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# Tornadoes and Storm Shelters: Update on FEMA Design Guides

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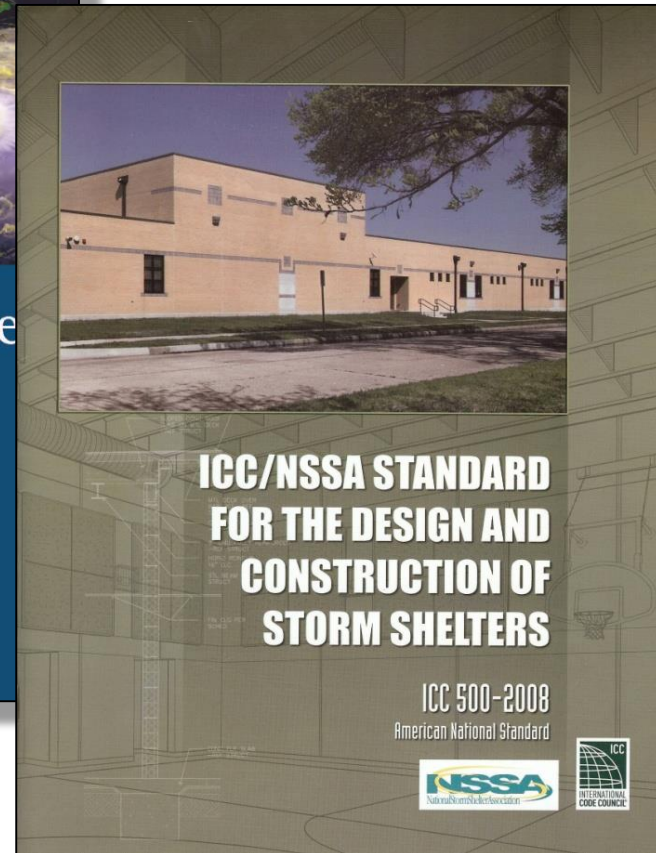
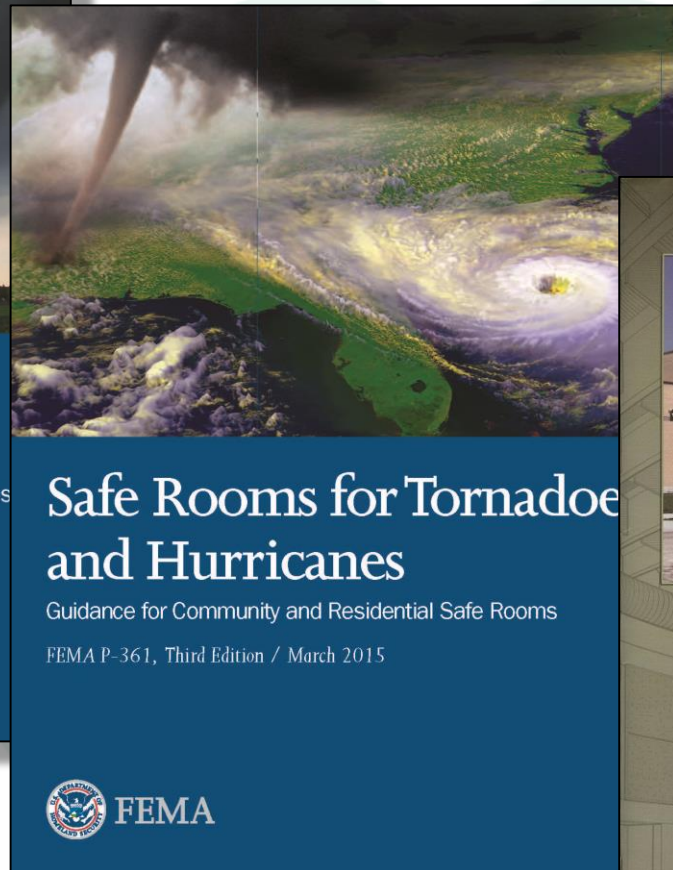
Resilient Housing Session 2

