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Hurricane Shelter Survey Program Manager – FL DCA, Emergency Management
Presentation / Forum Agenda

- The IS-STM Storm Shelter Standard and Public Comment Schedule
- Design Provisions (Structural & Building Envelope)
- Design Provisions (Operational & Human Features)
- Questions / Discussion
ICC/NSSA Storm Shelter Standard

- Collaborative Effort
  - International Code Council
  - National Storm Shelter Association
  - Federal Emergency Management Agency

- Begun in Spring 2003

- Public Comment Draft to be posted mid-August 2006
Storm Shelter Committee Members

- Building Code Officials
- Emergency Planning Managers
  - Federal (FEMA) and State Officials
- Industry
  - NAHB, NSSA, PCA, NCMA, AISI, Ingersoll Rand
- University faculty members:
  - LSU, Texas Tech, Clemson
- Consultants
  - URS, ARA, PBA, DuPont
Overall Goal of the IS-STM

Develop a standard that provides a very high degree of life-safety protection from extreme storm events for Residential and Community Shelters

Question: What is your performance expectation of a storm shelter?
Purpose of the IS-STM

Establish minimum requirements to safeguard the public health, safety, and general welfare relative to the design, construction, installation, repair, operation and maintenance of storm shelters constructed for refuge from high winds associated with tornadoes and hurricanes. This standard is intended for adoption by government agencies and organizations setting model codes to achieve uniformity in the technical design criteria in building codes and other regulations.
Scope of the IS-STM

This standard applies to design, construction, installation, inspection, and operation of storm shelters constructed independently or constructed as safe rooms within a building for the purpose of providing safe refuge from storms that provide high winds, such as tornados or hurricanes.

- Residential and Commercial
- Includes Considerations for
  - Architectural
  - Structural
  - Mechanical
  - Electrical
  - Plumbing
  - Other
References Documents

- FEMA 320: *Taking Shelter from the Storm*
- FEMA 361: *Design and Construction Guidance for Community Shelters*
- ARC 4496: *Guidelines for Hurricane Evacuation Shelter Selection*
- Florida Building Code - Enhanced Hurricane Protection Areas (EHPA), Section 423.25
- FL DCA Statewide Emergency Shelter Plan
Public Comment Phase for IS-STM

- Completing draft in Committee
- Release for 45 day public comment in mid-August 2006
  - Draft will be posted on the internet
  - Comment format / submittal forms on the internet
- Notices, agendas and minutes posted on ICC web site
  
  www.icc safe.org/cs/standards/is-STM
Questions for ICC

- David Bowman - Manager of Codes
  International Code Council (ICC)
  Chicago District Office
  4051 W. Flossmoor Rd.
  Country Club Hills, IL 60478
  Ph: 888-422-7233 x4323    Fax: 708-799-0320
  dbowman@iccsafe.org

Next Meeting – Late fall / Early Winter 2006
Intent is to publish the standard in early 2007
Structural Loads

- Wind Speed Maps and Shelter Design
  - Wind Speeds / Wind Loads
    - Design methods
    - Design Parameters
  - Windborne Debris
  - Other Loads and Considerations
Shelter Design Wind Speeds

- Considered probabilistic maps
- Considered historical data and maps
- Proposing separate maps
- Tornado shelters
- Hurricane shelters

Theme throughout IS-STM Standard
ASCE 7 BASIC WIND SPEED MAP (Fig. 6-1)
Peak Gusts over Land by Hurricane Category
(after Vickery et al, 2000), and
Enhanced Fujita Scale
(Wind Science and Engineering Center, 2006)

<table>
<thead>
<tr>
<th>Saffir-Simpson category</th>
<th>Max (1 min) sustained wind speed over water (mph)</th>
<th>Max (3 sec) gust speed over land (mph)</th>
<th>Enhanced Fujita Scale</th>
<th>Fastest ¼ mile wind speed over land (mph)*</th>
<th>Calculated Max (3 sec) gust speed over land (mph)</th>
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<tr>
<td>TS</td>
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<td>&gt;191</td>
<td>EF5</td>
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* Original Fastest ¼ mph wind speeds proposed for Fujita Scale
Tornado Shelter Design Wind Speeds

Wind Zones:
- Zone I: (130 mph)
- Zone II: (160 mph)
- Zone III: (200 mph)
- Zone IV: (230 mph)

Other Considerations:
- Special Wind Region
- Hurricane-Susceptible Region

Design Wind Speed measuring criteria:
- 3-second gust
- 33 feet above grade
- Exposure C

HAWAI'I
Hurricane Shelter Design Wind Speeds

Wind speeds in miles per hour at 33 feet above ground for Exposure for Category C. Linear interpolation between contours is permitted. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area. Multiply miles per hour by 0.447 to obtain meters per second.

