National Institute of Building Sciences

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Lessons Learned from the 2017 Hurricanes: A Technical Evaluation of Building Performance & the Impact of Code Adoption and Enforcement

TU2A: Resilience: Learning from the Past, Adapting to the Future

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Agenda

• FEMA Mitigation Assessment Team (MAT) Program
• 2017 Hurricane MAT - TX, USVI, PR, FL
  – General Observations
  – Lessons Learned/ Key Recommendations
  – Building Science SME Support
Mitigation Assessment Team (MAT)

- The Federal Emergency Management Agency (FEMA) Mitigation Assessment Team (MAT) Program is managed by the Building Science Branch at FEMA Headquarters.
- Following a natural disaster, the team conducts field assessments and makes technical observations on the performance of buildings subjected to the effects of the natural hazard event.
What does the MAT do?

• Observes building performance under severe hazard events.

• Determines causes of building damage, failure and success.

• Evaluates performance of mitigation projects.

• Provides design and construction strategic recommendations for reducing damage and protecting lives in hazard areas.

• Draws on combined resources of federal, state, local, academia, and private sectors.

• Supports building science/building code elements of NDRF.
Mitigation Assessment Team (MAT)

The MAT’s observations are used to recommend changes to building codes and standards groups, prepare recovery advisories, gather information to improve guidance and influence construction practices during repair, support the integration of hazard mitigation measures into the repair process, provide technical assistance related to codes and standards, and contribute to research efforts.
2017 Hurricanes

FEMA Mitigation Assessment Teams

- Harvey – TX
- Irma – USVI, PR, & FL
- Maria – USVI & PR

Source: www.rms.com
Hurricane Harvey – Texas

- Landfall as a Category 4 hurricane
- Winds of 130 mph near Rockport and Fulton, TX
- System remained over Texas for several days, resulting in constant rain from Houston to western LA
General Observations – TX MAT (Wind)

- Extensive water damage primarily due to inadequately secured rooftop equipment
- Similar damage to school in Fulton, TX

Recovery Advisory 2
Attachment of Rooftop Equipment in High-Wind Regions
General Observations – TX MAT (Flood)

• Elevation matters - damage to non-conforming buildings was noticeably greater than damage to NFIP-compliant buildings
General Observations – TX MAT (Floodproofing)

• Dry Floodproofing System Failures
  – Overtopping Failure of Opening Protection
  – Structural Failure of Flood Barrier
  – Failure to Identify and Protect Lowest Point of Entry
  – Failure to Maintain Structural Integrity of the Flood Barrier
  – Seepage Issues
  – Sanitary Sewer or Stormwater System Flows

• Flood Vulnerability Assessments
• Planning and Pre-Design Considerations
• Design Considerations
General Observations – TX MAT (Floodproofing)
General Observations – TX MAT (Floodproofing)
Lessons Learned: Hurricane Harvey MAT in Texas

• Roof-mounted equipment lacked adequate attachments.
• Widespread flood damage was observed within and outside the regulatory floodplain.
• Damage to non-conforming buildings was noticeably greater than damage to NFIP-compliant buildings.
• Dry floodproofing measures failed under less than design flood conditions.
• Dry floodproofed buildings sustained damage and experienced significant loss of function while repairs were completed.
Hurricane Irma – Florida

- Landfall 1: Cudjoe Key Sep 10 at 9AM EDT (130 mph-Cat 4)
- Landfall 2: Marco Island Sep 10 at 3:30PM EDT (115 mph-Cat 3)
General Observations – FL MAT
(Building Envelope)

- Roof Covering
- Opening Protective Systems
- Wall Covering
- Soffits
Asphalt shingle loss was fairly widespread – in some cases, installation was faulty.
General Observations – FL MAT (Soffits)

- Soffit damage widespread
- Vinyl and metal soffits damaged
- Fascia cover loss common with damaged soffit
- Soffit edges exposed to more wind
- **FL Recovery Advisory 2**, Soffit Installation in Florida
General Observations – FL MAT (Wall Covering)

Wall Covering: Vinyl siding damage on 2017 construction – faulty installation factored into some failures
General Observations – FL MAT (Opening Protection)

• Damage less common
• All sites visited are within ASCE 7 WBDR
• Both examples from Little Torch Key
General Observations – FL MAT (Breakaway Wall)

- Visited on pre-MAT
- Siding (wind) damage (preceded flood)
- Water depth 9 in (front) to 24 in (rear) above top of slab

