

Storm Shelters: Selecting Design Criteria



FEMA

MAY 2007 TORNADO RECOVERY ADVISORY

FEMA DR-1699-RA2

Purpose and Intended Audience

The intended audience for this Tornado Recovery Advisory (RA) is anyone involved in the planning, policy-making, design, construction, or approval of tornado shelters, including designers, emergency managers, public officials, policy or decision makers, building code officials, and home or building owners. Homeowners and renters should also refer to the Tornado RA titled *Residential Sheltering: In-Residence and Stand-Alone Shelters*. The purpose of this advisory is to present information on different types of shelter design guidelines, code requirements, and other criteria that pertain to the design and construction of tornado shelters. There are various storm shelter criteria, each of which offers different levels of protection to its shelter occupants.

See these 2007 Tornado Recovery Advisories for information about sheltering from tornadoes:

- *Tornado Risks and Hazards in the Midwest United States* (Tornado RA1)
- *Residential Sheltering: In-Residence and Stand-Alone Shelters* (Tornado RA 3)

This Recovery Advisory Addresses:

- How shelter construction is different from typical building construction:
 - Structural systems
 - Windborne debris resistance
- Design criteria for different types of shelters
- Useful links and shelter resources

How Shelter Construction is Different from Typical Building Construction

A tornado shelter is typically an interior room, space within a building, or an entirely separate building, designed and constructed to protect its occupants from tornado wind forces and windborne debris. The level of occupant protection provided by a space specifically designed as a shelter is intended to be much greater than the protection provided by buildings that comply with the minimum requirements of building codes. The model building codes do not provide design and construction criteria for life safety for sheltering, nor do they provide design criteria for withstanding the forces of tornadoes.

Shelters typically fall into two categories: residential shelters and community (non-residential) shelters.

- Residential tornado shelters are constructed as in-residence or easily accessible external shelters. An ***in-residence shelter***, also called a “safe room,” is a small, specially designed (“hardened”) room, such as a bathroom or closet that is intended to provide a place of refuge for the people who live in the house. An ***external residential shelter*** is similar in function and design, but it is a separate structure installed outside of the house, either above or below ground. Refer also to the Tornado RA titled *Residential Sheltering: In-Residence and Stand-Alone Shelters*.
- A ***community shelter*** is intended to protect a large number of people, anywhere from 12 to as many as several hundred individuals. These shelters include not only public shelters, but also private shelters for businesses and other organizations.

The term “hardened” refers to specialized design and construction applied to a room or building to allow it to resist wind pressures and windborne debris impacts during a high-wind event and serve as a shelter.

Structural Systems

The primary difference in a building's structural system when designed for use as a shelter, versus conventional use, is the magnitude of the wind forces it is designed to withstand.

Buildings are designed to withstand a certain wind speed (termed "design [basic] wind speed") based on historic wind speeds documented for different areas of the country. The design wind speed used in conventional construction in the Midwest is a 90 mph, 3-second gust. By contrast, the design wind speed recommended by FEMA¹ for shelters in this same area is a 250 mph, 3-second gust to provide "near-absolute protection."²



Community storm shelter being constructed to FEMA 361 criteria in Wichita, Kansas.

Wind pressures are calculated as a function of the square of the design wind speed. As a result, the structural systems of a shelter are designed for forces several times higher than those used for typical building construction. Consequently, the structural systems used in shelters (and the connections between them) are very robust.

Windborne Debris Resistance

Windborne debris, commonly referred to as missiles, causes many of the injuries and much of the damage from tornadoes. Windows and the glazing in exterior doors of conventional buildings are not required to resist windborne debris, except for those in windborne debris regions (which are limited to hurricane-prone regions).³ Debris protection includes impact-resistant glazing, which can either be laminated glass or polycarbonate, and coverings such as shutters. The ASCE 7 missile criteria were developed to minimize property damage and improve building performance; they were not developed to protect occupants. To provide occupant protection, the criteria used in designing shelters include substantially greater windborne debris loads.

