National Storm Shelter Association
and the
Texas Hazard Mitigation Grant Program

Presented to:

Builders and Contractors
Amarillo, Texas
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Presented by:

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Meeting Agenda

- Background on shelter research
- Genesis of National Storm Shelter Association (NSSA)
- How to join NSSA
- Characteristics of extreme winds
- Important considerations in shelter quality
National Storm Shelter Association

Guide to Quality Assurance

Bartlett Shelter, Oklahoma
Fostering Quality in the Storm Shelter Industry
Genesis of Wind Engineering Research

• Began with Lubbock Tornado in 1970
  • 26 killed
  • 1/3 of city damaged

• Studied effects of 140 major storms since 1970
Observations, Conclusions

Small interior room often remains standing even when house is completely destroyed.
Inspiration of the Shelter Concept
In-Residence Shelter Concept
1974

- Design room or module to protect:
  - occupants
  - critical functions
  - critical contents

- Improve building envelope to reduce damage to building and contents
Shelter Options

- Many options available
- *Multiple use* is important in assessing cost
- Shelters available for new construction or retrofit
Shelter Benefits

• *Shelters can be constructed to:*
  - Save Lives
  - Reduce anxiety and suffering
  - Produce economic benefits
Recent Developments in Utilization

- 1997, Jarrell, Texas tornado
- Dateline NBC program; Other media coverage
- 1998, FEMA publication #320
Recent Developments in Utilization

1999

- Above-ground shelter survived F-5 in Oklahoma
- FEMA provided shelter incentives under HMGP

Bartlett Shelter, Oklahoma
Beth Bartlet, her mother Norma Bartlett, two dogs and two cats weathered out the tornado in their safe room.
Oklahoma Grant Program

• Incentive program in Oklahoma served as catalyst for higher level of activity in shelter construction.

• Lack of standards and quality control processes in this new, rapidly emerging industry illuminated many quality issues.
May 8, 2003 Tornado and Locations of Shelters Constructed Under the Oklahoma Safe Room Initiative
Recent Developments in Utilization

- Manufacturers created new products and expanded markets
- Founded the **National Storm Shelter Association**
Functions

Standards
- NSSA Industry Standard
- ICC/NSSA Standard by 2007

Education
Monitor Research
Quality Verification

NSSA Standard
For Design & Construction of Storm Shelters
Description of NSSA

• NSSA in a not-for-profit trade association

• Chartered in Texas as an IRS 501(c) 6

• Self-policing for the benefit of the public and a strong, credible industry
Membership Grades

MEMBER – Shelter Producers
Professional – Designers, Inspectors
Associate – Suppliers
Corporate Sponsor
Individual Sponsor
Shelter Quality Verification Process

1. MEMBER pledge to produce only those shelters that meet or exceed the Standard
2. Abide by NSSA Bylaws and Code of Ethics
3. Obtain third-party approval of design or variations from FEMA 320
4. Test shelter or FEMA 320 variations for debris impact resistance. Use tested door (www.wind.ttu.edu).
5. Affix Seal and file Certificate of Installation with NSSA for each shelter installed
Shelter Quality Verification Process

Home Builders

1. MEMBER Pledge to produce only those shelters that meet or exceed the Standard
2. Abide by NSSA Bylaws and Code of Ethics
3. Build from FEMA 320; Obtain third-party compliance check for variations
4. Alternative: Install manufactured shelter from NSSA MEMER
5. Affix Seal and file Certificate of Installation with NSSA for each shelter installed
Shelter Quality Verification Process

Manufacturers/Fabricators

1. MEMBER Pledge to produce only those shelters that meet or exceed the Standard
2. Abide by NSSA Bylaws and Code of Ethics
3. Obtain third-party compliance check of design
4. Test shelter for debris impact resistance
5. Affix Seal and file Certificate of Installation with NSSA for each shelter installed
Shelter Benefits

• **Quality Shelters**
  – Save Lives
  – Reduce anxiety and suffering
  – Produce economic benefits
    • Producers -- Improved marketability, enhanced reputation
    • Owners – Higher resale; avoid costs of evacuation

“We do not advocate that shelters be mandatory, but those that are built should be of high quality.”