April 15, 2015

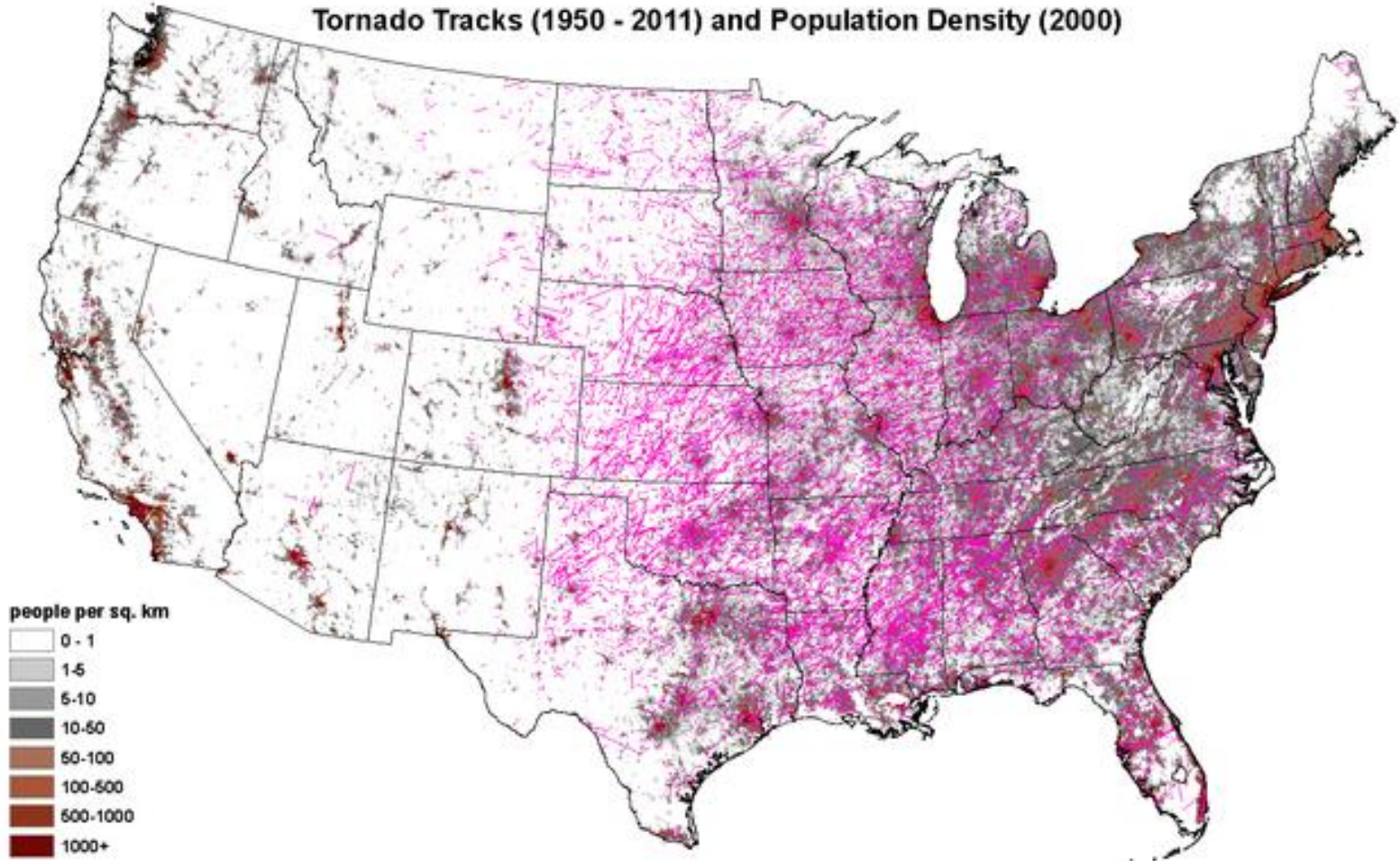
Lionel Lemay, NRMCA



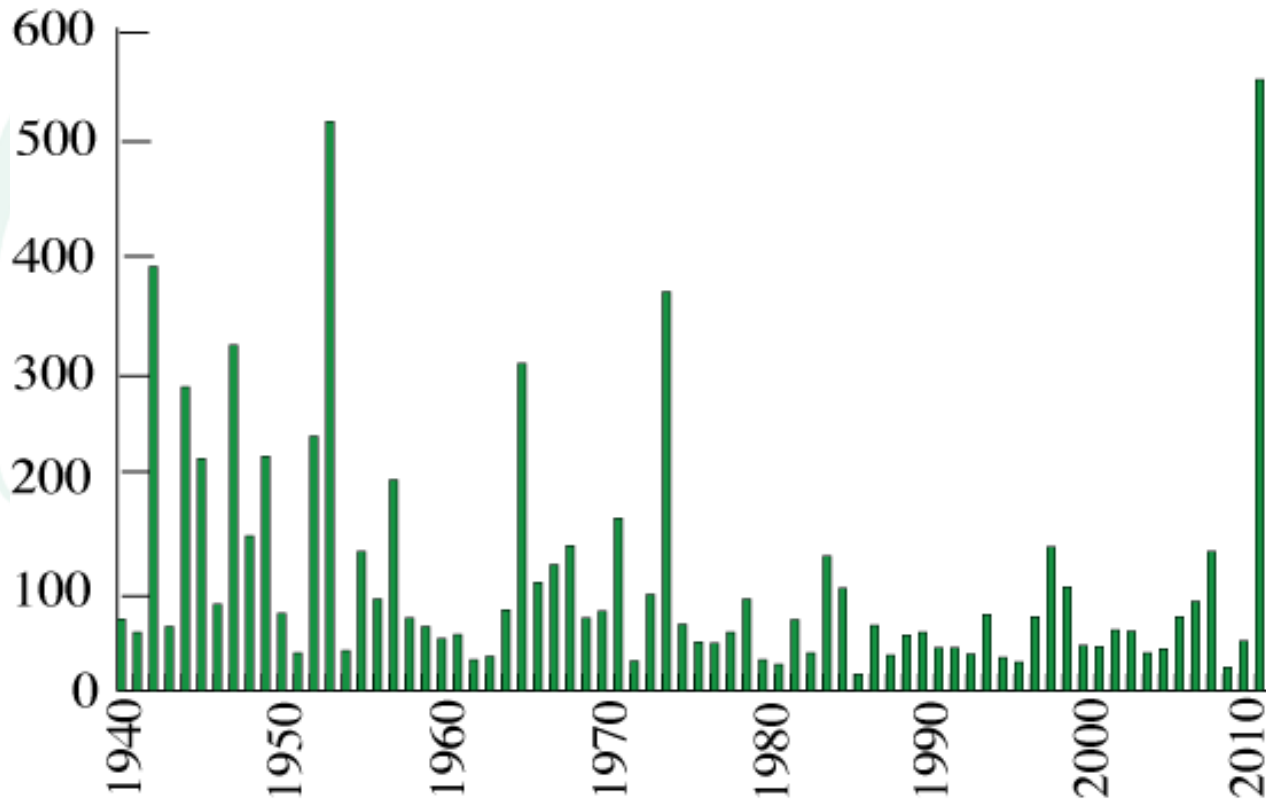
# Design Guidance



Tornado Tracks (1950 - 2011) and Population Density (2000)

