Association Standard

for the

Design, Construction, and Performance of Storm Shelters

Proposed as a forerunner for

A Storm Shelter Industry Standard

Developed by

The Standards Committee
of the
National Storm Shelter Association
with assistance from the
Wind Science and Engineering Research Center
Texas Tech University

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The ASSOCIATION STANDARD
Developed and adopted by the
NATIONAL STORM SHELTER ASSOCIATION

TABLE OF CONTENTS

FOREWORD

This publication represents the best efforts of the National Storm Shelter Association (NSSA) Standards Committee and an ad hoc Review Committee to prepare an Association Standard that is expected to lead to an industry standard for the design, construction, and performance of storm shelters. The material presented herein is based on extensive research on the effects of extreme winds and has been prepared in accordance with accepted engineering principles, consensus design standards, leading-edge test procedures, and extensive research on the effects of extreme winds. This Standard is consistent with Federal Emergency Management Agency (FEMA) Publication 320, *Taking Shelter From The Storm*, FEMA Publication 361, *Design and Construction Guidance For Community Shelters*, and with ASCE 7-98, *Minimum Design Loads For Buildings And Other Structures*.

Shelters designed and built to these standards will increase survivability during extreme wind events such as tornadoes, hurricanes, and downbursts. Because it is not possible to predict or test for all conditions and events that may occur during severe windstorms, the publication of this Association Standard should not be construed as a representation or warranty on the part of the NSSA or any member or consultant thereof that the information contained is suitable for general or any particular use. Neither does the use of this manual guarantee avoidance of infringement of any patent or patents. NSSA excludes all express or implied warranties of habitability or fitness for any particular use. Any user of this Standard assumes all liability for such use.

Wind science and engineering is a relatively new discipline. Aboveground storm shelter development has, for the most part, occurred during the past three decades; such shelters have only recently become widespread. Surely, design standards and practices will change as the science base expands and as shelter performance in windstorms is evaluated. Information on shelter performance or input to this Standard may be forwarded to:

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1. PURPOSE

The purpose of this Association Standard, referred to hereinafter as the Standard, and of the industry standard expected to evolve from it, is to provide a regulatory performance standards document to guide the design, testing, engineering evaluation, fabrication, installation, and construction of storm shelters. This will enhance the probability of survival of occupants during tornadoes and other violent windstorms in affordable storm shelters manufactured or constructed in accordance with this Standard. However, compliance with this Standard cannot ensure an occupant’s survival of violent windstorms because of the nature and unpredictability of natural catastrophes.

Enhanced protection of the public can be anticipated by the adoption and enforcement of this Standard by the National Storm Shelter Association (NSSA) for NSSA Members' storm shelter products, by adoption of and reference to this Standard by the model codes groups, and by adoption and enforcement of this Standard by regulating authorities at the local, regional, state, or national level. NSSA encourages and supports the use of this Standard as the basis for codes or for other standards.

2. OBJECTIVE

The objective of this Standard is to provide technical design and performance criteria that will facilitate and promote the design, construction, and installation of safe, reliable, and economical storm shelters to protect the public. It is intended that this Association Standard and the industry standards expected to evolve from it be used by design professionals, storm shelter designers, manufacturers, and constructors, building officials, emergency management personnel, and government officials to insure that storm shelters provide a consistently high level of protection to the sheltered public.

3. STORM SHELTER DEFINITION

A storm shelter is defined as an emergency occupancy structure designed to provide occupants a high probability of protection from injury or loss of life resulting from the forces, debris impacts, and other effects that may result from tornadoes, hurricanes, or other windstorm events. When the word *shelter* is used in this Standard, it is intended that the complete unit with all its components including, but not limited to, doors, hinges, latches, hardware, vents, steps, and anchorage, is referred to. A storm shelter may be private or public. The shelter may serve multiple purposes, e.g., as a closet in a residence or as a library in a school, but only the space available for occupancy in an emergency shall be considered usable shelter space. The enclosed volume of the shelter becomes a parameter in design.

4. SCOPE

The requirements set forth in this Standard shall apply to pre-manufactured or site-constructed storm shelters, or any combination of the above, regardless of whether these are public or private shelters, or whether shelters are located above ground or below ground, exposed or within another structure, and regardless of the type of construction or materials used to produce the shelter.

5. SIZE CLASSIFICATION OF SHELTERS

In this Standard, a shelter will be defined as:

Small if it has an interior volume of 500 ft^3 or less

Intermediate if it has an interior volume between 500 and 1,000 ft^3

Large if it has an interior volume of 1,000 ft^3 or more

6. BACKGROUND

Although the concept of storm shelters is not new, the widespread use of aboveground in-residence shelters has come about in the last decade. University researchers and design professionals have produced numerous publications to lead the development of storm shelters. The National Institute of Standards and Technology (NIST) has sponsored projects and performed in-house studies to evolve design criteria for shelters. The Federal Emergency Management Agency (FEMA) has affected technology transfer by publishing design specifications and guidelines. Only now are design and construction standards being written.

More extensive discussion of the background of this Standard is presented in the COMMENTARY along with references to the most widely used publications concerning design and construction of storm shelters.

7. STRUCTURAL DESIGN CRITERIA

Design criteria for the Standard are based on FEMA Publications 320 and 361 and are consistent with the provisions of ASCE 7-98, the most widely accepted standard for determining wind loads on buildings (See BACKGROUND, COMMENTARY).

Aboveground shelters and exposed portions of underground shelters shall be designed and constructed to have the structural integrity to withstand the forces and pressures associated with extreme winds and must prevent perforation by wind-borne debris and prevent deformation from debris impacts sufficient to cause serious injury to shelter occupants.

Below-grade shelters must be capable of withstanding soil and hydrostatic loads and to prevent flotation or water intrusion when surrounding soils are fully saturated.

Long-term corrosion protection shall be provided for those portions, including connections, of metal shelters that are subjected to oxidation from contact with soil, salt water, or other conditions that would lead to deterioration. Shelters and appurtenances shall be protected from deterioration by painting or other corrosion and rust-resistant coatings where conditions warrant.

Steel portions of shelters that are embedded in concrete shall be protected by a minimum concrete cover as required by the American Concrete Institute Building Code Requirements for Reinforced Concrete (ACI 318). The minimum concrete cover over steel portions of shelters that are placed underground and protected only by cast-in-place concrete shall be 3 inches.

Adequate means shall be employed in shelter design to assure that dissimilar metals in contact or in connectors do not result in electrolytic action between these metals. Where long-term deterioration of shelter components is a consideration, shelters shall be designed to provide residual long-term strength necessary to meet the manufacturer/constructor-warranted longevity for the shelter.

Site-built shelters with interior volume less than 500 ft^3 may be constructed using the prescriptive designs and specifications of FEMA 320. Those designs are capable of providing a high degree of occupant protection when subjected to ground-level wind speeds of 250 mph and debris impacts of a 2 x 4 board traveling at 100 mph. Venting shall be provided as discussed in the INTERNAL PRESSURE VS. SHELTER SIZE section. Any additional or complementary provisions of this Standard shall be met.

Manufactured shelters or others that are subject to being shipped to any location shall be designed for the worst-case conditions of 250 mph wind speeds (Zone IV) and 100 mph missiles. Designs presented in FEMA 320 for site-built shelters also meet these criteria. In small shelters, minimal savings result from designing for less stringent criteria.