_Ernst W. Kiesling_
Benefits of Membership

- Increased credibility, distinction
  - Identification with quality
    - Added value of seal
    - Decreased liability
      - Peace of mind, knowing you have “done it right”
        - Professional listings
        - “Head start” on inspections
        - Qualification for grants
How to Join

• Get application materials from web www.NSSA.cc or
• Call headquarters (806) 742-6772 or 1 (877) 700-NSSA (6772) to
• Request forms: Application, Pledge, Third-party Evaluation, Request for Testing Services
Information on Tested Products

• Texas Tech University
  Wind Science and Engineering Research Center
  www.wind.ttu.edu
  (TTU) WIND CTR
  1 (888) 946 - 3287
Important Considerations In Storm Shelter Quality

There are many elements of quality to lead to good performance. Major considerations are:

• **Structural integrity** to withstand external forces
  – Wind-induced pressures for all shelters
  – Hydrostatic pressures for underground shelters
  – Anchorage for above-ground shelters
  – Anchorage or ballast for underground shelters

• **Debris impact resistance** for all exposed surfaces
  • Includes doors for all shelters

• Access and egress

• Ventilation
Questions on NSSA

???????????????
Experiencing Extreme Winds

- **TORNADOES**
  strike terror wherever they occur
Experiencing Extreme Winds

- **Severe Weather Watches and Warnings** Lead to *Anxiety*
- Each year, over three billion person-hours are spent under severe weather watches
REPORTED TORNADOES PER YEAR
THREE-DIMENSIONAL TORNADO WIND VELOCITY COMPONENTS

Zone or strip of highest wind speed is rather narrow

Most damage occurs in wide zone of lower wind speeds
VARIATION OF WIND SPEED WITH HEIGHT

<table>
<thead>
<tr>
<th>Height (m)</th>
<th>Height (ft)</th>
</tr>
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<tbody>
<tr>
<td>600</td>
<td>2000</td>
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<tr>
<td>500</td>
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<tr>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>100</td>
<td>0</td>
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</tbody>
</table>

* Power-law
* Log-law
POWER LAW PROFILES
Observations, Early Contributions

• Observed maximum ground-level wind speed about 200 mph
  • Less than 150 mph in more than 90 percent of tornadoes
    – Adopted design wind speed 250 mph for shelters

• Observed most common debris to be a 2 x 4 board up to 14 feet long (15 lb.)
Design Wind Speeds

• Shelters designed for ground-level wind speeds 250 mph
• Fujita Scale developed without proper accounting of building type, quality
• Doppler radar measures wind speed at some height above ground level
Atmospheric Pressure Change (APC)

- Rotating winds create low pressure near center of storm
- Maximum APC is less than 3 psi in the most intense tornado
- Affects structures slowly; partially relieved by natural venting
- Required venting of residential shelters relieves APC
More on Design Wind Speeds

• Why not design all buildings for higher wind speeds, say 300 mph?
Wind Loads on Buildings

- Intensity is proportional to square of wind speed
  \[ p = \frac{1}{2} \rho V^2 \]
- Loads act on all exposed surfaces, including doors
Wind Speeds vs. Pressures

\[ p = \frac{1}{2} \rho V^2 \]

<table>
<thead>
<tr>
<th>Wind Speeds</th>
<th>Pressure Magnification</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 mph</td>
<td>1.0</td>
</tr>
<tr>
<td>125 mph</td>
<td>1.56</td>
</tr>
<tr>
<td>150 mph</td>
<td>2.25</td>
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<tr>
<td>200 mph</td>
<td>4.0</td>
</tr>
<tr>
<td>250 mph</td>
<td>6.25</td>
</tr>
<tr>
<td>350 mph</td>
<td>12.25</td>
</tr>
</tbody>
</table>
Observation

- It is not affordable to design building envelopes, including doors, windows, and roofs/ceilings, to withstand 250 mph winds.

