Mitigation Assessment Team Report

Hurricane Sandy in New Jersey and New York

Building Performance Observations, Recommendations, and Technical Guidance

FEMA P-942 / November 2013

FEMA

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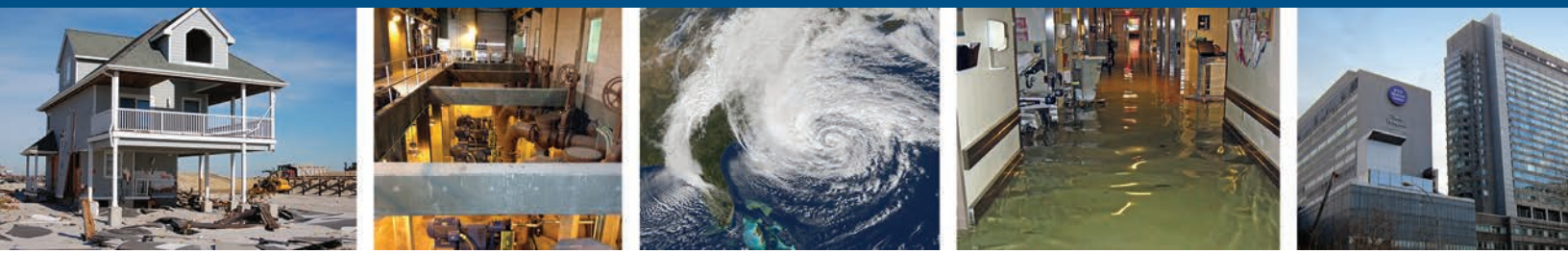
MITIGATION ASSESSMENT TEAM REPORT

In response to Hurricane Sandy, the Federal Emergency Management Agency (FEMA) deployed a Mitigation Assessment Team (MAT) to evaluate damage from the hurricane, document observations, and based on these, offer conclusions and recommendations on the performance of buildings and other structures affected by flood and wind forces. The MAT included FEMA Headquarters and Regional Office engineers, representatives from other Federal agencies, local government officials, academia, and experts from the design and construction industry. The conclusions and recommendations in this report are intended to provide decision makers, designers, contractors, planners, code officials, industry groups, government officials, academia, homeowners, and business owners and operators with information and technical guidance that can be used to reduce future hurricane damage.

DEDICATION

FEMA and the Hurricane Sandy Mitigation Assessment Team dedicate this report to the memory of the victims of Hurricane Sandy, their families, friends, and communities suffering from their loss. The Mitigation Assessment Team hopes this report will help others avoid similar losses in the future.

Photographs that appear across the top of the first page of each chapter (from left to right): Residential building with failed column due to floating debris and failed connection between the column and column footing (Ortley Beach, NJ); Subgrade motors at sewage treatment plant for effluent pumping with power and electronic controls in conduits (Bay Park, NY); Satellite image of Hurricane Sandy on Oct. 28 (Source: NOAA GOES Project); Flood levels approximately 6 inches above the finished floor inside the Hoboken University Medical Center (Hoboken, NJ) (photo courtesy of Hoboken University Medical Center); NYU Langone Medical Center with Tisch Hospital on the left (New York, NY)



HURRICANE
SANDY
IN NEW JERSEY
AND NEW YORK

Executive Summary

On October 29, 2012, Hurricane Sandy made landfall on the East Coast of the United States. Hurricane Sandy was the deadliest and most destructive hurricane of the 2012 Atlantic Hurricane Season and the third-costliest hurricane in United States history (New York City 2013b; NHC 2013b).

Hurricane Sandy made landfall near Brigantine, NJ, as a 1,000-mile-wide post-tropical cyclone. It had an estimated sustained wind speed of 80 miles per hour and a minimum pressure of 945 millibars. Although the wind speed was on the lower end of a Category 1 hurricane,[1] the pressure was typical of a Category 3 hurricane. Hurricane Sandy approached the East Coast at a perpendicular angle and coincided with a spring high tide that was higher than normal because of a full moon. All of these factors combined to generate a massive surge that caused flooding and wind damage in 24 states across the northeastern and mid-Atlantic United States (Hurricane Sandy Rebuilding Taskforce 2013). New Jersey and New York were the most severely damaged. Nearly 2 million energy users lost power, contributing to the widespread impact of the storm. Total economic losses across the United States from Hurricane Sandy are estimated to be $50 billion (New York City 2013b).