Shelters may be designed using either Strength Design methods (Load and Resistance Factor Design [LRFD]) or Allowable Stress Design (ASD) methods with appropriate load factors and load combinations as defined in the DESIGN LOADING COMBINATIONS section of this Standard. Only Method 2 – Analytical Procedure (Section 6.5, ASCE 7-98) should be used with some coefficients specified by FEMA 361. Appendix I of this Standard gives a synopsis of the procedure. For Main Wind Force Resisting System (MWFRS) considerations, shelters shall be considered “rigid buildings of all heights”. For Components and Cladding (C&C) considerations, shelters shall be considered “low-rise buildings with height $h \leq 60$ feet”.

Above-ground shelters that depend on the weight of concrete slabs on grade for resistance to uplift, lateral movement, and overturning shall be anchored to slabs not less than 4 inches thick which shall be reinforced with bi-directional steel reinforcing such as reinforcing bars, welded wire mesh, or post-tension cables. Reinforcement shall comply with local building codes and construction practices appropriate to soil conditions.

A small shelter, as defined by this Standard, may be constructed freestanding on its own concrete slab and foundation. The weight of the concrete slab on grade and its foundation, along with interacting soil, shall resist the forces of the uplift, overturning, and lateral movement. The design of the foundation shall also consider the soil conditions and frost depth requirements for the specific site.

Fiber reinforced concrete slabs shall be considered non-reinforced. Only those portions of concrete slabs within an area bounded by construction joints or sawn joints (crack control joints) and which anchor the structure shall be considered as contributing to the stability for the shelter.

Exceptions:

1. Non-reinforced concrete slabs on grade that are 18 inches or more in thickness may be used to anchor small shelters as defined by this Standard provided that stability of the shelter is considered to be provided by only those portions of the concrete slab on grade that lie within a horizontal distance of two and one-half times the slab thickness from the location of the anchoring connections.

2. Where slab reinforcing is continuous through construction joints or is not cut by sawn joints, such joints shall not limit the area of the slab contributing to shelter stability.

Shelters shall not be anchored to existing slabs of questionable quality. Existing slabs exhibiting excessive surface cracking or surface spalling shall be evaluated and core tested, if necessary, to determine the slab's ability to carry the shelter design loads. Slab reinforcing shall be investigated by such methods as metal detectors or core drilling.

Shelters that are located with the floor of the shelter above the ground or slab on grade level shall be designed for wind forces, pressures, and debris impacts acting on the fully exposed shelter and above ground supporting structure [See COMMENTARY].

8. INTERNAL PRESSURE VS. SHELTER SIZE

If venting sufficient to relieve atmospheric pressure changes is provided in *small* shelters, then the Internal Pressure Coefficient $GC_{pi} = \pm 0.18$ may be used to calculate wind pressures on the shelter. Venting in the amount of 1 ft^2 per 1,000 ft^3 of shelter volume should be provided through the roof of a flat-roofed (less than 10^o from horizontal) shelter or with approximately equal (± 10%) vent areas (non-airtight openings) in opposite walls. A combination of roof and opposite-wall openings may be used. This venting is more than is required for occupant breathing. Vents provided through the roof or opposite walls do not foster internal velocity pressure build-up.

Large shelters with interior volume of 1,000 ft^3 or more shall be designed with $GC_{pi} = \pm 0.55$. Venting sufficient to relieve atmospheric pressure changes for large volumes is difficult to achieve without creating openings that allow velocity-induced pressures, i.e., the shelter becoming "partially enclosed." Alternate venting schemes for large shelters intended to relieve atmospheric pressure changes accompanying tornadoes must be approved by NSSA. No venting to relieve atmospheric pressure change is assumed in this Standard in designing large shelters although code-compliant ventilation for habitable spaces is required.

Shelters with volumes between 500 and 1,000 ft^3 are of an intermediate size for which both the internal pressure coefficient and the vent size are transitioned from values used for small shelters and those used for large ones.

For *intermediate* size shelters with volume between 500 and 1,000 ft^3, GC_{pi} may be scaled linearly, i.e.:

$$GC_{pi} = \pm (0.74)(10^{-3})\text{Volume} - 0.19$$

Where: $500\ ft^3 \leq \text{Volume} \leq 1{,}000\ ft^3$

The venting area required to relieve internal pressures due to atmospheric pressure changes sufficiently to justify the internal pressure coefficient calculated above may be determined by the formula:

$$A_{vent}\ (ft^2) = [1.0 - (\text{Volume}/1{,}000)]$$

Where: A_{vent} is the vent area in square feet

Note that as the shelter interior volume increases from 500 ft^3 to 1,000 ft^3, the Internal Pressure Coefficient increases linearly from ±0.18 to ±0.55 while the required vent area decreases linearly from 0.50 ft^2 to zero. Alternatively, shelters of any size may be designed with the Internal Pressure Coefficient $GC_{pi} = \pm 0.55$ with venting only sufficient to meet code requirements for ventilation of a habitable space.

Alert: Calculated pressures must be applied to all shelter surfaces, including doors. Doors specified in FEMA 320 were tested for pressures up to 1.37 psi, computed with the Internal Pressure Coefficient $GC_{pi} = \pm 0.18$. When larger values of GC_{pi} are employed, doors must be tested for the pressures up to 1.75 psi, depending upon their location in the shelter, the most critical location being near the corner (See Appendix I, Determining Design Wind Pressures). Alternatively, doorways must be protected to prevent intrusion of wind-borne debris in the event the door fails when subjected to wind-induced pressure.

9. MATERIAL STANDARDS

Design of storm shelters shall be based on the material standards (hereinafter Material Standards) listed in Chapter 35 – Referenced Standards, International Building Code 2000, First Printing, International Code Council.

10. DESIGN WIND LOADS

Wind pressures and loads on shelters should be determined using ASCE 7-98 with some coefficients and load factors specified by FEMA 361 and presented in the DESIGN LOADING COMBINATIONS section of the Standard and in Appendix I – Determining Design Wind Pressures. Appendix I presents the formulas and procedures for calculating wind pressures and then presents examples of calculated wind loads for one small and one intermediate size shelter.