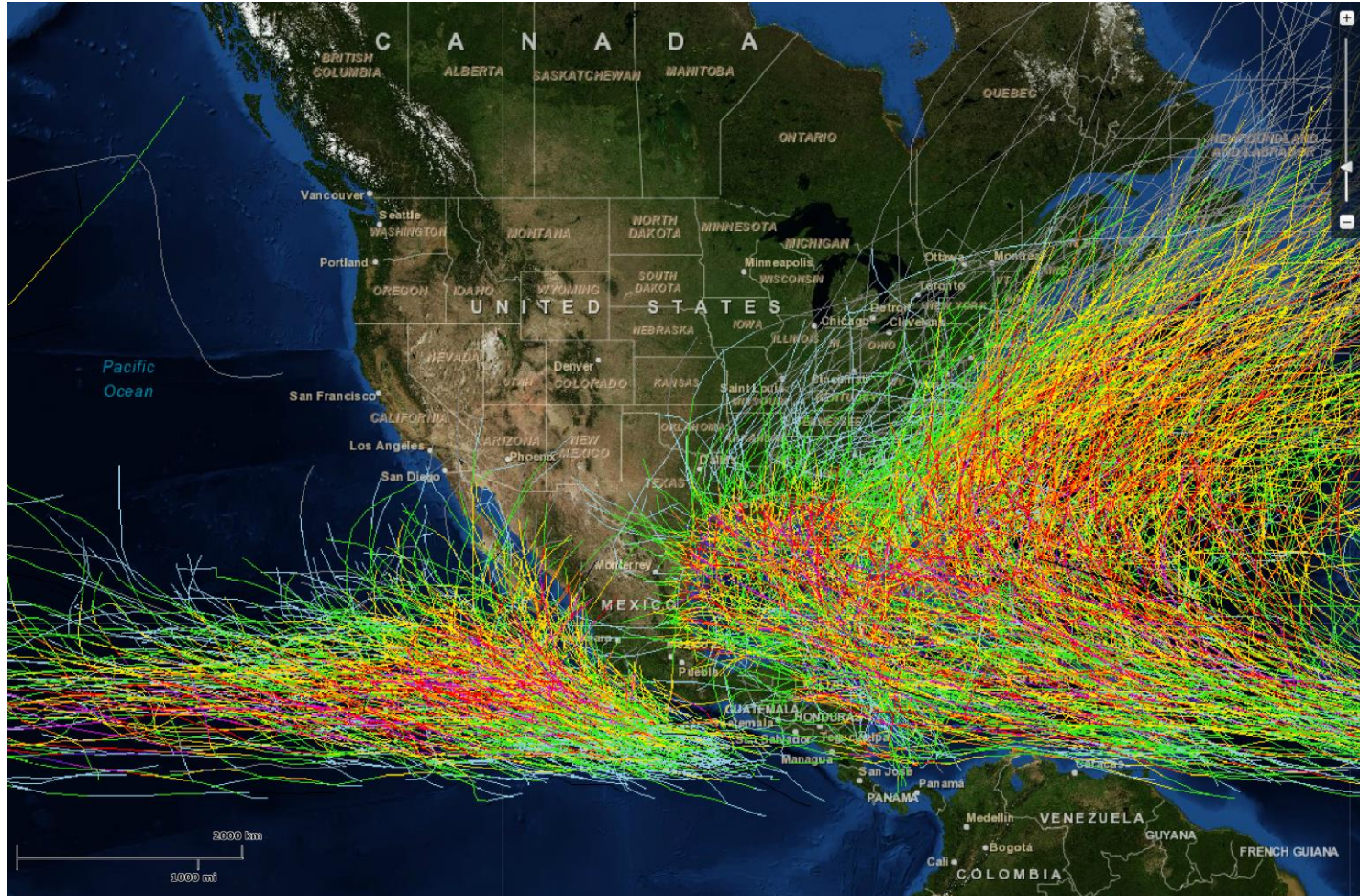


## Annual Fatalities from Tornadoes

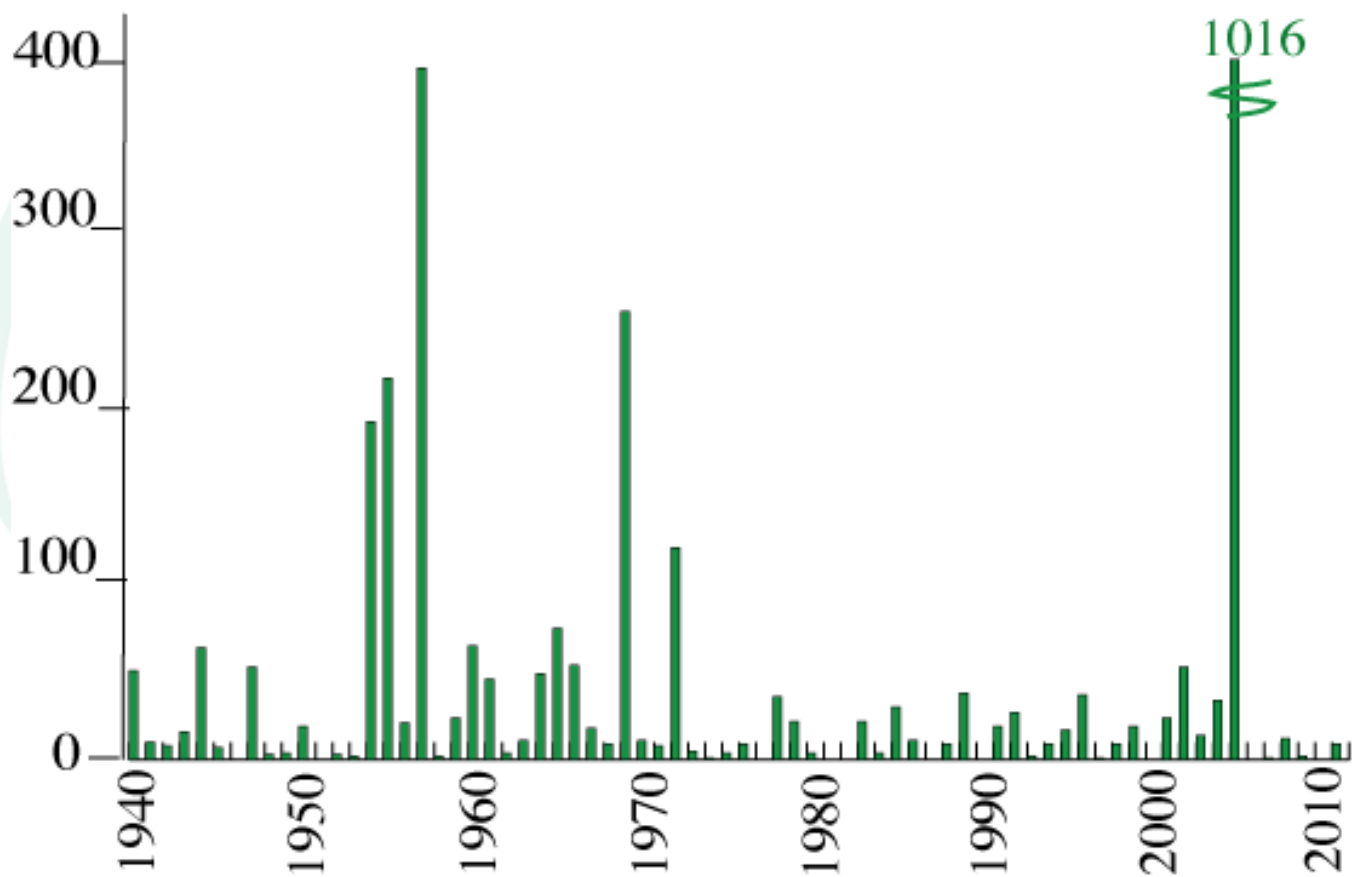




# Hurricane tracks 1958-2011



## Annual Fatalities from Hurricanes









**Hurricane damage**

**Tornado damage**





# 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

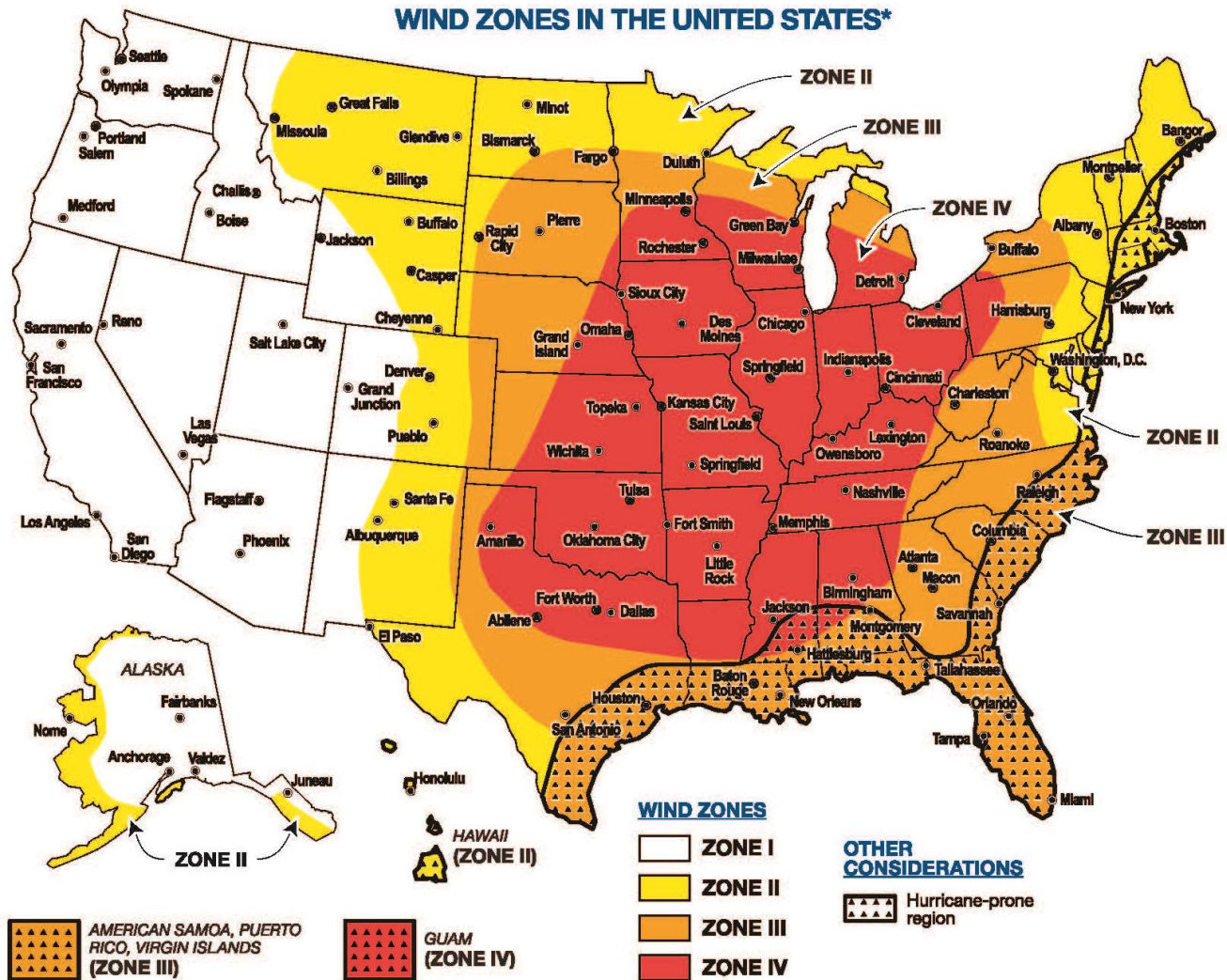


Up to 16 people (FEMA 320 or 361)