1 According to the Saffir Simpson Hurricane Scale http://www.aoml.noaa.gov/general/lib/laescae.html.

Mitigation Assessment Team Deployment and Observations

In December 2012, in response to a request for technical support from their Joint Field Offices in New Jersey and New York, Federal Emergency Management Agency (FEMA) deployed a Mitigation Assessment Team (MAT) composed of national and regional experts to assess the performance of buildings in New Jersey and New York. The MAT conducts forensic engineering analyses of buildings and related infrastructure to determine causes or structural failure and success, and to recommend actions that Federal, State, and local governments; the construction industry; and building code organizations can take to reduce future damage and protect lives and property in hazard-prone areas.

The MAT deployed to New Jersey and New York assessed high-, mid-, and low-rise buildings; municipal buildings; historic buildings; transportation facilities; schools; coastal residential properties; data centers; and critical facilities such as hospitals, police, emergency medical service facilities, and fire stations.

MAT observations indicated that the wind speed of Hurricane Sandy was below a design wind event. However, the flooding caused by Hurricane Sandy was in excess of the 1-percent-annual-chance flood event across much of the area visited by the MAT. The 1-percent-annual chance flood event is used as the minimum NFIP design requirement by those communities that have adopted the NFIP. The storm caused significant flooding and erosion in most of the areas the MAT visited. Flooding caused widespread damage to structures, critical facilities, and infrastructure. Most damage to low-rise buildings resulted from inundation, and oceanfront low-rise buildings were damaged by wave action, erosion, and scour. Many low-rise one- and two-family dwellings in coastal areas were of older construction that pre-dates community adoption of floodplain regulations. Very few of these homes were elevated to the appropriate base flood elevation (BFE). Most damage to mid- and high-rise buildings resulted from the inundation of mechanical, electrical, plumbing, and other critical systems. Many of these systems were not elevated to or above the BFE. In addition to building damage, utility outages were widespread.

MAT Recommendations

The recommendations for disaster-resistant practices in hurricane-prone regions presented in this report are presented as potential resolutions to the conclusions based on the MAT's field observations. The recommendations are applicable to planners; decision makers; designers; contractors; building officials; Federal, State, and local government officials; building owners and operators; emergency managers; and homeowners. The following summarizes some of the key recommendations.

Climate Change and Sea Level Rise

All community reconstruction and mitigation decisions should consider the impact of climate change and sea level rise on the coastal environment and the structures in these areas.

Building Codes and Standards

■+ ***Ordinances.*** FEMA is developing its model floodplain management ordinance specifically to coordinate with building codes. The New Jersey Department of Environmental Protection (NJDEP) and the New York State Department of Environmental Conservation should evaluate the FEMA model ordinance and consider its merits related to reducing duplicate and potentially conflicting requirements. The two agencies should adopt a coordinated ordinance to enhance local enforcement.

■+ ***Inspections.*** Given the number of buildings damaged by Hurricane Sandy and the extent of Special Flood Hazard Areas (SFHAs) in the five boroughs of New York City, the New York City Department of Buildings should establish a mechanism to supplement inspections with a "flood zone compliance special inspection" to be conducted and certified by special inspectors or special inspection agencies, as proposed in pending legislation. The New Jersey Department of Community Affairs and NJDEP, in cooperation with FEMA, should develop one or more courses specifically on the flood provisions of the NJDEP rules and the New Jersey Uniform Construction Code and include inspection of SFHA development.

