Flood Resistant Design and Construction*, plus 3 feet. Once new flood maps are available and adopted, require new construction, substantial improvements, and repair of substantial damage to be elevated to or above the freeboard elevation specified by ASCE 24-05.

b. Enforce ASCE 24-05's Zone A design and construction standards in the area between the Effective Special Flood Hazard Area (SFHA) landward limit and a ground elevation equal to the adjacent Zone A Effective BFE plus freeboard.

c. Enforce ASCE 24-05's Coastal A Zone design and construction requirements in areas presently mapped as Zone A on the Effective FIRM.

d. FEMA should revise its regulations to require the entire floor system to be set at or above the BFE, and should implement the minimum floor elevation recommendations contained in the NFIP Evaluation Study (American Institutes of Research, 2006).

e. State and local governments should encourage siting away from eroding shorelines; employ coastal restoration, where justified, to mitigate erosion effects; and acquire erosion-damaged properties and prohibit reconstruction on those properties.

f. All new and replacement manufactured homes should be elevated to or above the BFE using wind- and flood-resistant foundations, such as those specified in the National Fire Protection Association 225-09, and installation of new manufactured homes should follow the guidance provided in FEMA 85, Manufactured Home Installation in Flood Hazard Areas (1985). (Note that FEMA 85 is currently under revision and is tentatively scheduled for release later in 2009.)

Figure ES-1 illustrates the recommendations outlined in bullets a, b, and c above.