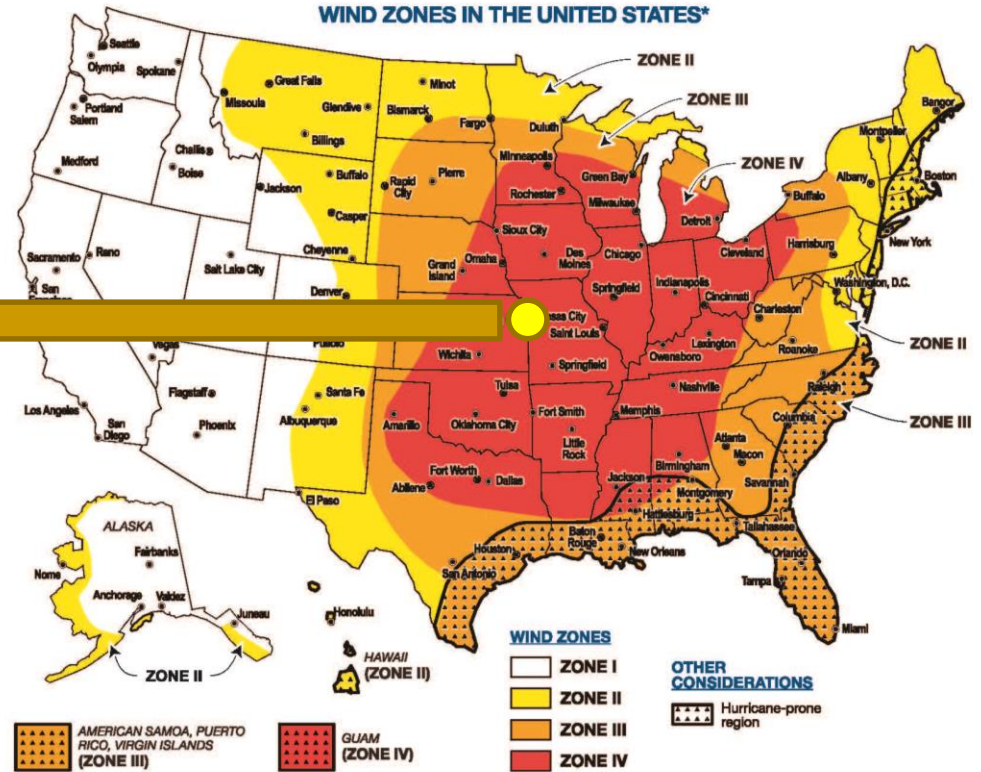
Typically more people (FEMA 361)

# Assessing Risk





## WIND ZONES IN THE UNITED STATES\*

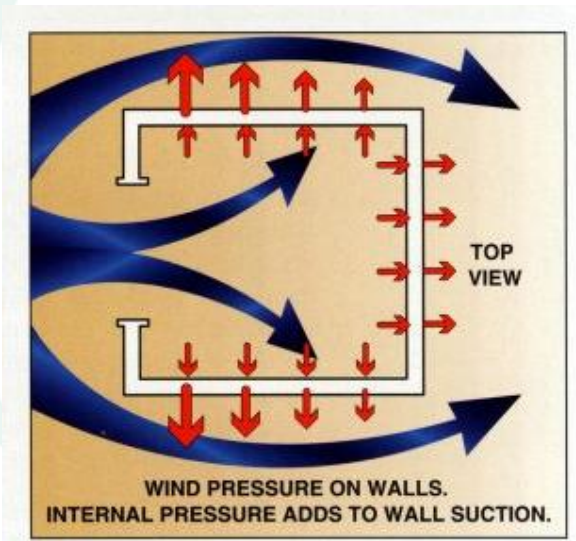
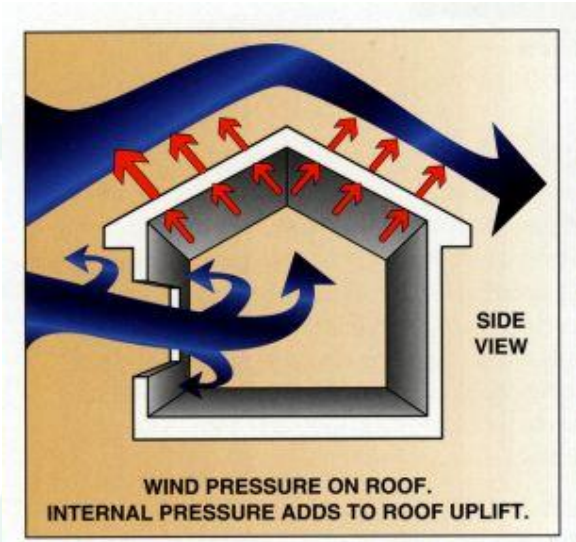


WIND ZONE	RISK	GUIDANCE
I	Low Risk	Need for an extreme-wind safe room is a matter of homeowner or small business owner preference
II	Moderate Risk	Safe room should be considered for protection from extreme winds
III and IV	High Risk	Safe room is the preferred method of protection from extreme winds
Hurricane-Prone Region	High Risk	Safe room is the preferred method of protection from extreme winds. 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.

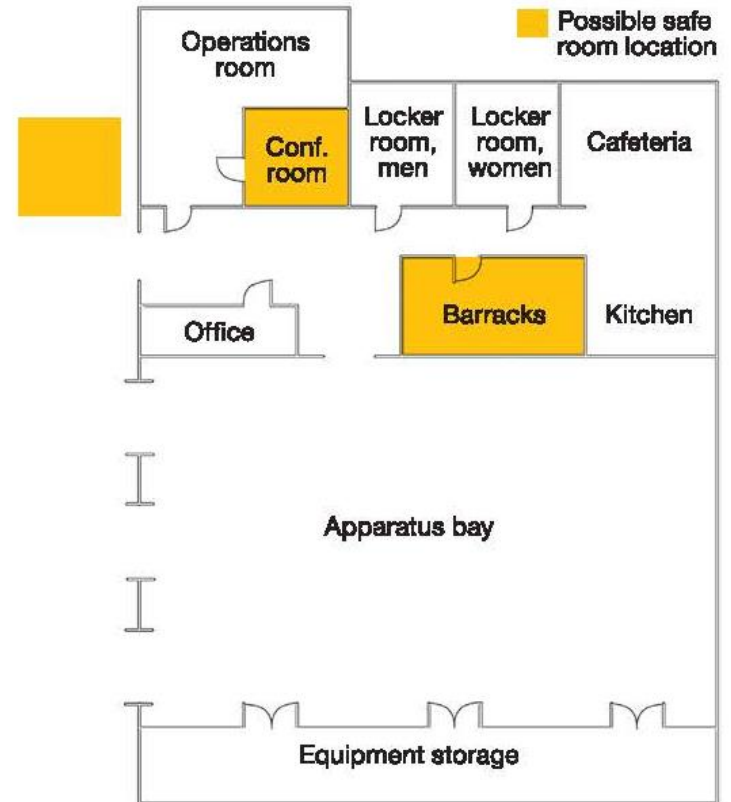
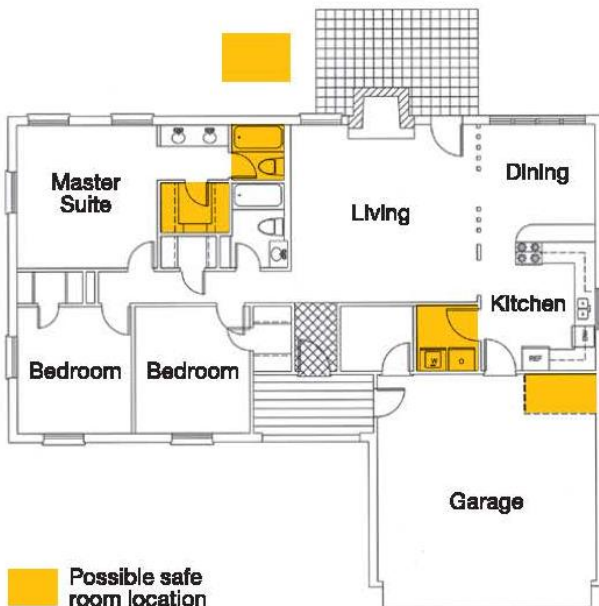
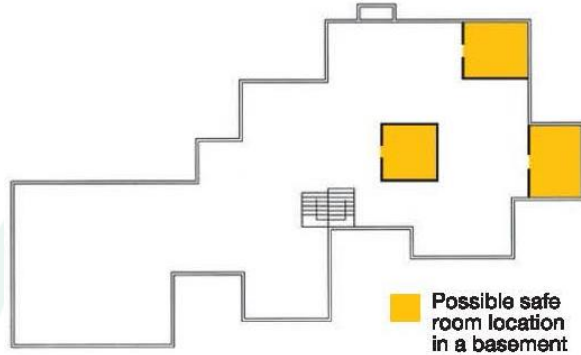


