Post-Flood and Wind Safety Evaluation of Buildings

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Agenda

- Overview of the process
- Inspection and posting categories
- Rapid evaluations
- Detailed evaluations
- Case studies
- Inspector safety
- Human factors
Overview

There are three levels of evaluations:
- **Rapid**
- **Detailed**
- **Engineering**

**Rapid Evaluation**
- The first, and many times the only, safety evaluation performed
- Often cursory in nature
- Designed to quickly designate the apparently safe structures
- Designed to quickly designate the obviously unsafe structures
- Doubtful structures move to the next level
Overview

- **Detailed Evaluation**
  - Second level of examination
  - Consists of a thorough visual examination of a structure
    - Exterior
    - Interior
  - Designed to rate all structures evaluated
    - safe for use, potentially unsafe (i.e., restricted use), or unsafe

- **Engineering Evaluation**
  - Third level of evaluation
  - If required, it is usually performed by a structural engineering consultant
    - Detailed reconnaissance and mapping of the structural damage, sometimes including testing
    - Preparation of structural calculations
    - Quantitative assessment of the strength of the damaged structure
Overview

- Goal is to post every building reviewed as either
  - INSPECTED
  - RESTRICTED USE
  - UNSAFE
- Buildings posted RESTRICTED USE or UNSAFE will normally require repair or demolition

Overview

- Posting Categories
  - Occurs after a Rapid or Detailed Evaluation
  - Primarily address the safety of the structure as a whole, that is, its potential for collapse
  - Lets owners, occupants, and the public know whether
    - Buildings have been inspected
    - They are safe for entry and use
Overview

- **INSPECTED (Green Placard)**
  - No apparent hazard found
  - Repairs may be required
  - Original lateral-load capacity not significantly decreased
  - **No restriction on use or occupancy**
Overview

- RESTRICTED USE (Yellow Placard)
  - Hazardous condition exists (or is believed to exist)
  - Hazardous condition requires restrictions on the occupancy or use of the structure
  - Entry and use are restricted as indicated on the placard
  - For commercial structures, entry by the public may not be permitted
Overview

- Typical Restrictions of Building Use
  - Brief entry allowed to retrieve possessions only
  - No Public Entry to Building: (Owners or contractors may enter to clean up or repair
  - Do not enter or use the following areas: (specify)
  - Do not use the following exits: (specify)

Overview

- UNSAFE (Red Placard)
  - Extreme hazard present
  - Imminent risk of further damage or collapse
  - Unsafe for occupancy or entry, except as authorized by the Authority Having Jurisdiction (AHJ)
  - Posting a building UNSAFE is not a demolition order
  - An UNSAFE posting does not mean a structure is substantially damaged
Overview

• Use of Judgment Required
  – For those situations where no guidance has been provided, or if the guidance furnished is not appropriate for the situation, the inspecting teams must use their collective wisdom and judgment
Who Are Qualified Personnel?

- **Rapid Evaluation**
  - Building Design Professionals
  - Building Inspectors
  - Disaster workers and Technical Staff familiar with building construction

- **Detailed Evaluation**
  - Building Design Professionals
  - Building Inspectors

Rapid Evaluation Procedure

- **Difficult Posting Decisions**
  - Posting decisions can have profound effects
    - Can force a family to seek new shelter
    - Can force a business to close
  - Inspection teams must find the balance
    - Unnecessarily conservative postings must be avoided
    - Individuals or the public must not be exposed to unnecessary risk
Rapid Evaluation Procedure

• Difficult Posting Decisions
  – When serious doubt exists as to the proper posting, the Inspection team should post it according to their best judgment and request a Detailed Evaluation
  – The Detailed Evaluation team can allocate more time to the evaluation
  – Meanwhile, the posting determined by the Rapid Evaluation team will be in force

Rapid Evaluation Procedure

• Rapid Evaluation Criteria
  – A Rapid Evaluation will typically be based only on the exterior conditions
    • Unless there is a known problem
    • Structure cannot be adequately viewed from the exterior
  – Buildings that are apparently safe are to be posted INSPECTED
    • Mark the INSPECTED placard to indicate whether the inspection covered the exterior only or both exterior and interior
Rapid Evaluation Procedure