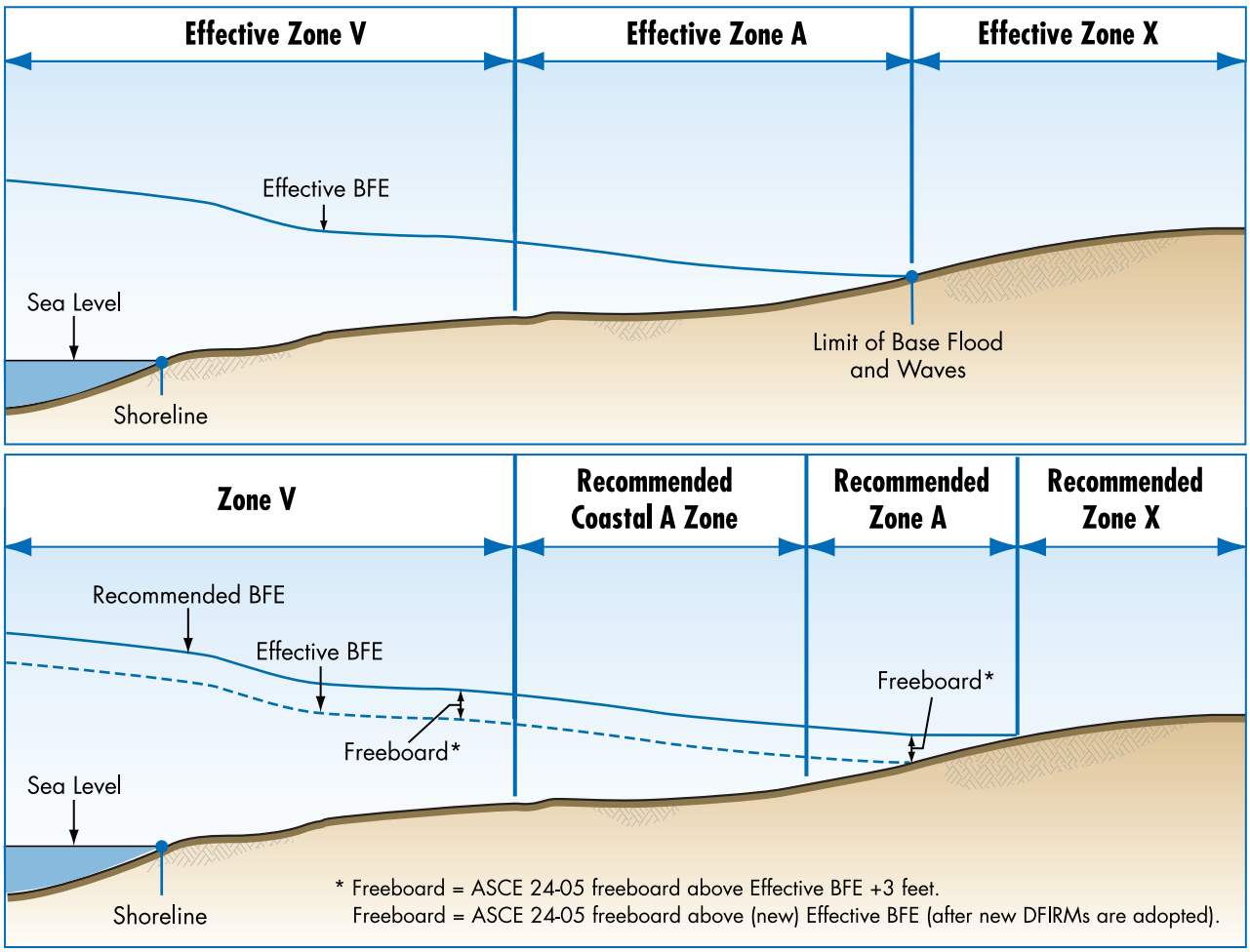

Figure ES-1. Comparison of Effective BFEs and flood hazard zones (upper figure), with MAT-recommended freeboard and flood hazard zones (lower figure)

Wind

a. An extensive amount of envelope wall covering, primarily vinyl siding and fiber cement siding, was damaged by Hurricane Ike. Municipalities with building code authorities, along with the Texas Department of Insurance (TDI) and their inspection program, should require that the installed products are on their approved and tested list and are installed in accordance with industry and manufacturer's recommendations for high-wind-zone installations.

b. Vinyl soffits and attic ventilation systems frequently failed, thereby allowing water infiltration into the homes, causing damage. The TDI and Building Inspection Program should ensure that vinyl soffits are installed in accordance with industry and manufacturer's recommendations for high-wind-zone installations.

c. Few impact-resistant laminated glass window units were observed by the MAT, with homeowners and builders opting to use shutters to provide windborne debris impact protection for glazed openings. TDI currently requires homes located in the Seaward Zone and the Inland (I) to be protected by impact-resistant glazing or shutters. The MAT recommends that opening protection by TDI include Inland (II [110 mph]) within 1 mile of the coastal mean high water line where the basic wind speed is equal to or greater than 110 mph, which is consistent with ASCE 7-05 and International Residential Code (IRC) 2003 recommendations.

Critical Facilities

a. New and replacement critical facilities should be sited outside the 500-year floodplain, where possible; where not possible, the critical facilities should be elevated higher than the residential and commercial building elevations called for in the flood recommendations. At a minimum, critical facilities should be elevated above the 500-year flood level or the freeboard requirements of ASCE 24-05, whichever offers more protection to the facility.

b. Do not locate equipment and utilities in the basements or ground levels of critical facilities; locate these above the BFE-plus-freeboard elevation. If elevation of these components is not feasible for existing critical facilities in Zone A, evaluate dry-floodproofing of these areas to an elevation several feet above the BFE; if the building structure cannot accommodate flood loads associated with dry-floodproofing to this elevation, consider relocation of the critical facility or replacement with a new critical facility.

c. Perform a comprehensive vulnerability assessment of the Main Wind Force Resisting Systems and building envelope. As part of the evaluation process, prioritize the identified vulnerabilities. FEMA 543, *Design Guide for Improving Critical Facility Safety from Flooding and High Winds: Providing Protection to People and Buildings* (2007) and FEMA 577, *Design Guide for Improving Hospital Safety in Earthquakes, Floods, and High Winds: Providing Protection to People and Buildings* (2007) recommend such an evaluation, regardless of building age, for critical facilities located in hurricane-prone regions.

d. Before a critical facility receives a grant from either the Hazard Mitigation Grant Program or the Pre-Disaster Mitigation Grant Program, the MAT recommends that a comprehensive vulnerability assessment be conducted. All significant wind vulnerabilities (including those related to interruption of municipal utilities) should be mitigated as part of the grant work, and for those that are not, the remaining residual risk should be recognized and documented.