# Designing a Safe Room/Storm Shelter

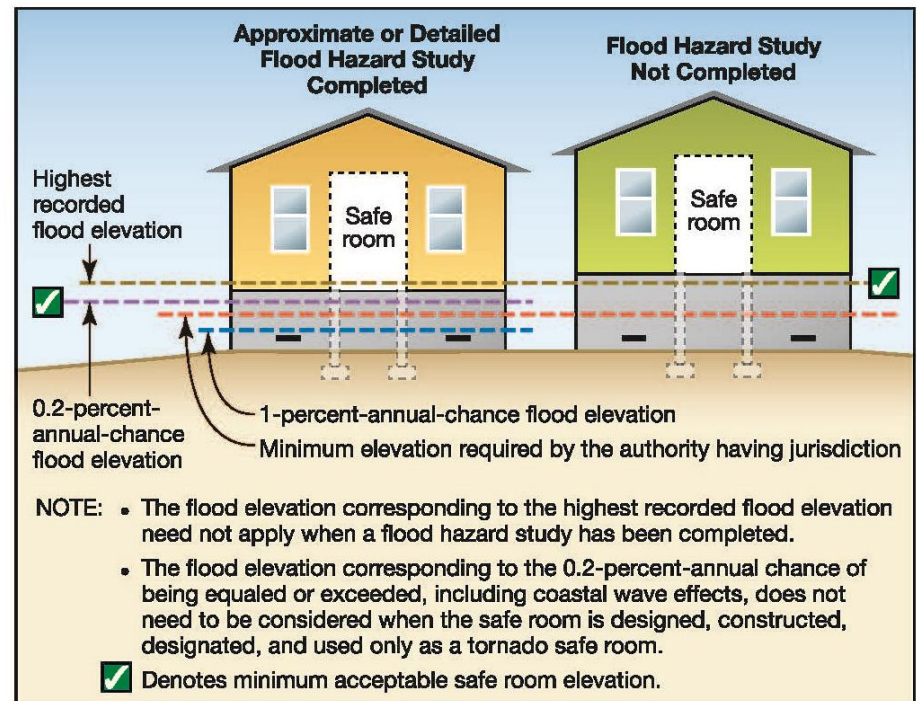
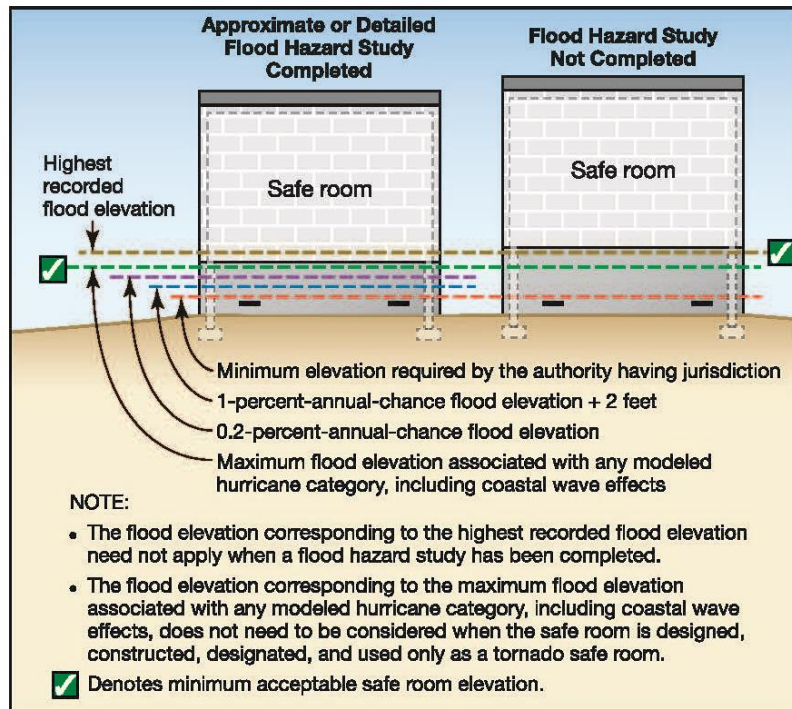
- Design main building
  - IBC/IRC
  - ASCE 7 Wind Loads
- Design storm shelter
  - Select best location
  - Flying debris
  - Design wind loads per
    - FEMA 320
    - FEMA 361
    - ICC 500



# Select Location



# Above Flood Elevation





# Design for Flying Debris



# Hurricanes

SAFE ROOM DESIGN WIND SPEED	MISSILE SPEED (OF 9-POUND 2X4 BOARD MEMBER) AND SAFE ROOM IMPACT SURFACE
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

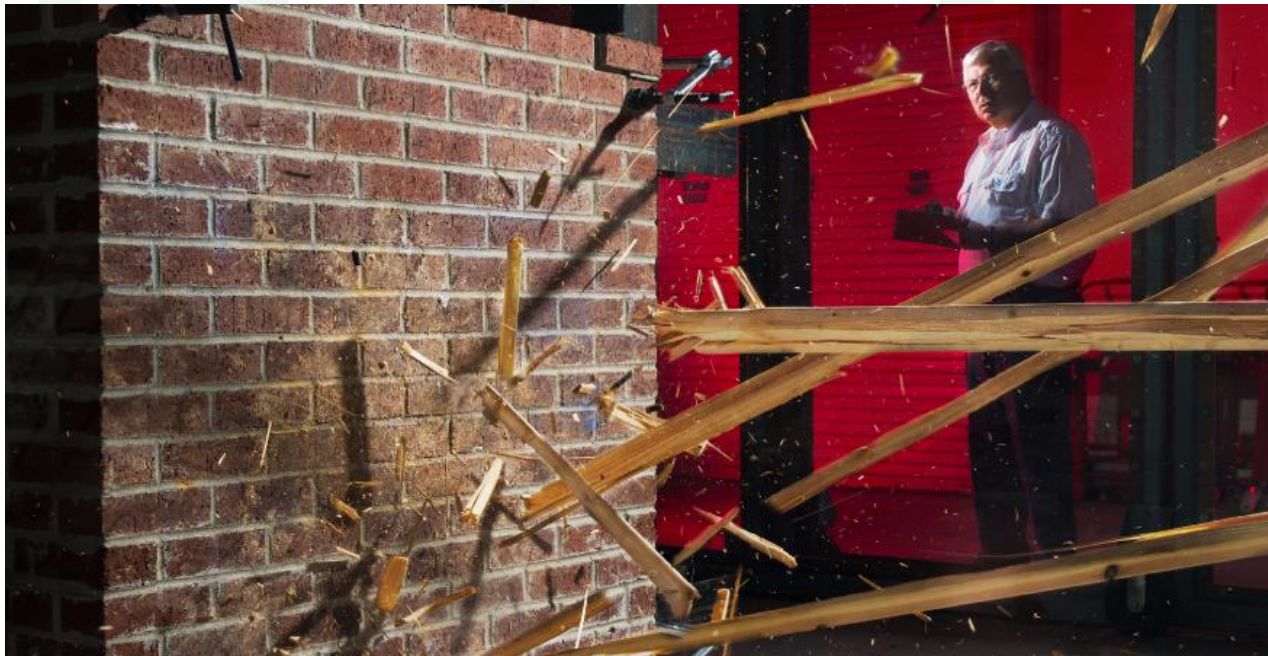
SAFE ROOM DESIGN WIND SPEED	MISSILE SPEED (OF 15-POUND 2X4 BOARD MEMBER) AND SAFE ROOM IMPACT SURFACE
250 mph	Vertical Surfaces: 100 mph Horizontal Surfaces: 67 mph
200 mph	Vertical Surfaces: 90 mph Horizontal Surfaces: 60 mph
160 mph	Vertical Surfaces: 84 mph Horizontal Surfaces: 56 mph
130 mph	Vertical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

# Residential Safe Rooms

SAFE ROOM DESIGN WIND SPEED	TEST MISSILE SPEED (OF 15-POUND 2X4 BOARD MEMBER) AND SAFE ROOM IMPACT SURFACE
250 mph	Vertical Surfaces: 100 mph Horizontal Surfaces: 67 mph