Effective Zone, BFE: AE 11 ft NGVD

Est. Depth of Water during Irma: ~ 1 ft above grade
Lessons Learned – Irma MAT (FL)

• The MAT observed evidence of inadequate resistance to wind loads for roof coverings, soffits, and certain wall coverings of residential buildings

• In some cases improper materials and installation contributed to building envelope damages; increased inspections may be needed

• Damage to non-conforming buildings was noticeably greater than damage to NFIP-compliant buildings

• This team also focused on dry floodproofing and had similar lessons learned to the TX Harvey MAT
Comparison of Select NFIP and 2018 I-Code Requirements for Special Flood Hazard Areas

**Comparison of Zone A Requirements: NFIP and IRC**

**Foundation Type**

- NFIP Zone A: 
  - SF-R 90
  - SF-R 30
  - SF-R 30 (Rigid)
  - SF-R 90 (Rigid)

- IRC Zone A: 
  - SF-R 90
  - SF-R 30
  - SF-R 30 (Rigid)
  - SF-R 90 (Rigid)

- IRC-OA-Z: 
  - SF-R 90
  - SF-R 30
  - SF-R 30 (Rigid)
  - SF-R 90 (Rigid)

**Lowest Floor Elevation**

- NFIP: 
  - Top of lowest floor above BFE
  - BFE + 12 feet

- IRC: 
  - Top of lowest floor at or above the height of BFE + 12 feet
  - BFE + 12 feet

**Equipment and Enclosures Below Elevated Buildings**

- NFIP: No equipment or enclosures located below elevated building

- IRC: No equipment or enclosures located below elevated building

**Notes:**

- NFIP Zone A may require structural support for equipment or enclosures.

- IRC Zone A may require structural support for equipment or enclosures.

**Did You Know?**

The NFIP refers to the National Flood Insurance Program and NFIP regulations. The I-Code refers to the International Building Code and other building codes. The BFE is the Base Flood Elevation.

The IBC is the International Building Code, and the IRC is the International Residential Code. Both codes are used for construction in flood-prone areas, and their requirements often overlap.
Hurricanes Irma & Maria – Puerto Rico

- Wind and Flood Impacts to Residential Buildings and Critical Facilities
- Topographic Effects, Erosion, Landslides, Storm Surge, Riverine
- Implementation of Georges MAT Recommendations
- Adoption of I-Codes, Corrosive Protection, Flood Risk Education
- Performance of post-Georges Construction and Mitigation Projects
- New Secure Housing Program, Storm Shutters, Generators
- Alternative Energy Systems including Solar Rooftop solar systems and solar farms
General Observations: Puerto Rico MAT

Shortcomings Observed

- Informal construction
  - Lack of continuous load path
  - Unpermitted
  - Not designed IAW Building Code
- Water intrusion through roofs and openings
- Rooftop equipment attachment
- Ground-mounted PV performance variable
- Siting
  - Landslide
  - Erosion
  - SFHA
  - Topographic Wind Speed-Up
- Corrosion Failures
  - Connections and Structural Members
- Tile Roof Attachment
General Observations: Puerto Rico MAT

Successes Observed

- Mitigation successes from FEMA-sponsored, locally supported mitigation programs:
  - New Secure Housing Program
  - Wind Retrofits (e.g., fire station shutters)
- Rooftop solar water heaters
- Flood damage resistant materials
New Secure Housing Program

- Program following Hurricane Georges in 1998
- Built to 1997 UBC
- Replaced vulnerable buildings with building-code-compliant concrete houses
- Successes and opportunities
PR MAT Location: Punta Baja, Humacao

- Direct hit from Maria
  - High winds, storm surge, large waves
  - Some buildings saw 7-9 feet (2.1-2.7 meters) of surge
  - 2005 & 2009 FIRMs show AE and V Zones
  - Advisory Mapping adds Coastal A Zones
- Apartment building elevated on fill to 2009 BFE did not flood (but many at grade did)
- Elevated wood-framed building destroyed
PR MAT Location: Punta Baja, Humacao

- Elevated wood-framed house that was destroyed and that survived
- The elevated concrete house performed well
PR MAT Location: Toa Baja Municipal Building

- Did not flood in 2017 hurricanes
- Underground parking structure
- Roof and glazing damage allowed water intrusion requiring the building to be closed
PR MAT Location: Toa Baja Municipal Building

- New building in 1996 to reduce flood risk
- Still in SFHA but elevated on fill
PR MAT Location: Vega Alta Municipal Building

- Shutters on east windows only
- Glazing failures led to water intrusion
PR MAT Location: Reden Solar Array, Humacao