If glazing is present in a tornado shelter, it should be protected by an interior-mounted shutter that can be rapidly deployed by the shelter occupants.

The roof deck, walls, and doors of conventional construction are also not required by the building code to resist windborne debris. However, the roof deck and walls around a shelter space, and the doors leading into it, must resist windborne debris. Additional information regarding the different levels of windborne debris loads is provided below.

Design Criteria for Different Types of Shelters

Shelters provide different levels of protection depending on the design criteria used. The level of protection provided by a shelter is a function of the design wind speed (and resulting wind pressure) used in designing the shelter, and of the windborne debris load criteria.

Design wind speed and wind pressure criteria: The required design strength of the shelter is dictated by wind pressure criteria given by different guides, codes, and standards. The design wind pressure is a function of the design wind speed. In FEMA's shelter publications (see Useful Links on page 3), recommended design wind speeds range from 160 to 250 mph. However, the 2006 International Residential Code and the 2006 International Building Code, which establish the minimum requirements for residential and other building construction, include a design wind speed of 90 mph in the Midwest. The table on page 4 compares shelter design criteria options. The table on page 5 presents comparative data for two locations using the design criteria presented on page 4.

1. FEMA 361, *Design and Construction Guidance for Community Shelters* (July 2000), available online at <http://www.fema.gov/library/viewRecord.do?id=1657>.

2. "Near-absolute protection means that, based on our knowledge of tornadoes and hurricanes, a shelter built according to this guidance will protect its occupants from injury or death." FEMA 361, page 1-2, *Design and Construction Guidance for Community Shelters* (2000).

3. ASCE 7, American Society of Civil Engineers Standard 7, *Minimum Design Loads for Buildings and Other Structures* (2005).

Windborne debris load criteria: The table below presents windborne debris criteria given in current FEMA guidance and a proposed International Code Council standard. The table shows different test missiles and their corresponding momentum. The first entry in this table is the FEMA missile guidance for residential and community shelters. These parameters provide near-absolute protection.

Tornado and Hurricane Windborne Debris Criteria

Guidance, Code, or Standard Criteria for the Design Missile	Debris Test Speed (mph)	Large Missile Specimen	Momentum at Impact (lb _f -s)
Tornado Missile Testing Requirements			
FEMA 320 / FEMA 361	100	15# 2x4	68
International Code Council (ICC) Proposed Shelter Standard	100 (maximum) 80 (minimum)	15# 2x4 15# 2x4	68 55

NOTES:

lb_f-s – Pounds (force) seconds

Useful Links and Shelter Resources:

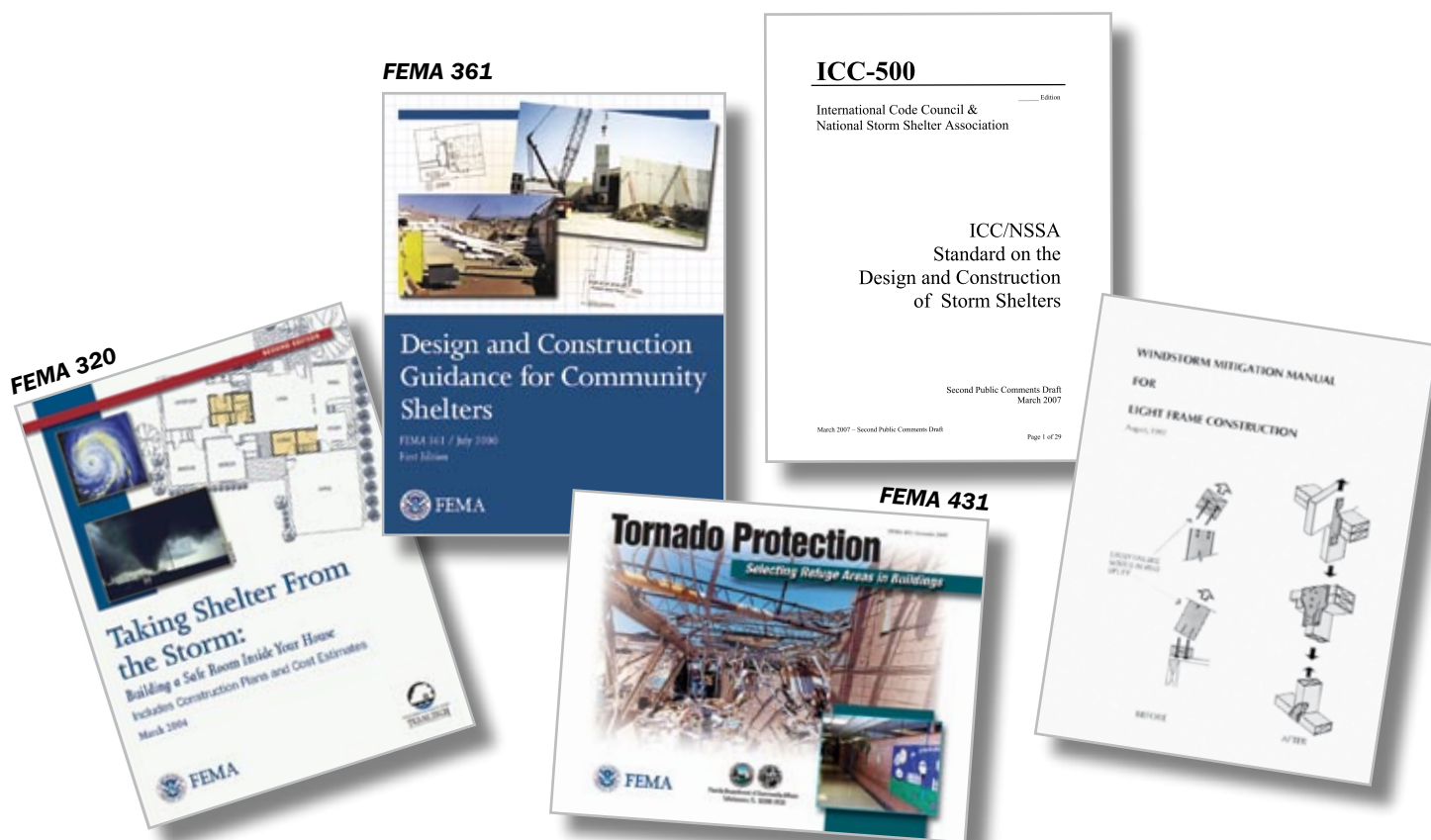
Taking Shelter From the Storm: Building a Safe Room Inside Your House (FEMA 320), FEMA, Washington, DC, Second Edition, March 2004.

Design and Construction Guidance for Community Shelters (FEMA 361), FEMA, Washington, DC, July 2000.

Tornado Protection: Selecting Refuge Areas in Buildings (FEMA 431), FEMA, Washington, DC, November 2003.

Standard on the Design and Construction of Storm Shelters, International Code Council and the National Storm Shelter Association (ICC-500), (Anticipated Release) Early 2008.

Windstorm Mitigation Manual for Light Frame Construction by David Wickersheimer, State Farm Fire and Casualty Company, FEMA Region V, Illinois.



Wind Shelter Design and Construction Codes, Standards, Guidance Comparison Table¹