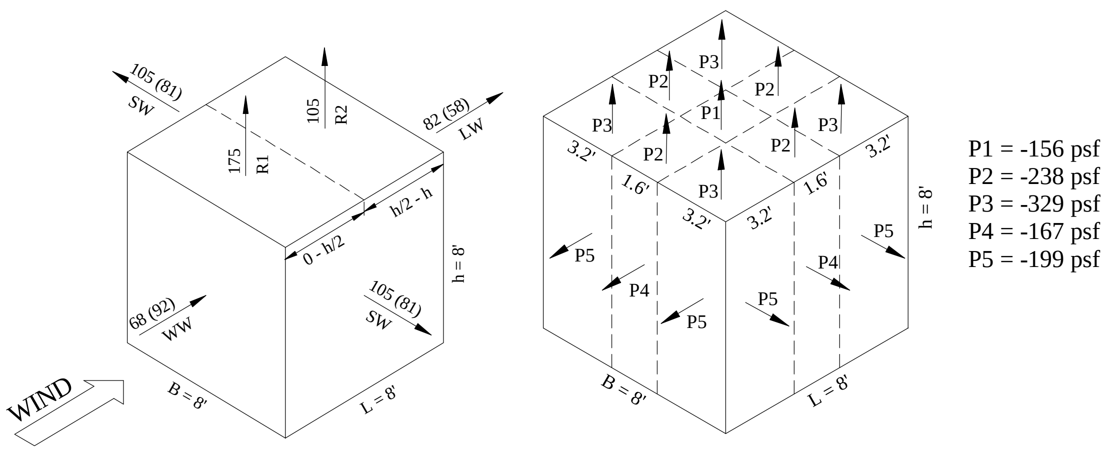
The design wind loads/pressures on a shelter are based on velocity pressure, an external gust/pressure coefficient GC_p, and an internal gust/pressure coefficient $GC_{pi.}$ The designer should calculate the extreme wind load (W_x) that will act on the shelter and include this load along with other loads in the combination that produces the most unfavorable effect. ASCE 7-98 allows the External Pressure Coefficient GC_p for walls to be reduced by 10 percent when the roof slope $\theta \leq 10^o$ (See Footnotes of Figure 6-5A, ASCE 7-98). Flat, open terrain is assumed with the Topographic Factor $K_{ZT} = 1.0$. This factor must be increased if the shelter is to be located on an escarpment or on the upper half of a hill (see ASCE 7-98).

Small residential shelters are considered enclosed structures. Impact-resistant vents or other openings must be provided to permit sufficient air transfer for occupant breathing. This ventilation provides some venting to relieve atmospheric pressure changes. Internal pressure coefficient $GC_{pi} = \pm 0.18$ may be used provided that adequate venting for atmospheric pressure change is provided (See 8. INTERNAL PRESSURE VS. SHELTER SIZE). Slots in walls and openings under and around doors that are not sealed may be counted as part of the required venting area.

Large shelters typically have more openings in surfaces that lead to increases in velocity pressure, but they are not easily and safely vented to relieve atmospheric pressure changes without creating other adverse effects. For large shelters the internal pressure coefficient $GC_{pi} = \pm 0.55$ should be used unless a suitable venting scheme, designed by a registered design professional, is utilized.

Figure 1 shows Main Wind Force Resisting System (MWFRS) pressures and Component and Cladding (C&C) pressures for a nominally 8'x 8'x 8' shelter (volume 500 ft^3) subjected to a 250 mph design wind speed. These pressures may be used in design for this size or smaller shelters that are vented, permitting use of the internal pressure coefficient $GC_{pi} = \pm 0.18$. The paper in Appendix I presents example calculations for pressures on an intermediate size shelter where values of GC_{pi} are between $\pm$ 0.18 and $\pm$ 0.55 (See 8. INTERNAL PRESSURE VS. SHELTER SIZE). For shelters with volumes greater than 1,000 ft^3, pressures and resulting forces shall be calculated using the FEMA 361 value of $GC_{pi} = \pm 0.55$.

Wind loads on shelter doors may be taken from Figure 1 for small shelters or, in all cases, calculated with procedures outlined in FEMA 361 (See Appendix I – Determining Design Wind Pressures for wind loads and example calculations on one small and one intermediate size shelter). Horizontal doors or those inclined less than 10^o with the horizontal shall be designed for –329 psf or –2.28 psi, the highest pressure shown in Figure 1 on the roof of the small shelter. Latching systems must be provided to carry this upward force, even if one of the latches is destroyed by missile impacts. Normally this requires three hinges or a continuous hinge and three latches at appropriate locations.



MWFRS Pressures **C & C Pressures**

Figure 1. Pressures on an 8'x 8'x 8' Shelter With Wind Speed of 250 mph

11. OTHER DESIGN LOADS AND CRITERIA

Live Loads: Shelters shall be designed for live loads, including transient loads such as vehicles, where applicable. Shelter roofs shall be designed for a minimum live load of 200 pounds per square foot. Where the shelter is subject to vehicular loads or to impacts by falling structural components or objects from adjacent or overhead structures, the shelter is to be designed to resist these forces.

Earth & hydrostatic pressures: Underground portions of shelters shall be designed for the at-rest earth pressures in combination with all possible hydrostatic pressures which can act on the exterior surfaces of the shelter. The full soil weight directly over shelter surfaces shall also be applied as a vertical load.

Buoyancy: Where shelters are subjected to hydrostatic pressures, the shelter ballast and anchorage shall be designed to resist 150% of the buoyancy force. Passive earth pressure resistance to buoyancy uplift, where applicable, shall be based on the saturated properties of the soil.

Seismic forces: Shelters must be able to resist the most unfavorable effects from both wind and seismic loads, but wind and seismic loads need not be considered to act simultaneously. Large and medium shelters must be designed for seismic loads for the applicable seismic zone as well as for wind and other loads. Small shelters designed in accordance with this Standard generally possess sufficient impact resistance, shelter strength, and structural stability to resist seismic loads for any seismic zone and are therefore not required to be designed specifically for earthquakes.

The COMMENTARY presents the best information available to the writers of the Standard on lightning effects on shelters. Aboveground metal shelters that are grounded to meet national electrical code and other local requirements need not have metal surfaces covered with gypsum board or other non-conducting sheathing to prevent occupant contact with metal. For metal shelters not grounded to meet electrical code requirements, contact of occupants with the metal shell or with metal connections to the shell shall be prevented. Each metal sheet used as a shelter component shall be either (1) covered to prevent occupant contact, (2) grounded by means of connections to a grounded metal structure, or (3) grounded by a separate ground rod. Literature searches and discussion among researchers continues on the subject of lightening protection in storm shelters. Limited research to date has yielded little definitive answers specifically related to storm shelters. The Standard will be refined should research lead to new results and conclusions regarding design of shelters to minimize the dangers of lightning to shelter occupants.

12. DESIGN LOADING COMBINATIONS

Design of shelters may be based on Allowable Stress Design (ASD) or on Strength Design (Load and Resistance Factor Design [LRFD]). For extreme winds, the load combinations specified in FEMA 361 shall be used. The designer should calculate the extreme wind load (W_x) that will act on the shelter using formulas and procedures presented in ASCE 7-98 with the specific requirements set forth in FEMA 361.

When LRFD is used for storm shelter design, FEMA 361 indicates that the following load combinations should be considered:

Load combination 1: $1.2D + 1.0W_x + 0.5L$
Load combination 2: $0.9D + 1.0W_x + 0.5L$
Load combination 3: $0.9D + 1.2W_x$

Where: D = dead load, L = live load, and W_x is the extreme wind load based on wind speed selected from Figure 2.2 of FEMA 361. Dead load factors are 1.2 or 0.9 depending upon whether the dead load adds to the wind loads or counteracts them, respectively.

When Allowable Stress Design (ASD) is used, the following load combinations should be considered:

Load combination 1: $1.0D + 1.0W_x + 0.5L$
Load combination 2: $0.6D + 1.0W_x$

Where: D = dead load, L = live load, and W_x is the load resulting from extreme wind loads. W_x represents the pressures and forces resulting from tornadic winds considering worst-case conditions for both MWFRS and C&C. Dead load factors of 1.0 or 0.6 depending upon whether the dead load adds to the wind loads or counteracts them, respectively. When the live load is to be combined with wind loads, live load is multiplied by a factor of 0.5. No reduction should be taken for wind loads under any circumstance.