Notes:
1. Values are nominal three-second gust wind speeds in miles per hour at 33 feet above ground for Exposure for Category C.
2. Linear interpolation between contours is permitted.
3. Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.
4. Multiply miles per hour by 0.447 to obtain meters per second.

FIGURE X-X. HURRICANE WIND SPEED
## Return Period Comparisons

<table>
<thead>
<tr>
<th>PERCENT CHANCE OF GETTING ONE OR MORE SUCH OR BIGGER FLOODS IN THESE MANY YEARS</th>
<th>RETURN PERIOD YEARS</th>
<th>ANY 1 YEAR</th>
<th>TEN YEARS</th>
<th>TWENTY FIVE YEARS</th>
<th>FIFTY YEARS</th>
<th>ONE HUNDRED YEARS</th>
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2006 Florida Governor’s Hurricane Conference
ICC/NSSA – Standard for the Design and Construction of Storm Shelters (IS-STM)

- Cat 5 – Hurricane Camille
- Weak Cat 4 – Hurricane Charley
- F3 tornado
- Strong Cat 4 – Hurricane Andrew

HURRICANE WIND SPEED

Wind speeds in miles per hour at 33 feet (10 m) permitted. Contour shall use the last wind speed measured in meters per second.
Calculation of Wind Loads

(Use ASCE 7, and adjust as proposed)

- **Velocity Pressure (psf):**
  \[ q = 0.00256 K_z K_{zt} K_d V^2 I \]
  - \( K_z \): Velocity Pressure Exposure Coefficient
  - \( K_{zt} \): Topographic Factor
  - \( K_d \): Wind Directionality Factor
  - \( V \): Design Wind Speed
  - \( I \): Importance Factor
Kz Velocity Pressure Coefficient and Site Exposure

- Velocity profiles remain unchanged, but selection of exposure categories is modified
- Use Exposure C for Tornado Shelters – MWFRS and C&C
- Use Exposure C Hurricane Shelters – MWFRS and C&C
  - Exception: Exposure B is permitted in cases where this roughness will very clearly remain in place even after an intense hurricane (MWFRS only)
‘Type’ of Exposure B Important
Example of pre-storm Exposure B, becoming Exposure C during storm

Hurricane Andrew
$K_{zt}$ Topographic Factor

Accounts for speedup in wind near top of hills, ridges and escarpments

- **Tornado Shelter**
  - $K_{zt} = 1.0$
  - Effects of topography on tornado windspeeds are unknown

- **Hurricane Shelter**
  - Per ASCE 7-05


**Kd** Directionality Factor

- Accounts for reduced probability of maximum wind speed occurring simultaneously with most vulnerable wind direction

- **ASCE 7-05**
  - $K_d = 0.85$

- **IS-STM Hurricane and Tornado Shelter**
  - $K_d = 1.0$
  - Changing wind direction may bring maximum or near maximum wind speeds over a wide range of wind directions
Importance Factor

Accounts for change in MRI based on relative level of hazard to human life

- **ASCE 7-05**
  - \( I = 1.15 \) for shelters

- **IS-STM Hurricane and Tornado Shelter**
  - \( I = 1.0 \)
  Already using an ‘ultimate’ wind speed with long mean recurrence interval
Summary of Velocity Pressure Differences

ASCE 7-02
- $K_z$ based on exp B or C
- $K_d = 0.85$
- $V = 2\%$ annual prob
  (64\% chance in 50 years)
- $I = 1.15$

Draft IS-STM Standard
- $K_z$ exp B limited
- $K_d = 1.0$
- $V = 0.01\%$ annual prob
  (0.5\% chance in 50 years)
- $I = 1.0$
Load Factor

- Strength design. Use the ASCE 7 load combinations with the following modifications:
  - In load combination 3, replace 0.8W with 0.5W
  - In load combinations 4 and 6, replace 1.6W with 1.0W
  - Exception 1 shall not apply

- Allowable stress design. Use the ASCE 7 load combinations with the following modifications:
  - In load combinations 5, 6, and 7 replace W with 0.6W
Design Pressure Comparison
Example - Ft. Lauderdale

- Proposed Design Pressures are 44% larger than ASCE 7
- Proposed Design Pressures are 13% lower than EHPA (using recommended wind speed of ASCE 7 + 40 mph)
- Percentages will vary with location along the coast
Enclosure Classification

