Tornadoes and Storm Shelters: Update on FEMA Design Guides

Resilient Housing Session 2
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Design Guidance

Taking Shelter from the Storm
Building a Safe Room for Your Home or Small Business
Includes Construction Plans

Safe Rooms for Tornadoes and Hurricanes
Guidance for Community and Residential Safe Rooms
FEMA P-361, Third Edition / March 2015

ICC/NSSA STANDARD
FOR THE DESIGN AND
CONSTRUCTION OF
STORM SHELTERS
ICC 500-2008
American National Standard
Annual Fatalities from Tornadoes
Hurricane tracks 1958-2011
Annual Fatalities from Hurricanes
Increasing Cost of Disasters
Safe Rooms and Storm Shelters

- Protect occupants
- Near absolute protection from injury or death
- Use a functional room inside the building:
  - Closet
  - Gymnasium
  - Storage area

Up to 16 people (FEMA 320 or 361)

Typically more people (FEMA 361)
Assessing Risk
<table>
<thead>
<tr>
<th>WIND ZONE</th>
<th>RISK</th>
<th>GUIDANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Low Risk</td>
<td>Need for an extreme-wind safe room is a matter of homeowner or small business owner preference</td>
</tr>
<tr>
<td>II</td>
<td>Moderate Risk</td>
<td>Safe room should be considered for protection from extreme winds</td>
</tr>
<tr>
<td>III and IV</td>
<td>High Risk</td>
<td>Safe room is the preferred method of protection from extreme winds</td>
</tr>
<tr>
<td>Hurricane-Prone Region</td>
<td>High Risk</td>
<td>FEMA recommends that all potential safe room occupants comply with local jurisdictional directions and evacuation orders during an emergency event, even if they have constructed a safe room.</td>
</tr>
</tbody>
</table>
Designing a Safe Room/Storm Shelter

- Design main building
  - IBC/IRC
  - ASCE 7 Wind Loads

- Design storm shelter
  - Select best location
  - Flying debris
  - Design wind loads per
    - FEMA 320
    - FEMA 361
    - ICC 500
Select Location
Above Flood Elevation

NOTE:
- The flood elevation corresponding to the highest recorded flood elevation need not apply when a flood hazard study has been completed.
- The flood elevation corresponding to the maximum flood elevation associated with any modeled hurricane category, including coastal wave effects, does not need to be considered when the safe room is designed, constructed, designated, and used only as a tornado safe room.

Denotes minimum acceptable safe room elevation.

NOTE:
- The flood elevation corresponding to the highest recorded flood elevation need not apply when a flood hazard study has been completed.
- The flood elevation corresponding to the 0.2-percent-annual chance of being equaled or exceeded, including coastal wave effects, does not need to be considered when the safe room is designed, constructed, designated, and used only as a tornado safe room.

Denotes minimum acceptable safe room elevation.
Design for Flying Debris
### Hurricanes

<table>
<thead>
<tr>
<th>SAFE ROOM DESIGN WIND SPEED</th>
<th>MISSILE SPEED (OF 9-POUND 2X4 BOARD MEMBER) AND SAFE ROOM IMPACT SURFACE</th>
</tr>
</thead>
</table>
| 235 mph                     | Vertical Surfaces: 118  
                              | Horizontal Surfaces: 24 mph                                             |
| 230 mph                     | Vertical Surfaces: 115 mph  
                              | Horizontal Surfaces: 23 mph                                             |
| 220 mph                     | Vertical Surfaces: 110 mph  
                              | Horizontal Surfaces: 22 mph                                             |
| 210 mph                     | Vertical Surfaces: 105 mph  
                              | Horizontal Surfaces: 21 mph                                             |
| 200 mph                     | Vertical Surfaces: 100 mph  
                              | Horizontal Surfaces: 20 mph                                             |
| 190 mph                     | Vertical Surfaces: 95 mph   
                              | Horizontal Surfaces: 19 mph                                             |
| 180 mph                     | Vertical Surfaces: 90 mph   
                              | Horizontal Surfaces: 18 mph                                             |
| 170 mph                     | Vertical Surfaces: 85 mph   
                              | Horizontal Surfaces: 17 mph                                             |
| 160 mph                     | Vertical Surfaces: 80 mph   
                              | Horizontal Surfaces: 16 mph                                             |