Title or Name of Document	Code, Reg, Standard, or Statute?	Wind Hazard	Wind Map ²	Wind Design Coefficient Considerations ^{3,4}	Debris Impact Criteria ⁵	Remarks
FEMA Shelter Publications: FEMA 320 <i>Taking Shelter From the Storm: Building a Safe Room Inside Your House</i> (2004) FEMA 361 <i>Design and Construction Guidance for Community Shelters</i>	FEMA guidance document, not a code or standard. "Best Practice" for high-wind shelters	Tornado and Hurricane	FEMA 320: Hazard map, but wind speeds not used for design FEMA 361: Map with four wind speed zones for design (wind mri is 10,000–100,000 years). This map is often referred to as the "FEMA 361 map."	FEMA 320: N/A – prescriptive design guidance for maximum hazard FEMA 361: Use FEMA 361 wind speed map with four zones. Calculate pressures using ASCE 7 methods and use $I=1.0$, $K_d=1.0$, Exposure C, no topographic effects, $G_{Cpi}=+/-0.55$ (this will account for atmospheric pressure change [APC])	Test all shelters with the representative missile: a 15-lb 2x4 at 100 mph (horizontal) and 67 mph (vertical)	FEMA 320: Intent is to provide "near-absolute protection." No certification is provided. FEMA 361: Intent is to provide "near-absolute protection." Shelter operations guidance is provided. Occupancy issues addressed. Wall section details provided. No certification is provided.
International Code Council/ National Storm Shelter Association (ICC/NSSA) High Wind Shelter Standard (ICC-500) – currently in development, tentatively available for adoption in January 2008.	Consensus standard for shelter design and construction, available for adoption in January 2008. To be incorporated by reference into the 2009 IBC and IRC.	Tornado and Hurricane	Tornado: Uses FEMA 361 map.	Tornado: Use FEMA 361 wind speed map. Calculate pressures using ASCE 7 methods and use $I=1.0$, $K_d=1.0$, Exposure as appropriate, no topographic effects, $G_{Cpi}=+/-0.55$ or $+/-0.18+APC$	Test shelters with representative missile (missile speed dependent on site design wind speed): Tornado: 15-lb 2x4 at 85–100 mph (horizontal) and 2/3 of this speed (vertical).	Intent is to provide a standard for the design and construction of high-wind shelters. Will not use term "near-absolute protection." Occupancy, ventilation, and use issues are also addressed. Shelter operations guidance is provided in the commentary only (commentary is a separate document—not a consensus document).
International Building Code (IBC)/ International Residential Code (IRC) 2000 and later/ASCE 7-98 and later.	Building code and design standards for regular (non-shelter) buildings. Some additional guidance is provided in commentary.	All but tornado	ASCE has its own wind speed map based on historical and probabilistic data; mri is 50 years in non-hurricane-prone regions.	Method is basis of most wind pressure calculation methods. All items in design process are site-specific. Use $I=1.15$ for critical and essential facilities.	None	The code requires increased wind design parameters only for buildings designated as critical or essential facilities.
Pre-2000 Building Codes	Building code and design standards for regular (non-shelter) buildings	All but tornado	Each of the older codes used their own published wind contour maps.	Typically these older codes provided a hurricane regional factor for design wind speeds, but little attention was paid to components and cladding.	None	These codes specified limited hazard-resistant requirements.
Areas of Refuge/ Last Resort	Guidance from FEMA and others for selecting best-available refuge areas	Tornado and Hurricane	None	None	None	Best available refuge areas should be identified in all buildings without shelters. FEMA 431, <i>Tornado Protection: Selecting Refuge Areas in Buildings</i> , provides guidance to help identify the best available refuge areas in existing buildings. Because best available refuge areas are not specifically designed as shelters, their occupants may be injured or killed during a tornado or hurricane.

TABLE NOTES:

1. The wind shelter guidance and requirements shown here are presented from highest to least amount of protection provided.
2. Mean recurrence intervals (mri) for wind speeds maps are identified by the code or standard that developed the map. Typically, the mri for non-shelter construction in non-hurricane-prone areas is 50 years and in hurricane-prone regions, approximately 100 years.
3. American Society of Civil Engineers (ASCE) 7-05 *Building Design Loads for Buildings and Other Structures* (2005) is the load determination standard referenced by the model building codes. The wind design procedures used for any shelter type in this table use one of the wind design methods as specified in ASCE 7-05, but with changes to certain design coefficients that are identified by the different codes, standards, or guidance summarized in this table.
4. From ASCE 7 method: I = importance factor; K_d = wind directionality factor; $G C_{pi}$ = internal pressure coefficient
5. Roof deck, walls, doors, openings, and opening protection systems must all be tested to show resistance to the design missile for the FEMA, ICC, and FL EHPA criteria.