- We can, and do, design for 100 mph winds with a factor of safety of about 1.5.

- We can reduce damage and economic loss by designing for relevant hazards and by exceeding code requirements (without substantial increases in cost).
Design Approach

- Design storm shelter to protect occupants even if house is totally destroyed
  - Should not be strongly connected

- Improve building envelope to reduce damage to building and contents
Wind-Induced Pressures on Buildings

• Pressures are generally outward, even in a straight wind

• Atmospheric pressure change and large opening on windward side increase outward pressures

• Uplift on roof or horizontal door is significant
Wind pressures on building with no openings
Wind pressures on a building with an opening on the windward side.
Wind Pressures On Roof And Walls

Wind pressure on roof. Internal pressure adds to roof uplift.

Wind pressure on walls. Internal pressure adds to wall suction.
Wind Loads on Buildings

- Intensity is proportional to square of wind speed
  \[ p = p(V^2) \]
- Loads act on all exposed surfaces, including doors
Wind Damage
Most Likely Failures of Aboveground Shelters

- Roof Failure
  - Bending of roof membrane
  - Separation of roof to wall connection
- Wall failure in bending
- Wall-to-floor or wall-to-foundation failure
- Foundation failure
- Door failure from pressure or debris impact
Critical Considerations In Shelter Design and Constructions

Connections!

- Wall-to-floor
- Storey-to-storey
- Roof-to-wall
- Roof ridges
Shelter Design Requirements

- For **safety**, shelter must have:
  - *Anchorage* to prevent overturning, sliding, or floatation
  - *Structural strength* to withstand wind forces
  - “**Hardness**” to prevent perforation by debris
Overturning Tendency

Overturning of shelter
Height Effect on Overturning

\[(M_A)_8 = F_8 (4') = 4F_8\]

\[(M_A)_{10} = 1.25F_8 (5') = 6.25F_8\]
Height Effect on Overturning

\[(M_A)_8 = F_8 \text{ (4') } = 4F_8\]

\[(M_A)_{10} = 1.5F_8 \text{ (6') } = 9F_8\]
Height Effect on Overturning

8 FT \((M_A)_8 = F_8 (4') = 4F_8\)
10 FT \((M_A)_{10} = 1.25F_8 (5') = 6.25F_8\)
12 FT \((M_A)_{12} = 1.5F_8 (6') = 9F_8\)

\[
\frac{(M_A)_{10}}{(M_A)_8} = 1.56
\]

\[
\frac{(M_A)_{12}}{(M_A)_8} = 2.25
\]
Sliding of shelter
Shelter Design Requirements

• **For safety**, shelter must have:
  
  – *Anchorage* to prevent overturning, sliding, or floatation
  
  – *Structural strength* to withstand wind forces
  
  – “*Hardness*” to prevent perforation by debris
Failure of Building at the wall-to-floor connection
Failure of building at the roof-to-wall connection
Failure of building through ridge separation
Roof-Wall Connection

Lubbock
1970
Roof-Wall Connection
Bending of the shelter
Wall Failure - Bending
Wall Failure - Bending
Leeward wall failure
Most Likely Failures of Underground Shelters

- Distress or buckling of walls or floor from hydrostatic pressure
- Floatation due to hydrostatic pressure
- Door failure from pressure or debris impact
Shelter Design Requirements

• For safety, shelter must have:
  – *Anchorage* to prevent overturning, sliding, or floatation
  – *Structural strength* to withstand wind forces
  – *“Hardness”* to prevent perforation by debris
Design Criteria for Occupant Protection

- **Design wind speed**
  250 mph at ground level

- **Debris impact criterion** (corresponding to 250 mph wind speed)
  15 lb. 2 x 4 board traveling at 100 mph
Observations, Conclusions