- Determined per ASCE 7-05 and:
  - Largest opening on each side of the building must be considered, in turn, as being open even though it may have protection

- Experience has shown - if openings are not breached, people open shelter doors and windows during the storm

- Damage to a window or door by a larger than tested for missile should not result in internal pressurization failure
Internal Pressure

- For Tornado shelters – APC must be considered
  - Use $G C_{pi} = +/- 0.18 + APC$ contribution
  - Use $G C_{pi} = +/- 0.18 +$ design for venting
  - Use $G C_{pi} = +/- 0.55$

- For Hurricane shelters – no APC
  - Use $G C_{pi} = +/- 0.18$ or +/- 0.55 per ASCE and largest opening requirement
Windborne Debris

- Much new research recently published and underway
- Aerodynamics – wind tunnel and analytical and numerical models indicate that missiles travel at higher wind speeds than previously assumed
- Post-disaster debris information gathered to help develop/validate new debris flight/trajectory models
IS-STM Tornado Missile

- Representative missile = 15 lb 2x4
- Horizontal missile speeds (see table)

- Current FEMA 361 missile for all zones:
  - 15 lb 2x4
  - Horizontal speed = 100 mph
  - Vertical speed = 67 mph

<table>
<thead>
<tr>
<th>Zone - Design Wind Speed (V)</th>
<th>Horizontal Missile Speed - Tornado</th>
<th>Vertical Missile Speed - Tornado</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone IV – 250 mph</td>
<td>100 mph</td>
<td>67 mph</td>
</tr>
<tr>
<td>Zone III – 200 mph</td>
<td>90 mph</td>
<td>60 mph</td>
</tr>
<tr>
<td>Zone II – 160 mph</td>
<td>85 mph</td>
<td>56 mph</td>
</tr>
<tr>
<td>Zone I – 130 mph</td>
<td>80 mph</td>
<td>53 mph</td>
</tr>
</tbody>
</table>
IS-STM Hurricane Missile

- **Representative missile = 9 lb 2x4**
- **Horizontal missile speed**
  - 0.4 x V
  - V = peak gust wind speed
  - See table
- **Vertical missile speed**
  - 0.1 x V
- **Current FBC large missile:**
  - 9 lb 2x4
  - Horizontal speed = 34 mph

<table>
<thead>
<tr>
<th>Hurricane Design Wind Speed (V)</th>
<th>Horizontal Missile Speed - Hurricane</th>
<th>Vertical Missile Speed - Hurricane</th>
</tr>
</thead>
<tbody>
<tr>
<td>255 mph</td>
<td>102 mph</td>
<td>26 mph</td>
</tr>
<tr>
<td>250 mph</td>
<td>100 mph</td>
<td>25 mph</td>
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<tr>
<td>240 mph</td>
<td>96 mph</td>
<td>24 mph</td>
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<tr>
<td>230 mph</td>
<td>92 mph</td>
<td>23 mph</td>
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<tr>
<td>220 mph</td>
<td>88 mph</td>
<td>22 mph</td>
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<tr>
<td>210 mph</td>
<td>84 mph</td>
<td>21 mph</td>
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<tr>
<td>200 mph</td>
<td>80 mph</td>
<td>20 mph</td>
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<tr>
<td>190 mph</td>
<td>76 mph</td>
<td>19 mph</td>
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<tr>
<td>180 mph</td>
<td>72 mph</td>
<td>18 mph</td>
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<tr>
<td>170 mph</td>
<td>68 mph</td>
<td>17 mph</td>
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<tr>
<td>160 mph</td>
<td>64 mph</td>
<td>16 mph</td>
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</table>
Other Debris Hazards

- Rollover hazards
- Laydown hazards
- Collapse hazards

- Siting requirements to minimize these hazards
- If they are present, must design for impacts
Protection of Building Envelope

- Walls and roof systems must be impact resistant
  - Roofs cannot have loose-laid roof coverings
- Openings required to be debris impact resistant or have impact resistant coverings (opening protectives)
Door Systems

Shelter doors will be opened during the storm, for numerous reasons including:

- late arrivals
- investigating damage
- moving between shelter areas
- people wanting to smoke
- etc. - human nature
Doors and opening protectives

- Must resist design wind pressures
- Must resist design forces from representative windborne debris

- No minimum requirements for hinges or latches – must pass tests
Baffled or Alcove Entry Designs
Opening Protectives

- Tornado Shelters
  - Readily available
  - Readily installed / closed
  - All components attached to protection

- Hurricane Shelters
  - Allowed to be stored and installed over time
  - Must resist pressures and debris impact
Opening Protectives (ie., Window Protection Systems)

Will systems requiring operation or installation work as planned?