The table below shows comparative data for a location in Kansas for the design criteria presented in the previous table. Where no guidance is provided for sheltering or basic construction, “N/A” (not applicable) is stated. Where there is no requirement, “Not required” is noted.

Design Criteria Comparison

Shelter Design Standard, Code, or Document	Data ¹	Example Location: Wichita, KS
FEMA 320/361	Design wind speed	250 mph
	Pressure on windward wall ²	167 psf ³
	Pressure on roof section ⁴	401 psf (suction)
	Test missile momentum at impact	68 lbf –s ⁵
ICC-500 (pending 1/08)	Design wind speed	250 mph
	Pressure on windward wall	167 psf
	Pressure on roof section	401 psf (suction)
	Test missile momentum at impact	68 lbf–s (tornado)
ASCE 7-05/IBC 2006 (ASTM E 1996)	Design wind speed	90 mph
	Pressure on windward wall	15 psf
	Pressure on roof section	36 psf (suction)
	Test missile momentum at impact	Not required
Pre-2000 Building Codes	Design wind speed	80 mph fastest-mile (100 mph 3-sec peak gust)
	Pressure on windward wall	16 psf
	Pressure on roof section	26 psf (suction)
	Test missile momentum at impact	Not required

NOTES:

1. Wind pressures were calculated based on a 40-foot x 40-foot square building, with a 10-foot eave height and a 10-degree roof pitch.
2. The wall pressures are Main Wind Force Resisting System (MWFRS) corner load.
3. psf – Pounds per square foot;
4. The given roof pressures are the wind loads for components and cladding at the corner of the roof (where pressures are highest) with an effective wind area of 40 square feet (sf).
5. lbf-s – Pounds (force) seconds

National Performance Criteria for Tornado Shelters

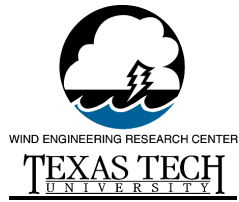


Tornado shelters under construction in the Country Club Courts subdivision by The Core Inc., Wichita, Kansas



**Federal Emergency Management
Agency
Mitigation Directorate
Washington, D.C.**

**First Edition
May 28, 1999**



**National Performance Criteria for Tornado Shelters
Federal Emergency Management Agency
Mitigation Directorate
Washington, D.C.**

Comments and Questions

The Federal Emergency Management Agency, in cooperation with the Wind Engineering Research Center at Texas Tech University, has developed these performance criteria for tornado shelters. Comments on these criteria should be directed to:

Program Policy and Assessment Branch
Mitigation Directorate
Federal Emergency Management Agency
500 C Street, S.W.
Washington, D.C. 20472
e-mail: building.science@fema.gov

Technical questions on these performance criteria should be directed to:

Wind Engineering Research Center
Texas Tech University
Box 41023
Lubbock, TX, 79409-1023
(888) 946-3287 ext. 336
e-mail: ltanner@coe.ttu.edu

Limit of Liability

These performance criteria are based on extensive research of the causes and effects of windstorm damage to buildings. Shelters designed and built to these performance criteria should provide a high degree of occupant protection during severe windstorms. Any variation from these design or construction performance criteria, or deterioration of the structure, may decrease the level of occupant protection during a severe wind event.

Because it is not possible to predict or test for all potential conditions that may occur during severe wind storms or control the quality of the design and construction, the Federal Emergency Management Agency, Texas Tech University and others involved in the development of this performance criteria do not warrant these performance criteria.

The Federal Emergency Management Agency, Texas Tech University and others involved in the development of these performance criteria neither manufacture nor sell shelters based on these performance criteria. The Federal Emergency Management Agency, Texas Tech University and others involved in the development of these performance criteria do not make any representation, warranty, or covenant, expressed or implied, with respect to these performance criteria, or the condition, quality, durability, operation, fitness for use, or suitability of the shelter in any respect what so ever. The Federal Emergency Management Agency, Texas Tech University and others involved in the development of these performance criteria shall not be obligated or liable for actual, incidental, consequential, or other damages of or to users of shelters or any other person or entity arising out of or in connection with the use, condition, and other performance of shelters built from these performance criteria or from the maintenance thereof.