- Rapid Evaluation Criteria
  - If the observed damage is too great to allow continuous occupancy, but is not sufficient to bar all entry, it should be posted RESTRICTED USE
  - Buildings posted RESTRICTED USE must be given a subsequent Detailed Evaluation
  - Remember, there are no post-wind storm or post-flood “aftershocks”

- Condition 1 (Table 3-1 FM Page 18)
  - The building has collapsed, partially collapsed, or moved off its foundation
Partial collapse of building - Post UNSAFE

Rapid Evaluation Procedure

- **Condition 2 (Table 3-1 FM Page 19)**
  - Building (any story) or foundation is significantly out of plumb or there are gaps between walls and ceilings or roof
Building/foundation out of plumb - Post UNSAFE

Rapid Evaluation Procedure

- **Condition 3 (Table 3-1 FM Page 19)**
  - Obvious severe damage to primary structural members, severe bowing or racking of walls, or other signs of severe distress
Rapid Evaluation Procedure

- **Condition 4 (Table 3-1 FM Page 19)**
  - Falling hazard present: roof or wall cladding damaged or missing; many cracked or broken windows, obvious parapet or building ornamentation damage, water saturated walls or ceilings; damage to heavy overhead objects, such as overhead light fixtures, piping ducts, or balconies
Rapid Evaluation Procedure

- **Step 1**
  Examine the entire outside of the building
  - Pay special attention to the roof and loss of exterior doors and windows in the case of possible wind damage
- **Step 2**
  Examine the ground for signs of soil movement, sedimentation, erosion, scour, slope failure, potential ground movement or any evidence of foundation displacement
Rapid Evaluation Procedure

- **Step 3**
  Ordinarily enter a building only when the structure cannot be viewed sufficiently from the outside or when there is a suspected or reported problem
  - **Do not enter obviously unsafe structures**

Rapid Evaluation Procedure

- **Step 4**
  Evaluate the structure using the 7 criteria
  - Complete the Rapid Evaluation Assessment Form
  - Make sure exit ways are clear
  - Doubtful buildings should be slated for Detailed Evaluation
Rapid Evaluation Procedure

• **Step 5**
  Post the structure using one of the three placards, INSPECTED, RESTRICTED USE, or UNSAFE
  - Indicate whether the inspection included only the “exterior” or the “exterior and interior”
  Post every entrance to a building classified RESTRICTED USE or UNSAFE (except single family dwellings)

Rapid Evaluation Procedure

• **Step 6**
  Explain the significance of RESTRICTED USE or UNSAFE postings to building occupants
  - Advise them to leave unsafe buildings immediately, but do not create panic
Rapid Evaluation (FM Page 28)

- 10 to 30 minutes
- Used to quickly post unsafe and apparently safe structures
- Identify need for further action
- Table 3-1 provides criteria

Rapid Evaluation

ATC-45 Procedures for Safety Evaluation of Buildings After Windstorms and Floods
### Rapid Evaluation

**Evaluation**
Investigate the building for the conditions below and check the appropriate column.

<table>
<thead>
<tr>
<th>Observed Conditions</th>
<th>Minor/None</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collapse, partial collapse, or building off foundation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building significantly out of plumb or in danger</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Damage to primary structural members, robbing of walls</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Falling hazard due to nonstructural damage (example: flood)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geotechnical hazard, scours, erosion, slope failures, etc.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrical lines / fixtures submerged / leaning trees</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Other (specify)</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

**Estimated Building Damage**
(excluding contents)

- None
- > 0 to < 1%
- 1 to < 10%
- 10 to < 30%
- 30 to < 60%
- 60 to < 100%
- 100%

**Posting**
Choose a posting based on the evaluation and team judgment. Severe conditions endangering the overall building are grounds for an Unsafe posting. Localized Severe and overall Moderate conditions may allow a Restricted Use posting.

- INSPECTED (Green placard)
- RESTRICTED USE (Yellow placard)
- UNSAFE (Red placard)

Record any use and entry restrictions exactly as written on placard:

Number of residential units vacated:

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### Further Actions
Check the boxes below only if further actions are needed.

- Barricades needed in the following areas:

- Detailed Evaluation recommended:
  - Structural
  - Geotechnical
  - Other:

- Substantial Damage determination recommended

- Other recommendations:

See back of form for further comments.