### Tornados

<table>
<thead>
<tr>
<th>SAFE ROOM DESIGN WIND SPEED</th>
<th>MISSILE SPEED (OF 15-POUND 2X4 BOARD MEMBER) AND SAFE ROOM IMPACT SURFACE</th>
</tr>
</thead>
</table>
| 250 mph                     | Vertical Surfaces: 100 mph  
                              | Horizontal Surfaces: 67 mph                                             |
| 200 mph                     | Vertical Surfaces: 90 mph  
                              | Horizontal Surfaces: 60 mph                                             |
| 160 mph                     | Vertical Surfaces: 84 mph  
                              | Horizontal Surfaces: 56 mph                                             |
| 130 mph                     | Vertical Surfaces: 80 mph  
                              | Horizontal Surfaces: 53 mph                                             |

### Residential Safe Rooms

<table>
<thead>
<tr>
<th>SAFE ROOM DESIGN WIND SPEED</th>
<th>TEST MISSILE SPEED (OF 15-POUND 2X4 BOARD MEMBER) AND SAFE ROOM IMPACT SURFACE</th>
</tr>
</thead>
</table>
| 250 mph                     | Vertical Surfaces: 100 mph  
                              | Horizontal Surfaces: 67 mph                                             |
Tornado Cannon
Concrete Systems Tested

a. Reinforced concrete wall, at least 6 inches thick, reinforced with #4 rebar every 12 inches both vertically and horizontally.

b. Insulated concrete form (ICF) flat wall assembly at least 4 inches thick, reinforced with #4 rebar every 12 inches both vertically and horizontally.

Note: These wall assemblies may be impacted on either face.

a. Fully grouted 6 inch CMU with #4 rebar spaced at 32 inches on center (o.c.) and at every opening and each corner.

b. Fully grouted 8 inch CMU with #5 rebar spaced at 48 inches on center (o.c.) and at every opening and each corner.
## Structural Design

<table>
<thead>
<tr>
<th>ICC 500 REFERENCE</th>
<th>ICC 500 REQUIREMENT FOR STORM SHELTERS</th>
<th>FEMA RECOMMENDED CRITERIA FOR SAFE ROOMS&lt;sup&gt;(a)&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Section 304.2</strong></td>
<td>For tornado shelters, the design wind speed shall be in accordance with Figure 304.2(1). For hurricane shelters, the design wind speed shall be in accordance with Figure 304.2(2).&lt;sup&gt;(b)&lt;/sup&gt;</td>
<td>For all residential safe rooms, the design wind speed shall be 250 mph, regardless of location.</td>
</tr>
</tbody>
</table>

**Bolded text** denotes differences between the ICC 500 Requirement and the FEMA Recommended Criteria.

**Table notes:**

(a) Table only lists differences between FEMA P-361 and ICC 500 Chapter 3. All ICC 500 Chapter 3 requirements not listed in the table should also be met in their entirety.

(b) ICC 500 tornado wind speeds for all storm shelters range from 130 mph to 250 mph. ICC 500 hurricane wind speeds for all storm shelters range from 160 mph to 235 mph.
Select Wind Speed

Notes:
1. Values are nominal three-second gust wind speeds in miles per hour at 33 feet above ground for Exposure Category C.
2. Multiply miles per hour by 0.447 to obtain meters per second.
Loading
Clara Barton Hospital
Hoisington, KS
EF-4 tornado, April 2001
Coming Soon

Design Guide 3, *Tornado Design for Buildings*
Thank you