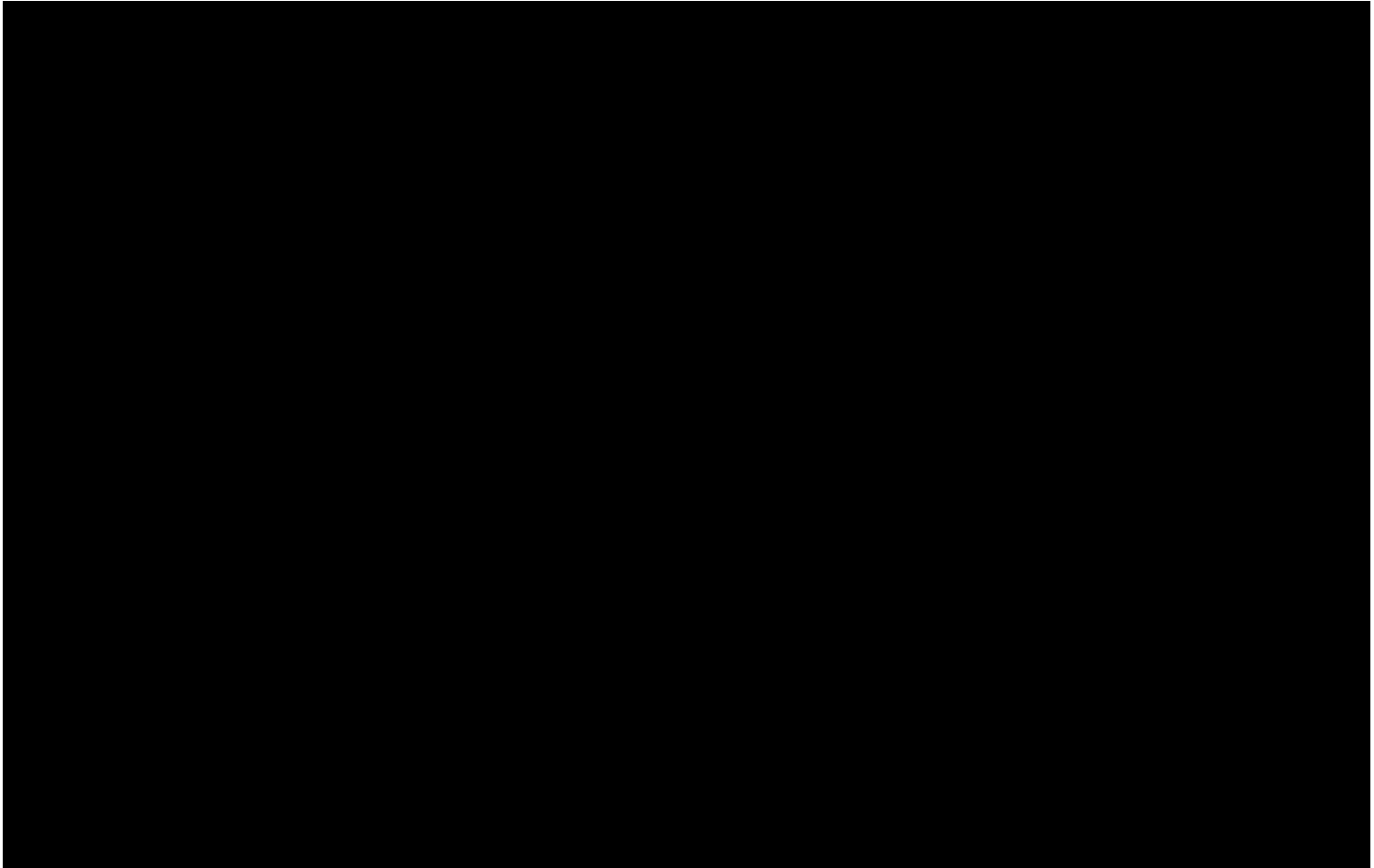
# Tornado Cannon





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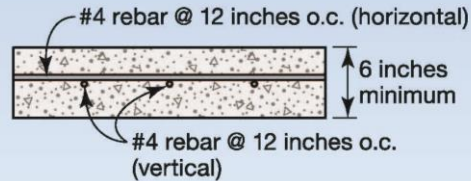
# Tornado Cannon Video



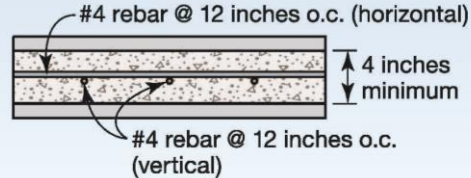
Courtesy PCA and PCI

# Concrete Systems Tested

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

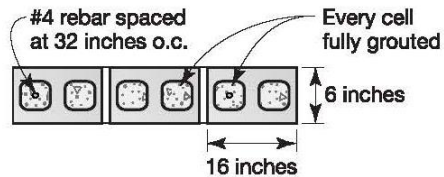


- b** Insulated concrete form (ICF) flat wall assembly at least 4 inches thick, reinforced with #4 rebar every 12 inches both vertically and horizontally

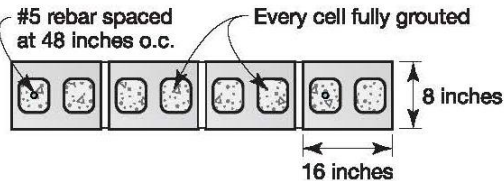


Note: These wall assemblies may be impacted on either face.

- 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

ICC 500 REFERENCE	ICC 500 REQUIREMENT FOR STORM SHELTERS	FEMA RECOMMENDED CRITERIA FOR SAFE ROOMS <sup>(a)</sup>
<b>Section 304.2 Design Wind Speed</b>	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). <sup>(b)</sup>	<b>For all residential safe rooms, the design wind speed shall be 250 mph, regardless of location.</b>

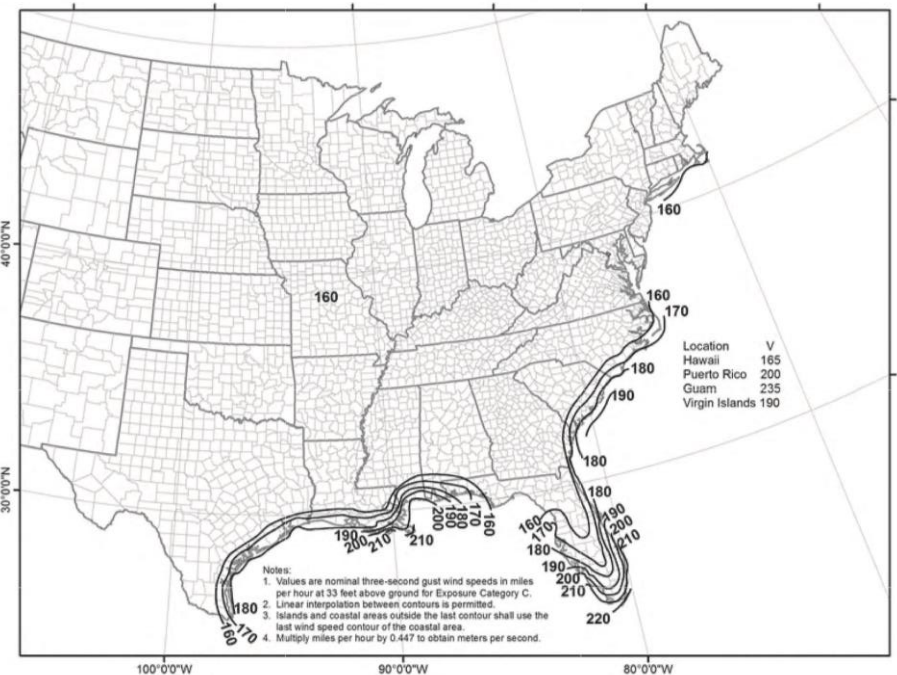
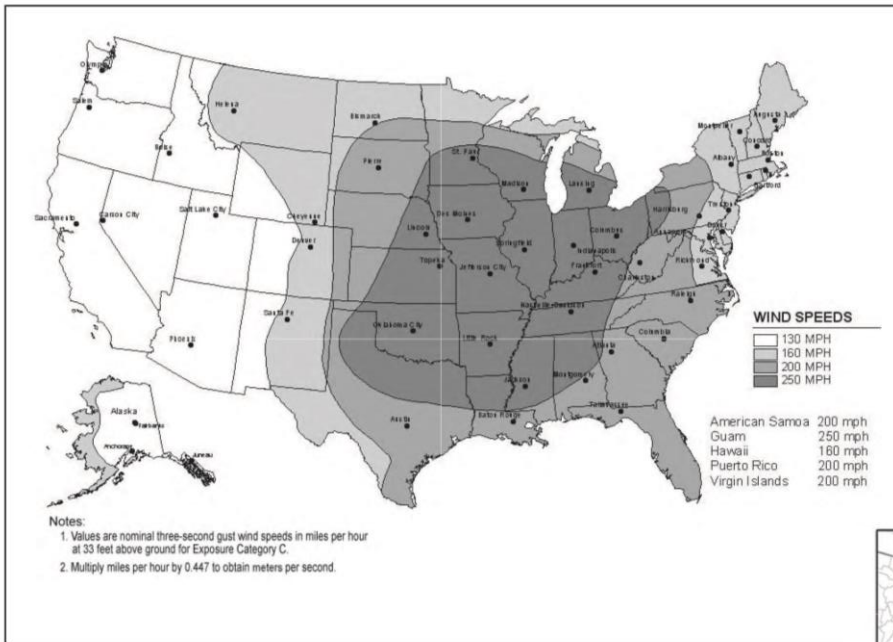
**Bolded text** denotes differences between the ICC 500 Requirement and the FEMA Recommended Criteria.