Introduction

Shelters constructed to these performance criteria are expected to withstand the effects of the high winds and debris generated by tornadoes such that all occupants of the shelter during a tornado will be protected without injury. These performance criteria are to be used by design professionals, shelter manufacturers, building officials, and emergency management officials to ensure that shelters constructed in accordance with these criteria provide a consistently high level of protection. The following describes the performance criteria.

Performance Criteria

1. Resistance to Loads from Wind Pressure for Shelters

- a) Wind pressures are to be determined using ASCE 7-95 *Minimum Design Loads for Buildings and Other Structures* (or revisions to this standard). Pressures for the Main Wind Force Resisting System (MWFRS) are to be used for the walls, ceiling, structural attachments and foundation system. Pressures for Components and Cladding are to be used for the door(s) and other attachments to the exterior of the shelter. For computing wind pressures to be used as a service load, the wind velocity (V) shall be 250 mph (3-second peak gust).
- b) The shelter walls, ceiling and floor will withstand design pressures such that no element shall separate from another (such as walls to floor, ceiling to walls). Such separation shall constitute a failure of the shelter.
- c) The entire shelter structure must resist failure from overturning, shear (sliding), and uplift from design pressures. *Note: For the in-residence shelter designs described in FEMA 320, ceiling spans and wall lengths were less than 8 feet and the design of the wall and ceiling was governed by the need for missile protection. For larger shelters, the capacity of structural elements to withstand the forces described in above in 1. (a) shall be determined by engineering analysis. For larger shelters, the plans in FEMA 320 can be used only for missile (airborne debris) resistance.*
- d) The Allowable Stress Design (ASD) method shall be used for the shelter design for any of the construction materials selected (concrete, concrete masonry, wood, etc.). Unfactored load combinations shall be used in accordance with ASCE 7-95 for allowable stress design. Because of the extreme nature of this design wind speed, other environmental loads, such as flood or earthquake loads, should not be added. An alternative design method for materials with accepted Load and Resistance Force Design (LRFD) standards may be used in lieu of ASD.

FEMA EMPLOYEE

Comment: I don't think we need to get this specific otherwise, otherwise we will have to go into more detail about acceptable deflection. If we have .25" deflection after the event—we were probably near failure of the shelter.

- e) No importance factor shall be added to the pressure calculations because the extreme nature of the design event already accounts for critical nature of the shelter. Therefore, the importance factor (I) used in the design computations shall equal one. The internal gust coefficient (GC_{pi}) shall be for buildings with no openings.
- f) In the event that the roof of the shelter is exposed at grade, the roof of the shelter shall be able to resist wind pressures as determined in sections 1(a) through (e).

2. Windborne Missile Impact Resistance On Shelter Walls and Ceiling

- a) Loads from windborne missile impacts must be considered. For design purposes, it is assumed that the design wind speed of 250 mph propels a 15-lb. missile horizontally at 100 mph. The design missile is a nominal 2x4 wood board, weighing 15 lbs., striking the shelter enclosure on end 90° to the surface. The vertical missile design speed is 2/3 of the horizontal speed or 67 mph. For Below-Grade Shelters, only the impact from vertical missiles on the shelter roof must be considered. *Note: From testing, it has been shown that the primary failure of enclosure materials from missile impact has been shearing of the material due to the high velocity and that missile perforation resistance is provided by a material (or combination of materials) that provide energy dissipation of the missile impact.*
- b) The walls and ceiling of a shelter must resist perforation by the design missile such that the missile does not perforate the inside most surface of the shelter. Only shelter wall openings used for access are permitted. Windows, skylights, or other similar openings shall not be used unless they have been laboratory tested to meet the missile impact criteria of section 2(a). *Note: The Wind Engineering Research Center at Texas Tech University has tested numerous materials and material combinations and should be contacted regarding performance of those materials. For in-residence shelters, the designs of FEMA Publication No. 320 Taking Shelter From the Storm: Building a Safe Home in Your Home should be used. For other than in-residence shelters, it is recommended that materials proven to provide the required stiffness and missile impact resistance such as reinforced concrete or reinforced concrete masonry should be used.*
- c) Alternative materials and material combinations for both shelter walls and ceilings shall be permitted after testing has proven the alternative materials will meet the missile impact criteria contained herein. *Note: Existing missile impact standards in the Standard Building Code, the South Florida Building Code, the Texas Department of Insurance Code, and ASCE 7 do not include missiles of the size, weight or speed of those discussed in these performance criteria. Therefore, those standards may not be used to determine applicability of alternative materials and material combinations for tornado-generated missiles.*