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**Links to further action including need for a detailed evaluation**
Case Study for Rapid Evaluation

ATC-45 Procedures for Safety Evaluation of Buildings
After Windstorms and Floods

Scenes from the Case Study
Case Study Statistics

- Hurricane with 115 mph gusts struck condo buildings
- Storm surge 12 ft. above mean sea level
- Ground level slabs collapsed and scour exposed pile caps
- Damage evident to concrete column
- Superstructure damage caused by wind
- Windows broken and wind-driven rain caused interior damage
- Perform Rapid Assessment on these buildings

Rapid Evaluation Safety Form
## Detailed Inspection Process

- **Step 1 – Survey Building from Outside**
  - Look for signs of roof uplift
  - Look for signs of foundation movement
  - Look for visible signs of connection failure (gaps, cracks, vertical discontinuities)
  - Look at non-structural elements
  - Look for signs of water level at flooding events

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**ATC-45**  
Procedures for Safety Evaluation of Buildings  
After Windstorms and Floods
Detailed Inspection Process

• Step 2 – Examine site for geotechnical hazards
  – Slope failure
  – Sink holes
  – Risk may extend outside of a single building

Detailed Inspection Process

• Step 3 – Inspect Structural System from Inside
  – Before entering, look for falling hazards and risk of collapse – Don’t enter obviously unsafe areas
  – Look above ceiling panels, expose as much as you can
  – Examine vertical and lateral load carrying system
  – Examine every floor
**Detailed Inspection Process**

**Step 4 – Inspect for Non-structural Hazards**
- Look for signs of damage to partitions, finishes, utilities
- Look for spills or leaks of chemicals
- Don’t restart electrical system, elevators, etc.
- If building was inundated, make sure power is secured, and building marked unsafe until electrical system can be inspected

**Step 5 – Complete checklist and post building**
- Mark estimated damage
  - Ballpark, not precise
  - Not meant to require significant extra work
- Complete checklist
- Post structure
  - Make sure any restrictions are clear
  - Communicate to occupants if present
Detailed Evaluation (FM Page 52)

- 30 min. to 4 hours
- Careful visual examination
- Used to identify necessary restrictions on building use or need for engineering evaluation
- Table 4-4 provides criteria

**ATC-45 Procedures for Safety Evaluation After Windstorms and Floods**

**ATC-45 Detailed Evaluation Safety Assessment Form**

- **Building Description**
  - Building name:
  - Address:
  - Building contact phone:
  - Number of stories:
  - "Footprint area" (square feet):
  - Number of residential units:

- **Type of Building**
  - Mid-rise or High-rise
  - Low-rise multi-family
  - Low-rise commercial

- **Primary Occupancy**
  - Dwelling
  - Other residential
  - Public assembly
  - Emergency services

- **Final Posting from page 2**
  - Inspected
  - Restricted Use
  - Unsafe

**ATC-45 Procedures for Safety Evaluation of Buildings After Windstorms and Floods**
Detailed Evaluation

Evaluations

Investigate the building for the conditions below and check the appropriate column. There is room on the second page for a sketch.

<table>
<thead>
<tr>
<th>Evaluation</th>
<th>Minor/None</th>
<th>Moderate</th>
<th>Severe</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall hazards:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collapse or partial collapse</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building or story lean or drift</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fractured or displaced foundation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structural hazards:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Failure of significant elements/connections</td>
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<tr>
<td>Columns, pier, or bearing wall</td>
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<tr>
<td>Roof/Parapet framing or connection</td>
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<tr>
<td>Superstructure/foundation connection</td>
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<tr>
<td>Moment frame</td>
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<tr>
<td>Diaphragm/unialigned bracing</td>
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<tr>
<td>Vertical bracing</td>
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<tr>
<td>Shear wall</td>
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<tr>
<td>Nonstructural hazards:</td>
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<tr>
<td>Parapets, ornamental</td>
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<tr>
<td>Canopies</td>
<td></td>
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<tr>
<td>Cladding, glazing</td>
<td></td>
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<tr>
<td>Gutters, light fixtures</td>
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<tr>
<td>Stairs, exits, access walkways, gratings</td>
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<td></td>
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<tr>
<td>Member walls, partitions</td>
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</tr>
<tr>
<td>Member walls, partitions and electrical equipment</td>
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<tr>
<td>Elevators</td>
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<tr>
<td>Building contents, other</td>
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<td></td>
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<tr>
<td>Geotechnical hazards:</td>
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<tr>
<td>Slope failures, debris impact</td>
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<tr>
<td>Structural movement, erosion, submergence</td>
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<tr>
<td>Differential settlement</td>
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</tbody>
</table>