Table notes:

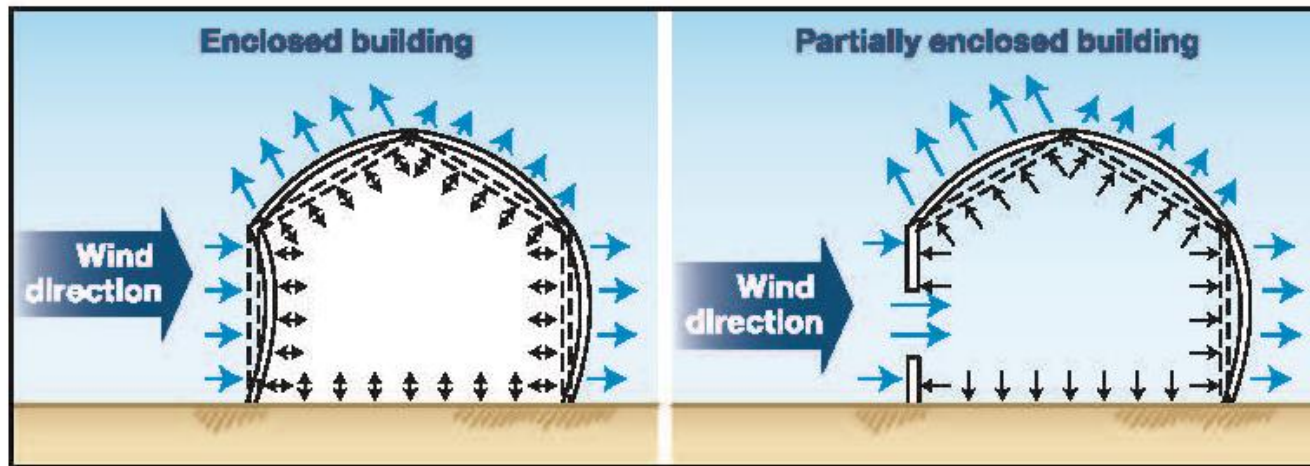
- (a) Table only lists differences between FEMA P-361 and ICC 500 Chapter 3. All ICC 500 Chapter 3 requirements not listed in the table should also be met in their entirety.
- (b) ICC 500 tornado wind speeds for all storm shelters range from 130 mph to 250 mph. ICC 500 hurricane wind speeds for all storm shelters range from 160 mph to 235 mph.



# Select Wind Speed



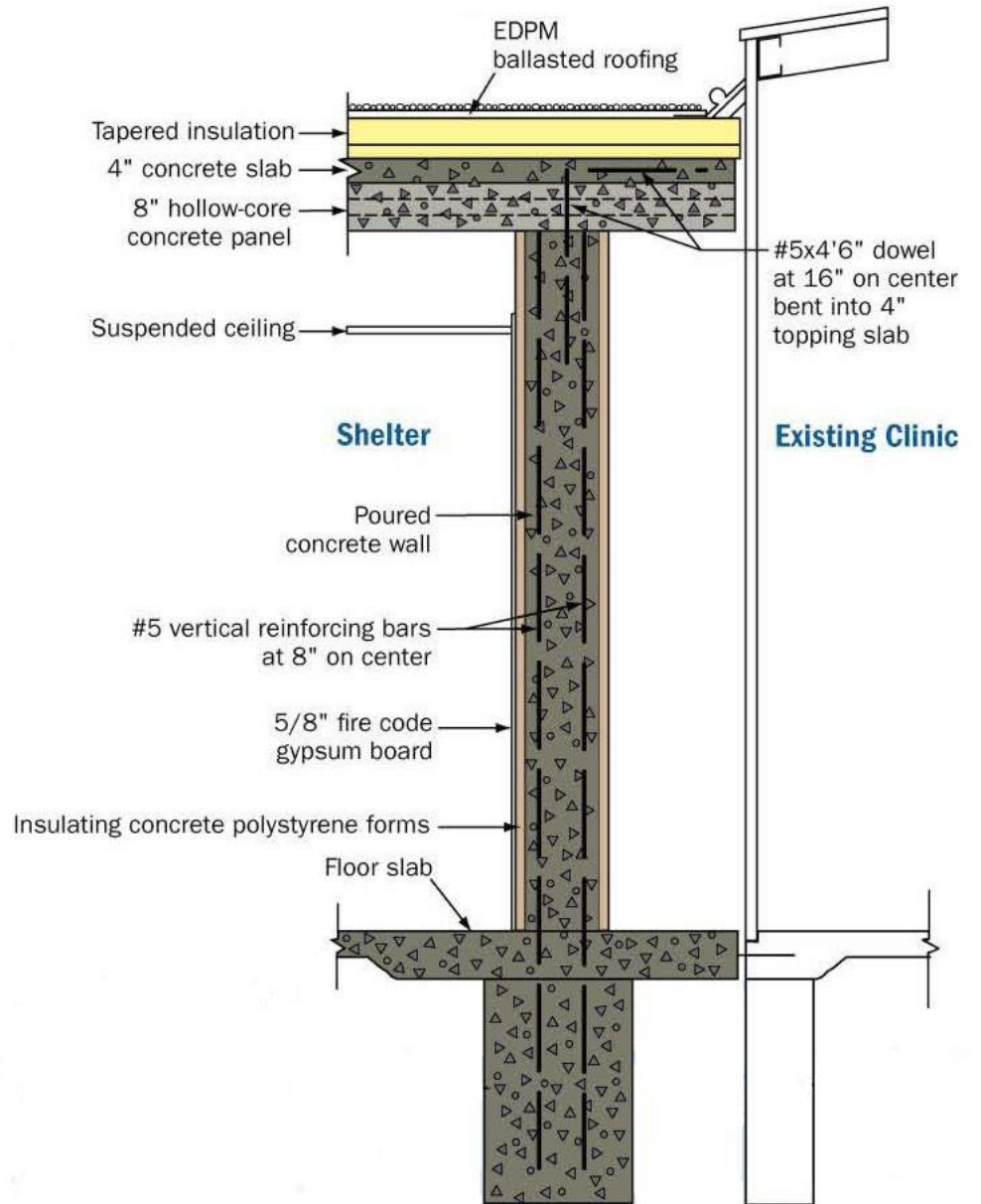
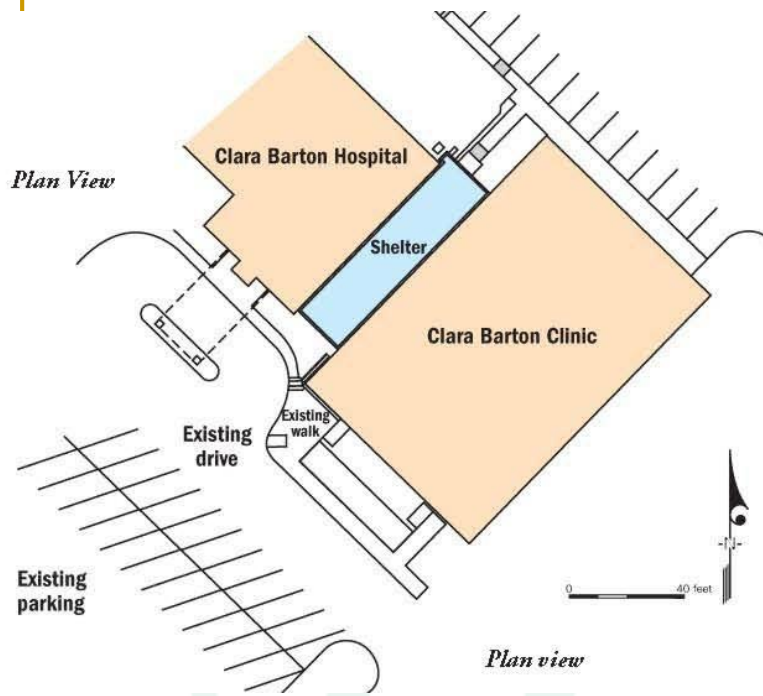
# Loading