3. Other Loads

- The designer should assess whether an adjacent structure is a liability to the shelter, that is, if it poses a threat to the shelter from collapse. If the adjacent structure is deemed a liability, the loads imposed upon the shelter due to the collapse of this adjacent structure shall be considered as an additional impact load on the shelter.

4. Shelter Access Doors and Door Frames

- a) Shelter entry doors and their frames shall resist the design wind pressures for components and cladding in section 1 of this criteria and the missile impact loads of section 2 of this criteria. Only doors and their frames that can resist calculated design wind pressures and laboratory tested missile impacts are acceptable. All doors shall have sufficient points of connection to their frame to resist design wind pressure and impact loads. Unless specifically designed for, each door shall be attached to their frame with a minimum six points of connection. *Note: See the design specifications and details for shelter doors in FEMA publication 320 for additional guidance. Door designs and materials of construction included in FEMA publication 320 were developed through calculations and laboratory testing at Texas Tech University.*
- b) A protective missile resistant barrier is permitted to protect the door opening. The door should then be designed to resist wind pressures.
- c) The size and number of shelter doors shall be determined in accordance with applicable fire safety and building codes. In the event the community where the shelter is to be located has not adopted current fire safety and building codes, the requirements of the most recent editions of a model fire safety and a building code shall be used. *Note: The design specifications and details for shelter doors in FEMA publication 320 are for single swinging doors not exceeding 3 feet in width. No laboratory missile impact testing has been performed on double swinging doors or other door configurations other than 3 feet wide single swinging doors.*

FEMA EMPLOYEE

Comment: We would expect a greater rebound of the missile from a very heavy massive wall. The rebound missile could have considerable energy. However more importantly, the missile impact was determined by test not analysis – we don't want to introduce another missile test.

5. Shelter Ventilation

- a) Ventilation for shelters shall be provided through either the floor or the ceiling of the enclosure. A protective shroud or cowl, meeting the missile impact requirements of section 2 of these criteria, must protect any ventilation openings in the shelter ceiling. The ventilation system must be capable of providing the minimum number of air changes for the shelter's occupancy rating. In the event the community where the shelter is to be located has not adopted a current building and/or mechanical code, the requirements of the most recent edition of a model building code

shall be used. *Note: Ventilation may be provided with ducts to an outside air supply.*

- b) If ventilation to the shelter is provided by other than passive means, then all mechanical, electrical and other equipment providing this ventilation must be protected to the same standard as the shelter. In addition, appropriate design, maintenance and operational plans must ensure operation of this equipment following a tornado.

6. Emergency Lighting

- Emergency lighting shall be provided to all shelters serving over 15 persons.

7. Shelter Sizing

- The following are minimum floor areas for calculating the size of shelters:
 - Adults 5 square feet per person standing
 - Adults 6 square feet per person seated
 - children (under the age of 10) 5 square feet per person
 - Wheelchair bound persons 10 square feet per person
 - Bed-ridden persons 30 square feet per person

8. Shelter Accessibility

- a) The needs of persons with disabilities requiring shelter space must be considered, and the appropriate access for such persons must be provided in accordance with the Americans with Disabilities Act (ADA).
- b) In designing shelter(s), the designer shall consider the time required for all occupants of a building and facility to reach refuge in the shelter(s).
Note: While the National Weather Service has made great strides in providing warnings, to provide greater protection, it is recommended that in locating shelters or multiple shelters, all occupants of a building or facility should be able to reach a shelter within 5 minutes, and that all occupants should be in a shelter with doors secured within 10 minutes.