Do Shelter operators have the knowledge, time, materials, tools, keys to install/operate hurricane protection systems?
Complete Testing Protocol for Pressure and Debris Impacts

- Complete protocol for pressure testing of walls, roofs, and opening protectives
- Complete protocol for debris impact testing of walls, roofs, and opening protectives
Other Loads
Flood Hazards – Tornado Shelters

- Proposed provisions - shelters should be constructed in accordance with local floodplain ordinances
- Use most restrictive of:
  - 500 year flood elevation, when determined
  - 100 year flood elevation + 1’ (BFE+1)
  - Local requirements
Flood Hazards - Hurricane Shelters

- Use most restrictive of:
  - Cat 5 hurricane surge zone as indicated by SLOSH or other recognized models
  - Storm surge or rainfall flooding considerations
  - 500 year flood elevation, when determined
  - 100 year flood elevation + 1’ (BFE+1)
  - Local requirements
Rain Loads for Hurricane Shelters

- Special Precautions should be taken:
  - Heavy rains can last several days
  - Pay special attention to design of secondary drainage
    - Drains may become clogged by debris or wind-induced movement of roof gravel
    - Must carefully consider ponding phenomena
Identification of Design Parameters

- Specified in Section 106 and 107
  - Addresses the need for special inspections
  - Addresses signage and labeling
  - Addresses identification of design parameters on building plans
  - Provides square footage assumptions
Application of Pressures and Debris Requirements

- **Wind Pressure Criteria**
  - Apply to all MWFRS per ASCE 7
  - Apply to all C&C per ASCE 7
    - Including all doors and protection devices

- **Debris Impact Criteria**
  - Apply to all exterior surfaces providing protection for shelter occupants
Discussion Topics


Next up is the Operational Provisions
Danny Kilcollins – FL DCA Shelter Program Manager, ICC/NSSA Committee Member
Shelter Design Considerations:
Special Occupancy

Danny J. Kilcollins, FPME
Florida Div. of Emergency Management
Information Sources

- *Design & Construction Guidance for Community Shelters* (FEMA 361)
- *Taking Shelter from the Storm: Building a Safe Room inside your House* (FEMA 320)
- National Storm Shelter Association Standard (NSSA 4000-02)
- Florida’s Public Shelter Design Criteria (section 423.25, Florida Building Code)
Information Sources

- MASS CARE—Management and Operations (ARC 3041)
- International Code Council (ICC) Codes
- Various FEMA, ARC and FBC publications and provisions
Use and Occupancy

- Normal use occupancy code reqm’ts apply, unless otherwise noted
  - Dedicated single-use shelters are “assembly” occupancy

- Shelter definition:
  - A building, structure, or portion(s) thereof, constructed in accordance with this standard, designated for use during a severe storm event.
Use and Occupancy

- Shelter reqm’ts separated into two types:
  - Tornado
  - Hurricane

- Shelter Types subdivided:
  - Large, 51 or more occupants
  - Small, 50 or less occupants
    - Exception: Residential and One & Two Family Dwellings (16 or less occupants)
Use and Occupancy

- Occupant density based upon “net usable floor area”
  - Net usable is space that can actually be occupied by a person
- Number of standing, seated, wheelchair and bedridden spaces to be determined by applicable authority
- Shelters shall be sized for at least one wheelchair space per 200 occupants
- Design occupancy period:
  - Tornado @ 2 hours
  - Hurricane @ 24 hours
Use and Occupancy

- Minimum net usable floor area per occupant, Community:
  - Tornado
    - Standing or seated = 5 sq.ft.
    - Wheelchair = 10 sq.ft.
    - Bedridden = 30 sq.ft.
  - Hurricane
    - Standing or seated = 20 sq.ft.
    - Wheel Chair = 20 sq.ft.
    - Bedridden = 40 sq.ft.
Use and Occupancy

- Minimum net usable floor area per occupant, Residential:
  - Tornado
    - Standing or seated = 5 sq.ft.
      - Exception for 1&2 Family Dwellings = 3 sq.ft.
    - Wheelchair = 10 sq.ft.
    - Bedridden = 30 sq.ft.
  - Hurricane
    - Standing or seated = 10 sq.ft.
      - Exception for 1&2 Family Dwellings = 7 sq.ft.
    - Wheel Chair = 10 sq.ft.
    - Bedridden = 40 sq.ft.
Use and Occupancy