**Clara Barton Hospital  
Hoisington, KS  
EF-4 tornado, April 2001**

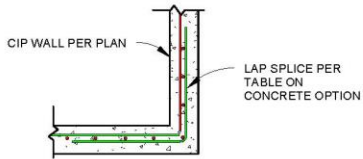






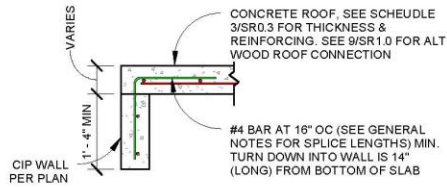
# FEMA 320 Safe Room Plans





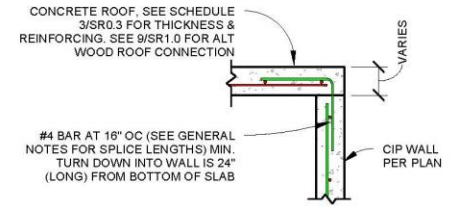
**9** CONC SECTION AT CORNER

SR1.1 Scale: 1/2" = 1'-0"



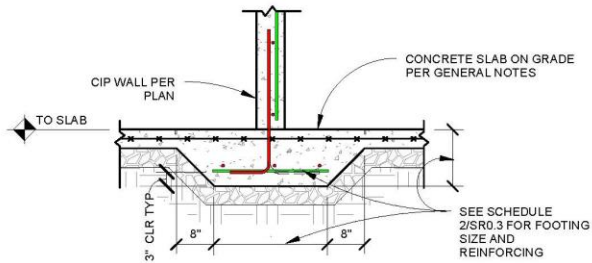
**8** CONC SECTION AT DOOR BEAM

SR1.1 Scale: 1/2" = 1'-0"



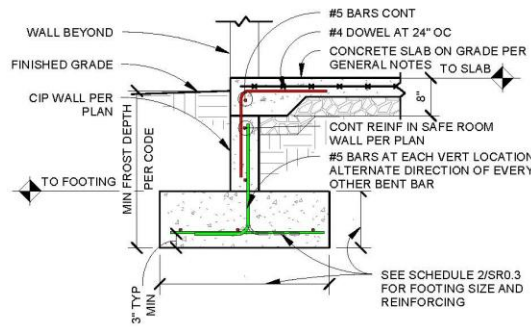
**7** CONC SECTION AT TOP

SR1.1 Scale: 1/2" = 1'-0"



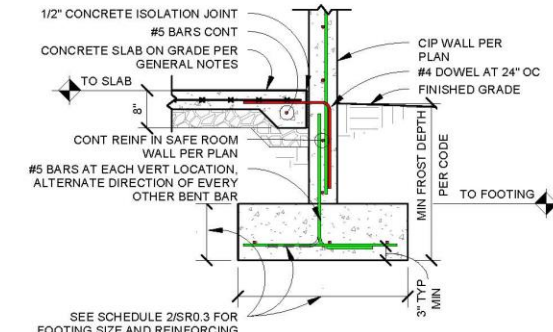
**6** ALT CONC INTERIOR WALL THICKENED SLAB

SR1.1 Scale: 1/2" = 1'-0"



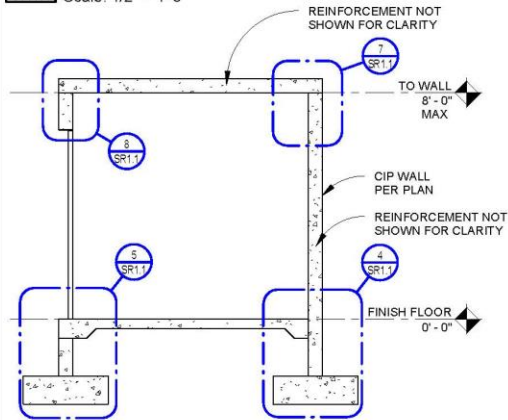
**5** CONC EXTERIOR WALL FOUNDATION AT DOOR

SR1.1 Scale: 1/2" = 1'-0"



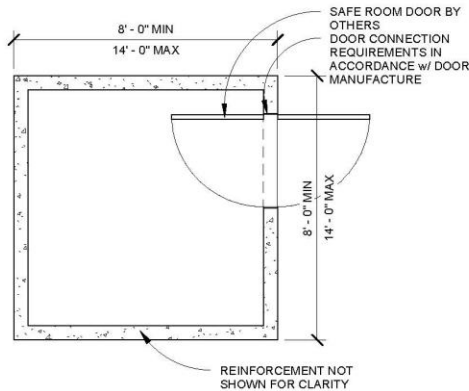
**4** CONC EXTERIOR WALL FOUNDATION

SR1.1 Scale: 1/2" = 1'-0"



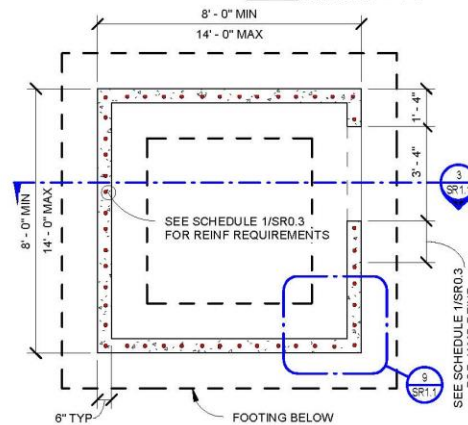
**3** CONCRETE CROSS SECTION

SR1.1 Scale: 1/4" = 1'-0"



**2** CONCRETE FLOOR PLAN

SR1.1 Scale: 1/4" = 1'-0"



**1** CONCRETE FOUNDATION PLAN

SR1.1 Scale: 1/4" = 1'-0"

NOTE:  
1. FINISHED FLOOR ELEVATION SHALL BE LESS THAN 5 FT ABOVE LOWEST FINISHED ADJACENT GRADE ELEVATION  
2. SEE SR0.3 FOR SCHEDULES

<b>FEMA P-320 (2014)</b>	
SHEET TITLE: CONCRETE SAFE ROOM PLANS AND DETAILS	
DRAWING NO: SR1.1	Sheet: 6 of 12
DATE: DECEMBER 2014	
REVISIONS	
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## **Design Guide 3, *Tornado* *Design for Buildings***

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Thank you

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