13. MINIMUM FACTORS OF SAFETY

This Association Standard recognizes the margins of safety embodied in allowable stress for materials permitted by MATERIAL STANDARDS for Allowable Stress Design (ASD). For ASD, structural components and assemblies shall be designed using these allowable stresses. Higher allowable stresses for short-term loads shall not be used.

Design wind speeds specified by FEMA 361 are based on long mean recurrence intervals and are higher than the most extreme winds that are expected to occur. The load combinations specified lead to calculation of higher-than-expected total loads on the shelter. With conservatism in determining loads on the one hand and, on the other, with reliability in determining load carrying capacity of the shelter structure, margins of safety are inherent in the design procedures embodied in FEMA 361 and in this Standard.

Design methods discussed in this Standard pertain to the shelter structure only. For soil/structure interaction, a factor of safety of 1.25 or higher should be used for soil resistance to uplift, lateral movement, and overturning, including anchorage and foundations. Ballast and anchorage for underground shelters shall be designed to resist 1.50 times the buoyancy force.

Factors of safety are used in design to assure safety in the face of uncertainties. Should uncertainties exist in determining loads or resistance (strength), then factors of safety appropriate to the degree of uncertainty may be used. Appropriate factors of safety must be determined by the design professional in charge.

14. WINDBORNE DEBRIS IMPACT CRITERIA

Providers of small residential shelters for which designs are not included in FEMA 320 must assure that the designs meet the debris (missile) impact requirements of this Standard. Large shelters must meet the requirements of FEMA 361 and applicable building codes. All shelters must be able to withstand design loads and be able to resist impacts of the design missile, a 15-pound wood 2 x 4 board striking normal (perpendicular) to the enclosure surface at speeds specified in the paragraphs that follow. Test procedures are explained in Appendix II – Test Procedures for Debris Impacts.

Walls, doors, and other enclosure surfaces inclined 30^{o} degrees or more from the horizontal are tested as vertical surfaces: the design missile speed is 100 mph.

Walls, doors, and other enclosure surfaces inclined less than 30^{o} from the horizontal are considered horizontal surfaces: the design missile speed is 67 mph.

Soil-covered underground shelters or portions of them with less than 12 inches of vertical soil cover should be tested for resistance to missile perforation as though the surfaces are exposed. Designs and installation instructions should show how the depth of the ground cover is maintained over long periods of time. To qualify for shielding due to soil cover, the soil surfaces shall slope away from the entrance walls or other near-grade enclosure surfaces of underground shelters at a slope of not more than two inches per foot for a horizontal distance of not less than three feet from the exposed portions of the shelter or unexposed portions deemed to be protected by soil cover.

Large site-built community shelters may be designed for wind speeds shown on the zone map, Figure 2.2 of FEMA 361. Missile impact speeds of 100 mph are specified for vertical surfaces regardless of the zone or design wind speed. Since the vertical missile speed of 67 mph is based on the free-fall speed of

missiles, all shelter surfaces that are inclined 30^o or less from the horizontal are subject to missile impacts of a 15 pound
2 x 4 traveling at 67 mph regardless of the design wind speed.

No allowance shall be made for shielding of shelter enclosure surfaces and components from missile impact, except as follows:

1. Adjacent or enclosing structures which are designed and constructed in accordance with this Standard and which are contiguous with, or completely enclose the shelter or shelter component.

2. Adjacent basement or foundation walls, which retain a minimum horizontal thickness of soil of three feet on the opposite face of the wall.

To qualify for shielding by an adjacent structure or wall, the surfaces qualifying for shielding from impact must meet the following requirements.

1. For total shielding - missile impact is totally prevented by the qualified shielding structure or wall.

2. For partial shielding - the angle of impact of the missile is limited by the qualified shielding to 45^o or less from the plane of the enclosure surface which is being impacted. Until further research produces other criteria, partially shielded surfaces must be designed for impacts by a 15 lb 2x4 board impacting perpendicular to the surface at 67 mph.

Missile Impact Requirements:

1. Test missiles must not perforate the shelter envelope. There shall be no opening that allows direct passage of life-threatening debris.

2. Shelter occupants shall be warned of potential injury from instantaneous deformations or impulse force due to windborne debris impacts or they shall be protected from such deformations. Warnings or protection shall be provided by permanently installed instructions, warnings, and/or installed components that prevent occupants from having bodily contact with the walls or doors of shelters during an extreme windstorm. Alternatively, the “safe distance” from original inside surfaces may be established and thus defined by permanently installed barriers, seats, rails, or rods that prevent occupants from sitting or standing sufficiently close to walls that they are susceptible to injury when windborne debris strikes the shelter wall.

3. The permanent displacements of shelter walls from debris impact tests shall be reported in test reports. The permanent displacement of the interior surface of any storm shelter wall, roof, doors, vents, and other shelter appurtenances toward the interior of the shelter as the result of missile impact tests shall not exceed 3 inches. For the purpose of measuring this displacement, the interior surface is defined as the interior installed wall or the inside edges or surfaces of flanges or ribs so long as the clear space between flanges or ribs is not more than 12 inches. If the clear span between flanges or ribs is more than 12 inches, then the inside surface is defined as the outermost surface with which occupants can make contact from the inside of the shelter.

4. Potentially dangerous fragments loosed by spalling of the interior surface or fracture of bolts or screws during testing shall also be reported and must be prevented by the shelter producer from becoming missiles or projectiles inside the shelter. Fragments or powder from sheetrock are not considered dangerous unless attached to other materials.

5. Any deformation or damage resulting from missile impact tests shall not reduce the structural integrity of the shelter so that it fails to meet the minimum design load requirements of this Standard.

15. VERTICAL ACCESS/EGRESS

Vertical access to underground storm shelters shall be designed to be consistent with the provisions of Occupational Safety and Health Standards for General Industry, (C29 CFT Part 1910) with amendments. Vertical access to private shelters may be in the form of stairs or ladders. Note: Neither type of access meets American with Disabilities Act requirements. Pertinent OSHA vertical access requirements are presented as follows:

15.1. Stairs

Stair treads are to be 8 inches in width, minimum, and are to have reasonably non-slip top surfaces. Risers are to be uniform in height and to have a maximum dimension of 9-9/16 inches. The minimum width of the stairway shall be 22 inches.

A continuous side handrail must be located on one side of the stairway. The angle of the stairway from horizontal shall be equal to or less than 50 degrees. Exception: When a continuous side handrail is provided on each side of the stairwell and the stairwell otherwise meets the requirements for ladders (see 15.2. Ladders). Stairs must be constructed so that the foot cannot slide off of the end of the stair tread on either side. The minimum clearance above any stair tread to an overhead obstruction shall be at least 7 feet, measured vertically.

Exception 1: The minimum clearance above any stair tread to an overhead obstruction may be reduced to 5 feet provided that signage is provided on the stairs at the top and bottom conspicuously warning the user that there is low headroom and that users must stoop down to use the stairs without injury.

Exception 2: Shelter entrances that are entered with persons seated on the entrance threshold and that are not high enough for a person to enter standing erect are exempt from the provisions for headroom and stair handrail, provided that there are a maximum of two stair risers not exceeding 10 inches in height for each riser, and provided that the stairs lead down into the shelter.