- **Number of Egress Doors**
  - Determined by normal use as req’d by applicable code
    - “Assembly” use shall apply to single-use shelters
  - Doors must swing in direction of egress

- An emergency escape opening is req’d where two or fewer doors that lead to outside of the shelter swing inward to shelter space
  - Exception for doorways protected from accumulation of debris
Use and Occupancy

- Shelters shall be provided with an accessible route (ANSI A117.1)
- Fire Extinguisher req’d within shelter areas
  - Exception for 1&2 Family Dwellings
Use and Occupancy

- Two-hour *fire barrier* separation req’d between shelter space and other building areas
  - Includes penetrations and openings
  - Exception for 1&2 Family Dwellings
- Exterior walls of storm shelters to be constructed with fire-resistance req’d by applicable code
Essential Features & Accessories

- Signage req’d for both Tornado and Hurricane Shelters, Large & Small
  - Interior signage must direct occupants to shelter areas
  - Signage req’d on inside of shelter area(s)
  - Floor Plan sign req’d in facility manager’s office, inside shelter area & at exits
- Exception for 1&2 Family Dwellings
Essential Features & Accessories

- **Tornado Shelters**
  - Natural Ventilation req'd
  - Ventilation and internal pressure relief may be designed concurrently
  - Two options based on NSSA standard; above ground and below ground cases
  - Outside air intakes to be located 10 ft from noxious contaminant sources
  - Exhaust or intake openings to be protected
Essential Features & Accessories

- **Tornado Shelters**
  - Back-up or emergency gen-sets not required
  - Emergency lighting req’d; avg=1 f.c.
    - Exceptions for small shelters and 1&2 family dwellings; one flashlight per 10 occupants
- **Plumbing/Sanitation**
  - Toilet fixtures: up to 50=1; 51-500=2; then 1 add’l:500
  - Temporary fixtures acceptable
  - Exception for 1&2 Family Dwellings
  - Handwashing facilities not req’d for small; 1:1000 for large
Essential Features & Accessories

- **Tornado Shelters**
  - **Plumbing/Water**
    - No potable or waste water reqm’ts for either large or small shelters
  - **First-aid kit req’d for small and large shelters**
    - Exception for 1&2 Family Dwellings
Essential Features & Accessories

- Hurricane Shelters
  - Natural Ventilation req’d
    - Two options based on NSSA standard; above ground and below ground cases
    - Outside air intakes to be located 10 ft from noxious contaminant sources
    - Exhaust or intake openings to be protected
  - Mechanical ventilation req’d consistent with emergency power system
Essential Features & Accessories

- Hurricane Shelters
  - Emergency power system req’d; system to support occupied spaces, critical support areas & systems:
    - Life safety systems
    - Standby lighting; avg=10 f.c.
    - Standby branch wall circuits
    - Mechanical ventilation circuits
  - Permanent-installed standby gen-sets not required
  - Standby gen-set(s) to be independent of off-site utilities
  - All components of emergency power system to be protected from design event; including temporary gen-set
Essential Features & Accessories

- Hurricane Shelters
  - Standby gen-set to operate continuously for 24 Hours
  - Standby & emergency power system’s access route to be protected from design event
  - Emergency lighting req’d; avg=1 f.c.
    - Exceptions for small shelters and 1&2 family dwellings; one flashlight per 10 occupants
Essential Features & Accessories

- Hurricane Shelters
  - Plumbing/Sanitation
    - Small shelter: One toilet
    - Large Shelter: One toilet/50 occupants
    - Small Shelter: Handwashing facilities not req’d
    - Large Shelter: One Handwashing facility/100 occupants
    - Temporary fixtures acceptable
    - Exceptions for 1&2 Family Dwellings
Essential Features & Accessories

- Hurricane Shelters
  - Plumbing/Water
    - Small shelter: No reqm’ts for potable or waste water
    - Large Shelter: One gallon potable water/occupant
    - Large Shelter: 1 1/2 gallons waste water/occupant
    - Temporary or on-demand resources acceptable
Essential Features & Accessories

- Hurricane Shelters
  - First-aid kit req’d for small and large shelters
    - Exception for 1&2 Family Dwellings
Status

- First committee meeting (May 2003)
- Gather input from scientific, technical, and user communities (ongoing)
- Develop draft standard and publish draft standard for public comment (August 2006)
- Formal, public committee meeting to address all comments (est. late 2006)
- Publish standard (est. mid 2007)
Questions ???