ATC-45  Procedures for Safety Evaluation of Buildings
After Windstorms and Floods
Detailed Evaluation

- Design and construction practices are largely dominated by local custom and local prescriptive building codes.
- Often receive little specific engineering attention.
- Wind-related failures range from failures initiated by inadequate component strength to failures initiated by poor connections.
Failure of the gable end wall below the roof

Detailed Evaluation for Wind

• Low-rise commercial buildings
  – Loss of the wall or roof diaphragm materials, either due to direct pressure or suction, or due to missile impact can cause partial or total collapse of the vertical-load-carrying system
  – Some utilize pre-cast, pre-stressed or post-tensioned members which can experience explosive failure due to stress reversals
Failure of roof and walls on a low-rise commercial building

Detailed Evaluation for Wind

- **Mid-rise or high-rise buildings**
  - Equipped with framing systems, which are designed to resist the full effects of the wind
  - Integrity of the main structural frame is not dependent on the survival of the cladding or secondary structural elements
  - Primary building frame is rarely damaged by the effects of wind
Detailed Evaluation for Flood

- **Building Classification for flood damage**
  - Building location
    - Flood prone areas are typically classified by the nature and severity of the associated flood hazards
    - Flood hazard area - divided into zones & mapped
      - \( V \) zones are subject to waves, high velocity flow
      - \( A \) Zones occur in both coastal and inland areas
      - Floodways occur in many rivers and large streams
      - Flash flood areas are not always mapped
      - Mudslide areas are rarely mapped.
Detailed Evaluation for Flood

- Building Classification for flood damage
  - Lowest floor elevation
    - The elevation of the lowest floor of a building determines whether or not the building will be above or below the flood surface
    - Elevation determines whether or not a building and its contents will be inundated during a flood, affected by flood velocity and debris, and in coastal areas, struck by waves
    - Building damage increases as the flood depth increases above the lowest floor

- Damage due to Inundation and Hydrostatic force - Floodwaters that rise slowly can cause two types of damage:
  - Material degradation or contamination
  - Lateral or vertical (buoyant) hydrostatic forces
    - The former can be avoided through the use of flood-damage resistant materials below the flood level
    - The latter can be avoided by elevating all but the foundation above the flood level, and by designing the foundation to resist the hydrostatic loads that will be applied
Structure that floated off its foundation. Post: UNSAFE

Differential water levels caused lateral hydrostatic loads – the wall cracked. Post: UNSAFE or RESTRICTED USE
Detailed Evaluation for Flood

- **Damage due to velocity**
  - Flowing water in floods can exert large lateral (drag) forces on buildings and foundations
    - Lightweight buildings can be swept off their foundations
    - Water moving at high velocities can carry debris into a building
    - High velocity flow can also erode soil around a foundation, leading to building undermining and damage

Building moved and damaged by rapidly moving floodwaters. Post portion of building in foreground UNSAFE, post portion of building in background UNSAFE or RESTRICTED USE.
Detailed Evaluation for Flood

• **Damage due to waves**
  - Breaking waves can exert lateral loads on structures that approach thousands of pounds per square foot.
  - Most buildings are incapable of withstanding these loads unless they are elevated above the wave crest on a deep pile or column foundation.
  - Unreinforced masonry walls and wood-frame walls are particularly vulnerable.
  - Many buildings in coastal areas are designed and constructed with “breakaway” walls.