15.2. Ladders

Ladders shall have a clear length of rungs or cleats of not less than 16 inches. The rungs shall be constructed such that the foot cannot slide off the end of the rung. Stair rungs shall be ¾” diameter, minimum, and shall be spaced uniformly at not greater than 12 inches on center. Ladder wells shall have a minimum of 15 inches clear on either side of the centerline of the ladder and a minimum of 27 inches clear from the centerline of the rungs to a smooth ladder well or cage on the climbing side of the ladder. Where obstructions occur in the ladder well, this distance shall be increased to 30 inches. The distance between the centerline of rungs or steps to the nearest permanent object in back of the ladder (on the toe side) shall be no less than 7 inches.

Exception: See Figure 2

No minimum clearance on the toe side of the ladder is required where there is no obstruction on the climbing side of the ladder and where ladder steps of 11 inches or greater width are molded or fabricated in a continuous series of treads and risers in which the foot can neither slip through the riser nor be trapped by the riser or next higher ladder stair tread.

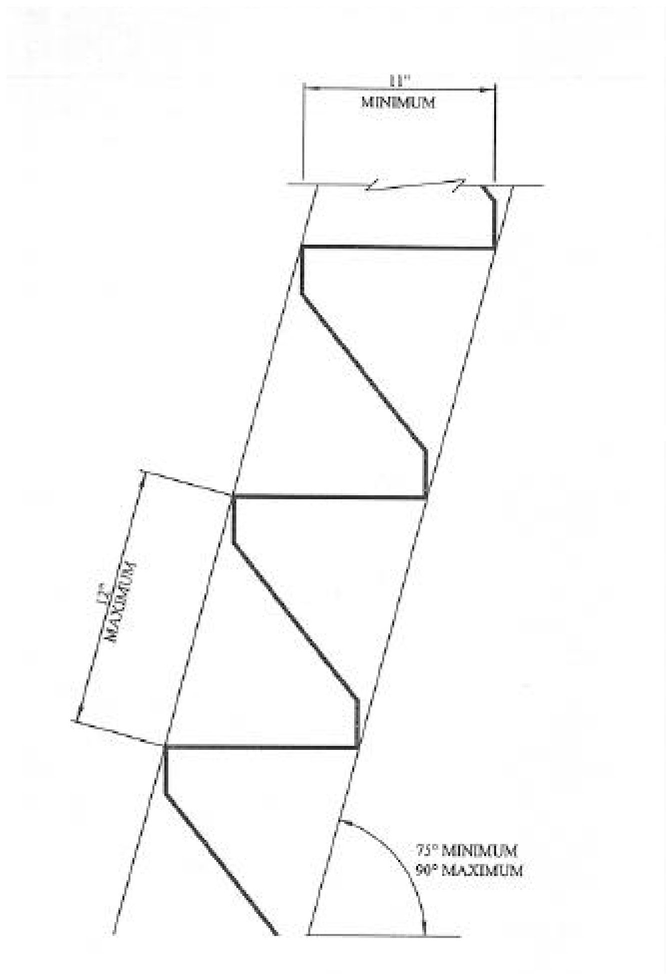


Figure 2 - Ladder with Continuous Treads and Risers

Cages or ladder wells are required for stairs extending in excess of 8 feet from the floor.

15.3. Overhead Hatches

Access doors (hatches) at the tops of ladders shall have a minimum opening 24” x 30”-- a clear opening of 24 inches minimum from the centerline of the rungs on the climbing side of the ladder and a clear width of 15 inches on either side of the centerline of the rungs. Hatches must open fully or must open a minimum of 60 degrees from the closed position and be counterweighted or otherwise held in the open position when opened.

16. SITING

Storm shelters should not be located where occupants will be exposed to substantial risks from other hazards or where access is impeded. Sites should be avoided where flooding could pose a threat to occupants. FEMA 361 stipulates that shelters should be located outside areas known to be flood-prone, including areas within the 500-year flood plain. It is recognized that many residences in the United States are located in areas where shallow flooding is a threat, flooding that threatens property damage but not loss of life. Storm shelters are not designed to provide protection of shelter occupants from death or injury due to flooding. But it is not the intent of this Standard to deny occupants of residences in flood-prone areas the opportunity to have or to be sold storm shelters. Common sense should influence the siting and occupancy of storm shelters to minimize the risks of death or injury from other catastrophic events that could occur simultaneously with their occupancy during a tornado or other windstorm event. Questions regarding appropriate siting of residential storm shelters in flood-prone areas should be resolved with counsel from county emergency management officials.

Entrances to shelters should be located at such elevations that surface water will drain away from the entrance. Underground or partially underground shelters should not be located where the water level will reach such heights that the hydrostatic pressure on the shelter vessel will cause the shelters to "pop up" from the ground or leak from standing water. Where such shelters are subject to hydrostatic pressures, they shall be designed to provide the minimum factors of safety against uplift from these forces (see 13. MINIMUM FACTORS OF SAFETY section).

Shelters should preferably not be located directly under overhead electrical power lines, under the umbrella of large trees, or within the fall radius of towers, non-reinforced masonry chimneys, or other tall structures.

Because wind speeds are markedly increased by airflow over steep hills or escarpments, these locations should be avoided in siting shelters. If a large site-constructed shelter is located on an escarpment or upper half of a hill, the Topographic Factor K_{ZT} shall be taken from ASCE 7-98. When manufactured shelters are installed on escarpments, design wind pressures and forces shall be increased by one-third to account for increase wind speeds.

Storm shelters are not to be located in areas where normal building use, activity, or functions would hinder or delay access to the shelters. For example, an underground shelter shall not be located in a garage where parked vehicles can block access.

Hostile environments: Shelters should not be located in environments where toxic or volatile vapors are generated or stored. Where such hazards are possible, shelters or their enclosing environments must be vented to avoid accumulation of toxic or volatile vapors in the shelter.

17. TYPES OF CONSTRUCTION

The form and function of storm shelters shall not be limited by this Standard beyond the requirement to provide safe and reliable shelters. Shelter construction material is not to be limited by this Standard except as may be inferred by the requirement to meet the ENGINEERING TESTING AND EVALUATION criteria and the requirements of ESSENTIAL STORM SHELTER FEATURES & ACCESSORIES.

Construction of in-residence shelters based on FEMA Publication 320 shall also meet the requirements of this Standard.

Where storm shelters depend on integrity of the door for the security of the occupants during a storm, the door shall be constructed in such a manner that failure of a single point of attachment, such as a hinge or a deadbolt, will not result in failure of the door due to design wind pressures or missile impact. However, failure of a door to operate or open freely after impact of a test missile does not constitute failure of the shelter.

18. ESSENTIAL FEATURES & ACCESSORIES

It must be recognized that the primary purpose for storm shelters is to provide short-term, emergency shelter from severe storms. It must also be understood that for shelters to be economically manufactured or constructed that certain amenities associated with normal use facilities must be waived or eliminated. Manufacturers and constructors of storm shelters may offer customers suggested lists of accessories for safety and convenience while occupying storm shelters. However, this Standard does not dictate that features or accessories are required to be included in storm shelters, except as follows.

1. Accessories and access for public storm shelters shall be provided in accordance with FEMA Publication 361 and applicable building codes.