- Large ground-mounted PV array
- Topography & construction may have contributed to performance differences between phases 1 and 2...
PR MAT Location: Reden Solar Array, Humacao

- Deformed hat clip still bolted to its supporting lateral rail
- PV panel was lifted out of position when hat clip was bent upward by wind uplift pressures
- Deformed steel lateral rails
- C-shaped lateral rail connections were unable to maintain connection to the steel beams in high winds.
Key Recommendations: Puerto Rico MAT

- Adopt the latest building code from ICC and update regularly.
- Publish prescriptive residential designs.
- Require construction documents to list critical parameters and load path connections.
- Perform vulnerability assessments for public buildings and critical facilities.
- Require design professionals and contractors to be licensed and registered.
- Develop hazard-resistant design guidance for alternative energy systems.
- Improve/construct life-safety hurricane shelter facilities (P-361/ICC 500).
Building Science SME Support – Puerto Rico MAT

- Support for Building Code update to 2018 I-Codes
  - Includes strengthening amendments based on PR MAT Recommendations
- Prescriptive Residential Designs
  - In collaboration with PR College of Architects and College of Engineers
- Best Available Refuge Area for Hurricane Shelters Job Aid
  - Assist PRDOH “Vivienda” with selection protocols
- Cost & Constructability Analysis for 2018 PRBC Update
  - from 2009 to 2018 IRC
- Guidelines for Wind Vulnerabilities Assessments for Critical Facilities
- Multi-Hazard Design Trainings
- Topographic Wind Speed-Up Microzoning incorporated into 2018 PRBC
Hurricanes Irma & Maria – USVI

FEMA’s Building Science Branch deployed a MAT composed of National and Regional experts to affected areas in the USVI starting in October and November, 2017.

Focus:

- Assess performance of residential, nonresidential, and critical facilities
- Performance of structures after Hurricane Marilyn (1995)
- Photovoltaic (PV) facilities
- Topographic Effects on Building Performance
- Building Codes
General Observations: USVI MAT

- Mitigation Successes from FEMA-sponsored and locally supported wind-mitigation programs including:
  - Home Protection Roofing Program
  - Construction Information for a Stronger Home (Stronger Homes Guide)
- Permitting and code enforcement is as important as the code itself
- Use of flood-resistant materials allowed some homes/buildings to rapidly recover
  - From flooding
  - From wind-driven rain and water intrusion
Key Recommendations: USVI MAT

- Adopt the latest building code from ICC
- Improve permitting and code enforcement programs
- Vulnerability Assessments for Public Buildings and Critical Facilities
- Hazard-resistant design guidance needed for alternative energy systems
- Improve/construct life-safety hurricane shelter facilities (P-361/ICC 500)
Building Science SME Support – USVI MAT

- Construction Information for a Stronger Home, 4th Edition
- Ongoing SME support for JFO, DPNR, other requests and support
- Support for Building Code update to 2018 I-Codes
- Develop prescriptive design details in support residential design plan sets as permitted by the USVI Building Code
- Provide Building Science training activities for designers, contractors, and local officials
2017 Hurricane MAT Themes

- Building codes work! AND hazard mitigation too!
- Codes and standards are the minimum requirement – performance reflects that
- A thorough vulnerability assessment is critical
- Redundancy, freeboard, additional level of protection is key
- Code officials expressed a need to reduce workload post-disaster
- Ensure seismic resistance is incorporated into all “new construction”
- Education of microzoning/topography and landslides into building code and guidance
- Performance of ‘homemade’ versus ‘tested’ (ASTM, ANSI, etc.) products
- Overestimating resources/implementation capacity
- Continued need to spread awareness of best practices
2017 Hurricane Building Science Branch Products

• Completed (or soon to be completed)
  – Sixteen Recovery Advisories across the four MAT
  – Four MAT Reports
  – Building Code Adoption Technical Assistance
    • Puerto Rico
      – Fact Sheets 2009 versus 2018 IBC/IRC
      – Cost & Constructability Analysis for 2018 PRBC Update
      – Topographic Wind Speed-Up Microzoning Maps
  – FEMA Flood Quick Reference Guide
  – Community Education and Outreach Flyers for select Building Science Branch Publications
2017 Hurricane Building Science Branch Products

- Ongoing
  - PR Prescriptive Residential Designs Guide
  - Best Available Refuge Area Guidance
  - Wind Vulnerability Assessment Publication
...and the research continues in 2019

- Hurricane Florence (NC Pre MAT)
...and the research continues in 2019

• Hurricane Michael