*ATC-45  Procedures for Safety Evaluation of Buildings After Windstorms and Floods*
Case Study for Detailed Evaluation

ATC 45
Procedures for Safety Evaluation of Buildings
After Windstorms and Floods

Scenes from the Case Study
Case Study Statistics

- Hurricane hit community with 110 mph gusts
- Storm surge was 20 ft. above mean sea level
- Rapid evaluation of building was completed and was posted unsafe
- Building is two-story concrete frame with reinforced CMU walls
- Damage to 2 first floor columns and to reinforced CMU infill walls
- Windows and doors lost
- Severe damage to nonstructural components on both floors
- Large flood-borne debris obstructs stairs

Detailed Evaluation Safety Form
RESTRICTED USE

Caution: This structure has been inspected and found to be damaged as described below:
Two first floor columns & column-to-beam connections were damaged as all walls broke away. Most windows are broken and there’s minor damage to roof sheathing and covering.

Entry, occupancy, and lawful use are restricted as indicated below:
No prolonged entry into building until repair is completed. Limit number of people on second floor until shorting is in place. Removed damaged nonstructural elements and clear debris from stairs.

Facility Name and Address:
Private Home
1212 Surfside Drive
Surfside

Date: September 15, 2002
Time: 10:00 AM

This facility was inspected under emergency conditions for:

Surfside
(Jurisdiction)

Inspector ID / Agency
2012
Surfside Building Department

Do Not Remove, Alter, or Cover this Placard until Authorized by Governing Authority

Engineering Evaluation Method

- Required whenever a building has been damaged to such an extent that it is not possible to rely on visual inspection techniques alone to assess its safety
- Require hiring a structural engineering consultant
- May require removal of portions of the building to complete the examination
- Items to be considered when assessing whether to put a structurally damaged building back into service
  - Support dead and live loads
  - Resist wind and other environmental loads
  - Falling risks have been abated
  - Geotechnical risks have been abated
Safety for Inspectors

- Your safety is first priority
- Many potential field safety risks
- If in doubt, avoid the potential hazard
- Let trained rescue and emergency response personnel handle hazardous situations
- Maintain effective communication

Field Safety Risks

- Downed power lines
- Leaning, broken, or uprooted trees
- Breached gas lines
- Debris
- Scour holes, unstable soil
- Displaced animals
  - Snakes, scorpions, escaped zoo animals
Field Risks

Safety Tips

- Always travel in teams of at least two
- Always wear hard hat and boots
- Always survey the entire building exterior prior to entering
- Enter building only if deemed safe to do so
- Avoid all areas of potential hazmat release
- Be alert for falling hazards
- Avoid downed power lines and buildings under them
- In case of gas leak, shut off if possible and alert authorities
Supporting Inspection Personnel

- Due to difficult conditions, team has to be supported with logistics
- Inspectors don’t want to become burden on already overburdened emergency response system
  - Timing critical
- Need organized effort to task inspectors, collect data, and process data

Supporting Inspection Personnel

- Frequently provided resources for inspectors
  - Official Ids
  - Inspection forms and placards
  - Caution Tape
  - Office goods
  - Food/Water **
  - Communication Equipment
  - Berthing
What Should the Inspector Bring?

• Personal Items
  – Personal ID / Driver’s License
  – Cash! / Credit Cards
  – Backpack
  – Eye Protection, Gloves, Boots, Hardhat
  – Sunscreen, Hat
  – Rain Gear/Extra Clothing
  – Dust Mask
  – Personal Hygiene Supplies (Two weeks of any prescription meds)

• Field Equipment
  – Cell Phone or radio
  – Maps
  – Data Recording gear – clipboard
  – Camera
  – Tape measure, laser measurer
  – Battery powered radio
  – Flashlight(s) / Lantern (extra batteries)
  – Compass / Multi-Tool
Human Factors - Inspectors

- Weather conditions harsh
- Physically difficult
- Long hours
- Must watch for “burnout” and overstress
- Need to plan cycling of personnel if expected work time passes one week
- Eat well, get plenty of rest

Human Factors - Residents

- Residents will have a range of emotions
- Inspector may be first person representing authorities the person sees
  - Know where to send people for aid
  - Answer what you are confident in, provide facts
- Clearly explain reasons for actions
- Beware of potential hostility
Looking Ahead. . .

Electronic data collection version ATC-45i is under development and has been pilot tested in Florida (similar to ATC-20i). Methodology is being revised to get closer to being useful for substantial damage determination.

Questions?
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