Appendix C

NATIONAL PERFORMANCE CRITERIA FOR TORNADO SHELTERS

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

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Building a Disaster Resistant Community
PROJECT IMPACT

WIND ENGINEERING RESEARCH CENTER
TEXAS TECH UNIVERSITY

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
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Washington, D.C. 20472
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Technical questions on these performance criteria should be directed to:

Wind Engineering Research Center
Texas Tech University
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Lubbock, TX, 79409-1023
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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.

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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.

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 90^0 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.*

5. Shelter Ventilation

a) Ventilation for shelters shall be provided through either the floor or the ceiling of the enclosure. A protective shroud or cowling, 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) or 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.