Flood Protection

■+ ***Mapping.*** FEMA should review the mapping procedures used to identify flood hazards landward of erosion control structures, such as bulkheads, seawalls, and revetments, and revise the procedures where Hurricane Sandy data and application of new simulation techniques indicate better guidance can be developed.

■+ ***Subgrade connections.*** In buildings that share subgrade connections (e.g., access tunnels, basements, underground parking), flood prevention measures should be implemented to prevent flooding from spreading to connected areas or to other buildings.

■+ ***Elevation.*** Local communities should require that new structures and structures undergoing Substantial Improvement or that have sustained Substantial Damage should be elevated in accordance with Table ES-1, and associated building systems elevated in accordance with Table ES-2. The elevation recommendations in Table ES-1 and ES-2 should also be applied, to the extent practical, to existing buildings that are undergoing repair or retrofit, and that do not meet Substantial Improvement/Damage criteria.

Residential Construction

■+ ***Elevation.*** Existing one- and two-family houses and other existing low-rise buildings should be elevated when possible, and the foundation should be replaced with a type suitable to the construction environment if needed. Recommended elevations for new buildings, those determined to have Substantial Damage, and those that will undergo Substantial Improvement are shown in Table ES-1.

■+ ***Below-grade spaces.*** Existing homes with first-floor framing at or below the BFE should be retrofitted by elevating higher and strengthening continuous load paths to resist both the uplift and shear loads associated with combined flood and wind loads. Below-grade garages or

basements are common in older construction in New Jersey and New York. The local community should consider that below-grade garages or basements in the SFHA should be filled and flood openings installed in any remaining enclosure that is above grade, but below the lowest floor.

■+ ***Addition of freeboard.*** Designers of new homes should consider the likelihood and consequences of flood levels that exceed the BFE and mitigate this risk by adding at least 2 feet of additional elevation (freeboard) for structures in all flood hazard areas.

Table ES-1: Recommended Elevations for New and Substantially Damaged or Substantially Improved Buildings

New and Substantially Damaged or Improved Construction, Building Type[a]	Minimum Recommended Elevation and Floodproofing Level (select highest)
• One- and two-family structures • Other Risk Category II residential structures • Risk Category II non-residential structures	• Effective BFE + 2 feet, or Preliminary BFE + 2 feet,[b] or State/local DFE
• Risk Category III structures housing occupants or residents with limited mobility • Risk Category III structures that a community considers essential	• Risk Category IV elevation, see below
• Risk Category III structures not included above	• Effective BFE + 2 feet, or Preliminary BFE + 2 feet,[b] or State/local DFE
• Risk Category IV structures	• Effective BFE + 2 feet, or Preliminary BFE + 2 feet,[b] or State/local DFE, or 0.2-percent-annual-chance (500-year) flood level • Where the design flood is associated with coastal flooding, add 1 additional foot of freeboard to account for future sea level rise.

a. See ASCE 7 (2010 Edition), Table 1.5-1 for Building Category explanation.

b. Use Advisory Base Flood Elevation (ABFE) where Preliminary Work Maps have not been released, but where ABFE is more than 2 feet above the Effective BFE.

BFE = base flood elevation

DFE = design flood elevation

Table ES-2: Recommended Elevations for Utility Systems

Risk Category(a)	Minimum Recommended Elevation and Floodproofing Level (select highest)
Risk Category II structures, and Risk Category III not treated like Risk Category IV	At structure elevation
Risk Category IV structures, and certain Risk Category III structures (see Table 7-1)	1 foot above the structure elevation from Table ES-1
Existing structures (where practicable)	Corresponding elevation for new construction; if not practicable, elevate/floodproof as high as practical

a. See ASCE 7 (2010 Edition), Table 1.5-1 for Building Category explanation.

Critical Facilities and Key Assets

- ***New buildings, existing buildings, and critical functions.*** New buildings, repairs to existing buildings, and systems that support critical functions should be designed to be more resistant to disruption by flood events. Owners and operators should provide emergency power systems or temporary connections to reduce outages when utilities are disrupted.