Debris is abundant in urban areas, often perforating building envelope
Debris--Xenia, OH School
Some debris gets inside!
Conclusion re: Testing

• We cannot predict or calculate the resistance of walls, doors, or roofs to debris impacts

• There is only a meager science base in this developing technology

• We therefore resort to full-scale testing
Missile Impact Simulation
Successful Performance
Designs for New Construction

- Reinforced Concrete
Impact Resistant Walls

Reinforced Concrete Systems
Designs for New Construction

- Reinforced CMU’s or ICF’s
Impact Resistant Walls

Concrete Masonry Unit Systems
Designs for New Construction

• Reinforced Brick Cavity
Impact Resistant Walls

Composite Wall System

Concrete Fill

Brick Masonry

#4 Rebar @ 12" o.c. (Vertical and Horizontal)
Impact Resistant Walls

Wood Systems
Important Considerations
In Door Swing

• Outward wind pressures are about the same as inward pressures

• Let function dictate the direction of swing on doors
Important Considerations In Door Selection

• At least one door meeting FEMA 320 specifications has failed to meet the debris impact test.

Important

• Use tested door (www.wind.ttu.edu) or have your door tested.
Important Considerations In Shelter Construction -- Doors

- Steel doors with 14 gage skins and (internal) steel lock-side channel are adequate

- Three dead-bolt latches are required, preferably at about the hinge levels
Important Considerations In Shelter Construction -- Doors

- Lighter doors must be modified with a supplemental steel plate.
Important Considerations In Shelter Construction -- Doors

- Plywood/steel sliding pocket door is an alternative
Shelter Options
With Slabs or Foundations

- Closet
- Bathroom
- Study
- Utility room
- Basement
- Underground

Multiple use is important in assessing cost

Works for new construction or retrofit
Shelter Concepts

for aboveground homes without foundations
Front Porch Shelter
Front Porch Shelter
Steps/Shelter

Concept one
National Consensus Standard

An agreement has been signed with the International Code Council to develop a ICC/NSSA National Consensus Standard For Storm Shelters
Information Sources

• Federal Emergency Management Agency (FEMA)
  www.fema.gov/MIT/tfs01.html

• “Taking Shelter from the Storm” booklet #320
  1-888-565-3896

• “Design and Construction Guidance for Community Shelters”,
  FEMA 361
  1 (800) 480-2520
Questions to Ask; Things to Look For

- Is the shelter adequately vented to provide breathing air for maximum occupancy and to relieve atmospheric pressure changes?
- Do the locking mechanisms engage and disengage without undue force?
- Can the locks be operated from the outside?
- Is the door provided with three heavy-duty hinges capable of withstanding wind-induced forces?
- Is the door frame capable of carrying the wind forces and adequately connected to the structure?
Questions to Ask; Things to Look For

• Have all exposed elements been tested for debris impact resistance?
• Are the vents protected from intrusion of wind-borne debris?

• *Is the shelter and/or door listed on the Texas Tech web site?*

www.wind.ttu.edu
Questions to Ask; Things to Look For
In Underground Shelters

• Has the door been designed to handle hydrostatic pressures and velocity (uplift) pressures?
• Is the shelter ballasted to prevent uplift from buoyancy of saturated soils?
• Has the structure been designed to handle hydrostatics pressures?
• Is the shelter adequately sealed to prevent water leakage?
Questions to Ask; Things to Look For in Underground Shelters

• Is the shelter designed to resist deterioration from moisture and/or corrosive soils?
• Are the vents protected from intrusion of wind-borne debris?
• Do the steps or ladders comply with the NSSA standard or OASHA standards?
Information Sources - TTU

- Texas Tech University
  Wind Engineering Research Center
  www.wind.ttu.edu
  (TTU) WIND CTR
  (888) 946 - 3287
Information Sources

National Storm Shelter Association

www. NSSA.cc

1 (877) 700 - 6772 (NSSA)

For Testing

(806) 742 - 6772 (NSSA)
Thank you for your interest!

Please join with us in fostering shelter quality