2. Passive ventilation for residential shelters: Passive ventilation is defined as the non-powered air flow into and through the shelter envelope by way of openings that provide air required for breathing. To relieve internal pressures due to atmospheric pressure changes in tornadoes, minimum non-airtight openings of one square foot per 1,000 cubic feet of shelter space shall be provided for shelters with volume up to 500 ft^3. With such openings the Internal Pressure Coefficient $GC_{pi} = \pm 0.18$ may be used. If openings to relieve atmospheric pressure change are less than one square foot per 1,000 cubic feet of shelter space in small shelters, $GC_{pi} = \pm 0.55$ shall be used as though they are not vented. Ventilation area provided for relieving atmospheric pressure change may also be considered as area available for passive ventilation. Openings must be protected to prevent intrusion of potential injurious wind-borne debris.

   When shelters are designed to provide air for breathing but not for pressure relief, the minimum area for non-airtight openings provided for residential shelters shall be two square inches per occupant capacity when breathing vents are located at or near the tops of occupied shelter spaces and air intake openings of at least one-half square inch per occupant capacity is afforded around an access door at or below the level of occupants' heads. The level of occupants' heads is defined as 30 inches above the level of fixed seating or 46 inches above the floor where no fixed seating is provided. For underground shelters or where no air intake is provided below occupant' heads, the minimum area of non-airtight openings at or near the tops of shelters should be four square inches per occupant capacity.

   When these minimum vent areas for breathing are used, the Internal Pressure Coefficient $GC_{pi} = \pm 0.55$ shall be used in design. This has special implications for doors that must be able to withstand internal pressures higher than those used in door tests conducted in preparing FEMA 320 (see Alert in the INTERNAL PRESSURE VS.SHELTER SIZE section of the Standard). Further discussion of opening size is presented in the COMMENTARY – DESIGN WIND LOADS section.

3. Access doors shall have sufficient hardware to prevent perforation when tested in accordance with this Standard and to safeguard against accidental door opening during a windstorm. The hinge side of the door shall include a minimum of three hinges or a continuous hinge. The lock

side shall include three deadbolts or other positive latching devices. Deadbolts that are operable from the inside shall be keyed on the outside. Alternate locking devices that meet the test requirements of this Standard may also be used. Latching devices for manufactured or custom-built doors shall be shown to be adequate by engineering reports or test reports.

Guidance is given in FEMA 320 and in FEMA 361 on doors and hardware for residential and public shelters, respectively. Inside locking mechanisms such as chain latches or slide bolts may be used for positive closure provided they act simultaneously. Doors in public shelters shall meet access/egress requirements of applicable building codes.

4. Exposed shelter components should be free of sharp edges and sharp, pointed corners.

5. Shelters shall be constructed of materials that are not highly flammable or corrosive [See 0. COMMENTARY].

6. Interior floor, seat, and other finishes shall be Class I as determined by NFPA 101, Section 6-5.6 (See 0. COMMENTARY). Interior seating shall not be covered with imitation leather or other material consisting of or coated with pyroxylin or similar, highly flammable materials.

7. For tornado shelters, FEMA 361 recommends the minimum spaces per occupant shown below, taking into account occupant ages and conditions. For hurricane shelters the minimum recommended space is 10 ft^2 per person.

Table 1. FEMA Space Requirements for Shelter Occupants

Occupant	**Sq. Ft./Person***
Adult, standing	5
Adult, seated	6
Children (under age 10)	5
Wheelchair	10
Bed-ridden persons	30

*The area shall be taken as the gross inside wall-to-wall area at the level of fixed seating.

Note: For private residential tornado shelters that are occupied for short periods of time this Standard allows for two-thirds of the values of space per occupant recommended in Table 1. It is reasoned that private residential shelters will accommodate family members who are not likely to be intimidated by close physical contact and who have more than likely had an opportunity to rehearse the procedures for entering and occupying the residential shelter. Advertising or statements of allowable occupancy by the manufacturer or constructor shall point out variances from FEMA occupancy criteria.

8. All community or public shelters and those designed to specifically accommodate disabled individuals shall meet the requirements of the ICC/ANSI A117.1 – 1998 (Americans with Disabilities Act).

9. According to FEMA 320, metal shelters or metal components available for contact by shelter occupants must be grounded with copper wire and ground rod to meet national electrical code requirements. Shelters with steel sheathing covered with gypsum board or otherwise separated from contact by shelter occupants need not be grounded. Licensed electricians should install wiring for all electrical fixtures and outlets other than those requiring only low voltage wiring. Research continues on lightning protection in shelters (See 0. COMMENTARY).

19. ENGINEERING TESTING & EVALUATION

Engineering evaluation and testing are required for storm shelter products that are different from or that vary from the prescriptive designs presented in FEMA 320 or an NSSA-approved design document. Only laboratories accepted by NSSA will perform tests on products that have had or are to have engineering evaluation. Storm shelter products submitted to NSSA or to NSSA-approved testing and evaluation entities for engineering testing and evaluation shall be fully described by design drawings and supporting engineering documentation (see STORM SHELTER DESIGN DOCUMENTATION section. Products not having sufficient descriptive design documentation will not be evaluated.

Products qualifying for engineering testing must be complete storm shelter units, which are constructed in compliance with submitted design documentation. A wall, vent, or door of a storm shelter may be tested as a sub-assemblage, but results of such tests may not be used to qualify a shelter, i.e., the performance of the complete shelter must be proven. The component may be tested separately provided the complete shelter has been previously tested with the sub-assemblage as a component and provided that the changes are fully described in accompanying descriptive design drawings and supporting engineering documentation; and provided that the support framing and attachments for the sub-assemblage used during the test represent the same extent and degree of support as is provided for the sub-assemblage when it is installed as part of the whole storm shelter unit. Changes in design or new designs shall be evaluated by a registered design professional and be tested by an independent testing agency. The independent testing agency shall determine whether or not additional testing is required. The testing agency may waive further testing based on similarity to shelter or component tests already conducted.

Evaluation of the design documents and other submittals shall be for compliance of storm shelter design with this Standard. Registered Professional Engineers employed by independent, third party firms, who are qualified by education and experience to evaluate the structural design documents and submittals for compliance with this Standard, shall conduct structural evaluation. Requests for evaluation shall be made to NSSA. Shelter design documents and calculations shall be submitted directly to the evaluating firm, which shall maintain confidentiality of all information. Where shelters in a range of sizes are to be built from one basic design, calculations shall be presented for the most critical sizes, usually the smallest and largest shelter, to be built. The evaluating firm may call for additional calculations if it is not clear that the most critical sizes are covered. All costs for engineering evaluation and administration thereof shall be borne by the entity requesting the evaluation.

Engineering evaluation and testing of storm shelter products shall include, but are not limited to the following elements.

> Function: The features and functions of the storm shelter; access, ventilation, lighting, environmental and fire safety considerations; capabilities versus claimed capabilities and stated product warranties.
>
> Reliability: Durability of the storm shelter for the intended installation conditions and environment.
>
> Structural capacity: Strength, serviceability, and stability evaluation.
>
> Storm shelter assembly, connectivity, and anchorage.