9. Emergency Management Considerations for Shelters

- a) Each shelter shall have a tornado emergency refuge plan; this plan is to be exercised at least twice per year.

- b) Shelter space shall contain, at a minimum, the following safety equipment:
 - Fire extinguisher surface mounted on the shelter wall. In no case shall a fire extinguisher cabinet or enclosure be recessed into interior face of the exterior wall of the shelter.
 - Flashlights with continuously charging batteries
 - First aid kit rated for the shelter occupancy
 - Potable water in sufficient quantity to meet the drinking needs of the shelter rated occupancy for 8 hours
 - A NOAA weather radio with continuously charging batteries
- c) The following placards and identification shall be installed in each building with a shelter other than shelters within single family residences:
 - The location of each shelter shall be clearly and distinctly identified with permanently mounted wall placards located throughout the building that direct the building occupants to the shelter.
 - The outside of all doors providing access to a shelter shall be clearly identified as a location to seek refuge during a tornado.
 - Placards shall be installed on the inside of each shelter access door or immediately adjacent that instructs shelter occupants on how to properly secure the shelter door(s).

10. Additional Requirements for Below Grade Shelters:

- The shelter must be watertight and resist flotation due to buoyancy from saturated soil.
- The shelter must contain either battery-powered radio transmitters or a signal-emitting device to signal the location of the shelter to local emergency personnel should occupants in the shelter become trapped due to debris blocking the shelter access door.

11. Multihazard Mitigation Issues

- a) **Flooding**
 - No below grade shelter shall be constructed in a Special Flood Hazard Area or other area known as being flood prone.
 - In the event that an above ground shelter is located in a Special Flood Hazard Area (SFHA) of other known flood prone area, the floor of the shelter shall be elevated to or above the Base Flood Elevation or other expected level of flooding.
 - All shelters constructed in a SFHA and/or other regulatory floodplain areas shall conform to state and local floodplain management requirements.

b) **Earthquake**

- Shelters located in earthquake prone areas shall be designed and constructed in accordance with seismic safety provisions contained in local building codes. In the event the community where the shelter is to be located has not adopted a current building code, the requirements of the most recent edition of a model building code and/or the National Earthquake Hazard Reduction Program Recommended Provisions shall be used.

12. **Construction Plans and Specifications**

- Complete detailed plans and specifications shall be provided for each shelter design. Sufficient information to ensure that the shelter is built in accordance with both the specific requirements and intent of these performance criteria shall be provided. *Note: The plans and specifications found in FEMA publication 320 are a good basis for developing plans (including standardized details) and specifications.*

13. **Quality Control**

- The quality of both construction materials and methods shall be ensured through the development of a quality control program. This quality control program shall identify roles and responsibilities of the contractor, design professional, and local permit official in ensuring that the shelter is constructed with materials and methods that meet the requirements stipulated in the plans and specifications developed from these performance criteria.

14. **Obtaining Necessary Permits**

- Prior to beginning construction, all necessary state and local building and other permits shall be obtained and clearly posted on the job site. *Note: Model building codes do not address the design of a tornado shelter. Therefore the owner and the design professional should ensure that the shelter is properly designed and constructed.*

Sources of Additional Information

FEMA has developed two publications that may be of assistance in developing tornado shelter designs:

- FEMA TR-83B *Tornado Protection: Selecting and Designing Safe Areas in Buildings*
- FEMA 320 *Taking Shelter From the Storm: Building a Safe Room Inside Your House*

A copy of FEMA 320 can be ordered by calling 1-888-565-3896. FEMA TR-83B, and all other FEMA publications, may be ordered by calling 1-800-480-2520.