- ***Healthcare facilities.*** Healthcare facilities should plan for extended complete power loss and associated loss of other utilities by developing emergency plans that include emergency operations, training exercises, and procurement of emergency systems and supplies. Appropriate supplies may include headlamps for staff, backup communication systems with batteries, and battery-powered lighting.

- ***Essential utilities and ventilation equipment at maintenance facilities and associated transit facilities.*** Facility owners should consider elevating or protecting key utilities and ventilation equipment at maintenance facilities and the associated transit facilities to the 0.2-percent-annual-chance flood level, consistent with design guidance for critical facilities. Since there is a potential for seepage after the flood event to continue for several weeks, facility owners should consider protecting equipment from this seepage.

Mechanical, Electrical, and Plumbing Systems

- ***Fuel tanks.*** Fuel tanks located in below-grade spaces should be in dry-floodproofed enclosures per American Society of Civil Engineers 24, *Flood Resistant Design and Construction*, or be able to resist buoyancy, and crushing pressures.

- ***Critical building systems.*** When possible move mechanical and electrical systems to above the elevation specified by ASCE 24. When elevation is not possible, protect these critical building systems with wet or dry floodproofing.

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Acronyms and Abbreviations

ABFE	Advisory Base Flood Elevation
ASCE	American Society of Civil Engineers
BFE	base flood elevation
CFR	Code of Federal Regulations
CMU	concrete masonry unit
CRS	Community Rating System
CT	computed tomography (scan)
DCEA	Division of Code Enforcement and Administration (New York State)
DFE	design flood elevation
DHS	Department of Homeland Security
DOB	Department of Buildings (New York City)
DOI	Department of the Interior
FDNY	New York City Fire Department
FEMA	Federal Emergency Management Agency
FGI	Facility Guidelines Institute
FHADFE	Flood Hazard Area Design Flood Elevation
FIMA	Federal Insurance and Mitigation Administration
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
GIS	geographic information system
HSIP	Homeland Security Infrastructure Program
HVAC	heating, ventilation, and air conditioning
HWM	high water mark
IBC	International Building Code
ICC	International Code Council
I-Codes	International Code Series
ICU	intensive care unit
IEBC	International Existing Building Code
IFC	International Fire Code
IFGC	International Fuel Gas Code
IMC	International Mechanical Code
IPC	International Plumbing Code
IPMC	International Property Maintenance Code
IRC	International Residential Code for One- and Two-Family Dwellings
IS	intermediate school
IT	information technology
JCFD	Jersey City Fire Department
JFO	Joint Field Office
kW	kilowatt(s)
LEED	Leadership in Energy and Environmental Design
LiMWA	Limit of Moderate Wave Action
LIPA	Long Island Power Authority
MAT	Mitigation Assessment Team
MEP	mechanical, electrical, and plumbing
MOTF	FEMA Modeling Task Force
mph	miles per hour
MRI	magnetic resonance imaging
MTA	Metropolitan Transit Authority
MWFRS	main wind force resisting system
NAVD88	North American Vertical Datum of 1988
NFIP	National Flood Insurance Program
NFPA	National Fire Protection Association
NHC	National Hurricane Center
N.J.A.C.	New Jersey Administrative Code
NJDCA	New Jersey Department of Community Affairs
NJDEP	New Jersey Department of Environmental Protection
NOAA	National Oceanic and Atmospheric Administration
NYCHA	New York City Housing Authority
NYPD	New York City Police Department
NYSDEC	New York State Department of Environmental Conservation
NYU	New York University
OEM	Office of Emergency Management
PATH	Port Authority Trans-Hudson
PS	primary school
PSEG	Public Service Enterprise Group
RSF	Recovery Support Function
SCADA	supervisory control and data acquisition
SFHA	Special Flood Hazard Area
SIRR	Special Initiative for Rebuilding and Resiliency
STP	Sewage Treatment Plant
UCC	Uniform Construction Code
UPS	uninterruptible power supply
USGS	U.S. Geological Survey
WWTP	wastewater treatment plant
YMCA	Young Men's Christian Association