Missile impact resistance: Impact tests on shelter enclosure surfaces, doors, vents, windows, etc. as required by this Standard. Impact tests shall be conducted by testing laboratories or test facilities, which are accredited to conduct these types of tests (see 20. TESTING FACILITY ACCREDITATION). The NSSA Standards Committee may prescribe test series to be conducted on all shelters or they may prescribe tests in addition to those normally conducted or previously conducted by the testing facility. The Standards Committee may either accept or amend the proposed test program.

Door & door hardware tests: Special tests may be required to verify structural capacity of door panels and hardware under forces and pressures prescribed by this Standard. Door/door-hardware systems shown in FEMA 320 for vertical doors were tested for pressures up to 1.37 psi, the pressure calculated for wind speeds of 250 mph using an Internal Pressure Coefficient $GC_{pi} = \pm 0.18$. For large shelters designed for 250 mph winds and $GC_{pi} = \pm 0.55$, pressure on the door might reach 1.75 psi. All doors, including hatches and horizontal or inclined doors to underground shelters, must be designed to withstand wind pressures prescribed in the DESIGN OF WIND LOADS section of this Standard. Door systems intended for applications where pressure on the door might exceed 1.37 psi must be tested or the door must be protected with an alcove or be shielded from windborne debris impacts.

Other evaluations: Other evaluations, which may be deemed necessary to prove the competency of the shelter may be required by the approved testing or evaluation entities or by the Standards Committee for unusual storm shelter construction, design or use conditions.

20. TESTING FACILITY ACCREDITATION

Appendix II -- Test Procedures for Debris Impacts presents guidelines for testing storm shelters for compliance with the quality and performance required by FEMA and by this Standard. NSSA will decide which testing agencies to recognize in evaluating application for membership in NSSA. Texas Tech is widely recognized for its pioneering role and expertise in shelter testing and development and will serve as NSSA's agency for missile testing and evaluation until other laboratories are accredited or authorized by NSSA to perform testing as required by this Standard.

21. STORM SHELTER DESIGN DOCUMENTATION

All storm shelters shall be documented to comply with the Standard. Design documentation for shelter designs not shown in FEMA 320 or deviations in design of small shelters from those shown in FEMA 320 shall be prepared by a registered design professional. The letter of transmittal or cover sheet for submittals to the evaluating firm shall be sealed by the preparing design professional. Submittals shall include material and component test reports, design calculations, specifications, design criteria, fabrication, assembly, and erection or installation drawings or instructions. Design calculations shall include design loads and combinations used, assumptions, and design methods as required to make review of the calculations and association with the product components readily clear to the evaluating entity. Construction documents and/or shop drawings shall be dimensioned and drawn upon suitable material. Construction documents shall be of sufficient clarity to indicate the material and configuration of the individual elements, the juxtaposition of the elements in the finished form, the type and size of all connections of the elements, and the procedure for erecting and anchoring the storm shelter. All information furnished the testing and evaluating firm shall remain the confidential property of the owner.

22. REFERENCES

References are given here although not referred to by number in this Standard. They are referred to and numbered in the Appendix I – Determining Design Wind Pressures.

Al-Menyawi, Yahya, Russell Carter, Ernst Kiesling and Kishor Mehta, "Explanation and Examples of Wind Pressures on Storm Shelters According to FEMA 361 and ASCE 7-98" prepared for publication, December 2000.

ASCE 7-95, (1996), "Minimum Design Loads for Buildings and Other Structures," American Society of Civil Engineers.

ASCE 7-98, (1999), "Minimum Design Loads for Buildings and Other Structures", American Society of Civil Engineers.

FEMA, (1999), "Taking Shelter from the Storm," Federal Emergency Management Agency, FEMA 320, 2nd Edition.

FEMA, (2000), "Design and Construction Guidance for Community Shelters," Federal Emergency Management Agency, FEMA 361, First Edition.

International Building Code 2000, (2000), International Code Council, Inc., 1st Printing.

Kiesling, Ernst W. and Russell R. Carter, "Considerations in Designing Above-Ground Storm Shelters". Unpublished report.

APPENDICES

The Appendices must be downloaded separately.

Appendix I - Determining Design Wind Pressures

This Appendix summarizes results of the calculations presented in the paper *Explanation and Examples of Wind Pressures on Storm Shelters* [5].

Appendix II - Test Procedure for Debris Impacts

COMMENTARY

A COMMENTARY is presented to provide explanation and discussion of elements of the Standard. Reference is made to the COMMENTARY at various points in the text of the Standard. Topic headings follow those in the text of the Standard and are presented in the same order.

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HISTORY

In May 2000, a group of storm shelter manufacturers, most of whom had had their shelters tested for tornado missile impacts at Texas Tech University, or had otherwise demonstrated the quality of their storm shelters, formed the National Storm Shelter Association (NSSA). Its purpose is to encourage quality in manufactured and constructed storm shelters capable of providing a high degree of survivability for shelter occupants during tornadoes or other violent windstorms.

BACKGROUND

Performance criteria and several prescriptive designs for small site-built residential shelters can be found in the Federal Emergency Management Agency (FEMA) 320 booklet, *Taking Shelter From the Storm: Building a Saferoom Inside Your House* [4]. Designs in FEMA 320 are based on 250-mph ground-level design wind speeds and debris impacts of a 15 lb. 2 x 4 board traveling at 100 mph and striking normal (perpendicular) to the surface. These are the most stringent load criteria for any location, so shelters built to these criteria may be built anywhere in the United States or its territories. Little guidance is given in FEMA 320 for manufactured shelters that are typically built off-site and installed in residences: very little is said about below-grade shelters. Furthermore, FEMA 320 gives little direction on how to calculate wind loads on shelters or components. In response to several requests for assistance in determining wind loads on residential shelters, a paper entitled *Considerations in Designing Above-Ground Storm Shelters* [1]. was developed that shows wind pressures on small shelters with dimensions of 8'x 8'x 8' (volume 512 ft^3).

Developed concurrently with this Standard is another paper entitled *Explanation and Examples of Wind Pressures on Storm Shelters* [6]. This paper shows examples of wind pressures on shelters ranging from small residential shelters with maximum dimensions of 8 ft. to somewhat larger shelters with maximum plan dimension of 12 ft. Excerpts of this paper that are pertinent to shelter design are included in Appendix I—Determining Design Wind Pressures. With the publication of the "Explanation" paper [6] and FEMA 361 discussed below, the "Considerations" paper is superseded and of little significance.

The pressures shown in the "Explanation" paper and the designs shown in FEMA 320 assume an "enclosed building". The American Society of Civil Engineers (ASCE) Standards 7-95[2] and 7-98[3], Minimum Design Loads for Buildings and Other Structures, specify that an internal pressure coefficient GC_{pi} may be taken as $\pm$ 0.18 for enclosed buildings. Designs in FEMA 320 were made assuming that sufficient venting is provided to relieve atmospheric pressure changes. Although likely conservative, venting areas of 1 ft^2 per 1,000 ft^3 of shelter volume should be provided in small shelters to insure adequate relief of internal pressures due to atmospheric pressure changes. Such openings provide adequate ventilation to prevent health hazards. Small shelters may be vented through the roof or, if vented through the wall, venting must be of approximately equal amounts (within 10%) on opposite sides of the shelter. Aboveground shelters may also be constructed with porous enclosure materials or with vented seams that provide all or portions of the necessary venting of the shelter but that are sufficiently small that windborne debris cannot perforate the shelter.

Guidance in designing large shelters is covered in FEMA 361, *Design and Construction Guidance for Community Shelters* [5], published in late summer, 2000. Since most states require that public buildings be designed by professional engineers or architects, FEMA 361 offers guidance and some examples but few specific design recommendations or product specifications. Wind load requirements presented in FEMA 361 are based on the ASCE 7-98 Standard and are intended to define wind loads resulting from all wind events including extraordinary events such as tornadoes and hurricanes. Some coefficients and design parameters are specified, resulting in wind pressure determinations that are higher than for small, vented residential shelters. FEMA 361 assumes large shelters to be enclosed buildings but considers effective venting to be impractical. An internal pressure coefficient $GC_{pi} = \pm 0.55$ is specified to account for greater internal pressures due to various causes including the effects of atmospheric pressure changes as well as velocity pressure build-up due to leakage paths that are not uniformly distributed over the shelter surfaces. This value of $GC_{pi} = \pm 0.55$ is the same as ASCE 7 specifies for partially enclosed buildings but no shelter should be designed with openings sufficiently large to make it a partially enclosed building.

FEMA 361 becomes the recognized guide for determining wind loads and expresses essential design and performance criteria for public shelters. A zone map is presented which shows minimum design wind speeds for the United States. Hence, site-built shelters may be designed in accordance with FEMA 361 for wind speeds less than 250 mph when appropriate for a given location. Access/egress and accessibility requirements as well as human factors criteria, such as ventilation and emergency provisions for community shelters, are covered in FEMA 361.

STRUCTURAL DESIGN CRITERIA

Elevated shelters: An in-residence shelter that is installed or erected with the shelter floor located at the first floor of a residence having a crawl space below the floor is an example of an elevated shelter. If the shelter is anchored at the shelter floor level to a supporting structure extending from the ground to the residence first floor, the supporting structure, in combination with the shelter, must be designed for wind forces considering that both are fully exposed i.e., the remainder of the residence has been removed and offers no support or protection. All load-carrying components of a shelter shall have a continuous load path to the foundation.

The occupied portion of the shelter and the volume to consider in determining venting requirements is confined to that portion located above the floor of the shelter (above the top of the supporting structure for the shelter). The interior of the shelter shall not be exposed to spalling fragments resulting from missile impacts with the walls of the supporting structure.

MATERIALS STANDARDS

- Flammability of Construction Materials and Interior Finishes

International Building Code 2000, Section 307.2, defines a flammable solid as a solid material that “has an ignition temperature below 212^{o} F (100^{o}C) or that burns so vigorously and persistently when ignited as to create a serious hazard.” NFPA 101, Section 6.5.6, Interior Floor Finish Classification, provides for the classification of interior floor finishes based on test results from NFPA 253, Standard Method of Test for critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source.

DESIGN WIND LOADS

Since 1970, researchers at Texas Tech have documented damage caused by nearly 100 tornadoes and hurricanes. The building damage observed could all be caused by wind speeds less than 200 mph. Hence using a design wind speed of 250 mph provides a factor of safety on wind loads of more than 1.5 since wind loads are proportional to the square of wind speed.

Venting requirements set forth in this Standard (e.g., 1 ft^2 of vent per 1,000 ft^3 of shelter volume) are based on limiting the speed of air flow through the vent so as not to create drafts sufficient to pull objects out of the shelter or to threaten occupants. The specified vent sizes are larger than required for occupants' breathing and may be larger than required to relieve atmospheric pressure changes sufficiently to avoid structural damage. Research is needed to more precisely determine required vent sizes.

The vent area and locations required for relief of atmospheric pressure changes in tornadoes is not related to the vent area required for occupant breathing. The venting area for pressure relief is significantly in excess of the requirements for occupant breathing. ASHRAE indicates that under normal conditions an air exchange rate of 2.5 ft^3/min/person is required to maintain an acceptable comfort level for occupants. FEMA 320 indicates that minimum ventilation of 0.5 air changes per hour is to be provided in small shelters. For an 8' x 8' x 8' shelter housing six people (10 square feet per person as in hurricanes) the FEMA requirement would result in approximately 0.7 ft^3/min/person. Due to the emergency occupancy nature defined in STORM SHELTER DEFINITION, it is evident short term comfort is sacrificed for the sake of protecting occupants during a tornado. Where air is not forced through the space by fans, the air transfer must be passive flow through vents or non-airtight openings around doors, or by internal air movement and convection of warmer, exhaled air toward vents in the upper part of the shelter. Research continues regarding the minimum venting requirements for shelters to assure adequate air for survival.

OTHER DESIGN LOADS AND CRITERIA

- Lightning and Metal Shelters

Concerns over safety in lightning storms for occupants of storm shelters have led to searches for applicable science or expert opinion. Little published information has been found that addresses directly the shelter safety issue. The advice of engineers and scientists with extensive research experience in lightning safety is reflected in this Standard.

Some evidence has been provided by experts on the subject of metal structures indicating that metal enclosures shield the interior from the effects of outside sources of electricity. The public intuitively acknowledges this principle when driving automobiles during thunderstorms. The "metal box" represented by a conventional car or van yields a skin effect that becomes the conductor and protects the occupants. More in-depth understanding can be obtained from the Boston Museum of Science, (http://www.mos.org/sln/toe/cage.html).

Dr. Michael F. Stringfellow, Chief Scientist, PowerCET Corporation, states, "Metal structures are self-protecting and rarely a lightning hazard for the occupants. Even thin metal can safely conduct lightning currents without needing lightning rods or down conductors."

BG (ret.) Claude B. Donovan, project officer for development of the Army's Bradley fighting vehicle, points out that "… tanks and armored vehicles get hit by lightening all the time, and in many cases they are uploaded with their basic loads of ammunition, pyrotechnics, and fuel. There isn't even a conscious effort to make the ammo or packing materials conductors or insulators, so grounding must not be a big factor."

FEATURES AND ACCESSORIES

As a service to customers, shelter producers may provide information to residential storm shelter customers on those accessories that should be owner-provided and that pertain to short-term livability and quick rescue or discovery/recovery. The section on Emergency Planning and Emergency Supply Kit in FEMA 320 provides such information. The American Red Cross (http://www.redcross.org) is also a source for information on planning and preparing for disasters. Information should be included on:

1. Minimum emergency lighting to provide two or more hours of light within the closed shelter should be provided or recommended for inclusion in the shelter.

2. Communication equipment including a battery operated radio and a telephone. The operation of these appliances inside the shelter should be checked initially and periodically. It must be recognized that communication services may be interrupted by an extreme wind event in the vicinity of the shelter. Such equipment is not essential to safety and is not within the scope of storm shelter design promulgated by this Standard.

3. Water supply and other provisions sufficient for at least a 4-hour stay should be carried into shelters occupied during hurricanes.

REFERENCES

The web site www.wind.ttu.edu of the Wind Science and Engineering (WISE) Research Center at Texas Tech University provides access to a list of publications developed at Texas Tech University and available from WISE.

The web site www.NSSA.cc includes information on NSSA as well as helpful resources including a computer program to compute wind loads on buildings consistent with ASCE 7 – 98.