National Storm Shelter Association

Standard

for the

Design, Construction, and Performance of Storm Shelters

A forerunner for

The International Code Council/National Storm Shelter Association
(ICC/NSSA)
Standard For Design And Construction Of Storm Shelters

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

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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, *Minimum Design Loads For Buildings And Other Structures*. Material developed by NSSA members of the Standards Committee who also are members of the ICC/NSSA committee for development of the storm shelter standard is included in this edition of the NSSA Standard. This NSSA Standard served as the starting point for the forthcoming International Code Council/National Storm Shelter Association (ICC/NSSA) Standard for Design and Construction of Storm Shelters. When completed and accredited by the American National Standards Institute, the ICC/NSSA Standard will supersede this industry standard.

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 Standard 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 are relatively new disciplines. Aboveground storm shelter development has, for the most part, occurred during the past three and one-half decades; such shelters have only recently become publicly acknowledged as providing a high degree of protection from tornadoes and violent windstorms. It is certain that 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:

National Storm Shelter Association
P.O. Box 41023
Lubbock, Texas 79409-1023

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 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. DEFINITIONS

Residential storm shelter. A storm shelter serving occupants of dwelling units and having an occupant load not exceeding 16 persons.

Community storm shelter. Any storm shelter not defined as a Residential Storm Shelter.

Host building. A building in which a storm shelter is constructed or is an integral enclosure of the storm shelter structure not meeting the requirements of this Standard.

Design wind speed. The maximum wind speed for which the shelter has been designed. Values shall be the nominal 3-second gust wind speed in miles per hour at 33 feet above ground for open terrain (Exposure C).

Design wind pressure. The wind pressure on a specific location of the shelter envelope, as determined in accordance with 10. Design Wind Loads, which controls the design of components and cladding (C & C) of the shelter envelope or the main wind force resisting system (MWFRS) for the shelter.

Natural ventilation. Passive ventilation, not requiring a power source, resulting from convection of heated air, movement of inside air, and movement of outside air over and around the storm shelter resulting in air exchange through vent openings.

Protected occupant area. The portions of the shelter area that are protected from intrusion of storm debris by alcove or baffled entry systems in accordance with Chapter 14.

Rebound impact. The rebound impact by a test missile, or fragments thereof, on a portion of the shelter protective envelope after the test missile has impacted another surface of the shelter protective envelope.

Storm shelter. A building, structure, or portion(s) thereof, constructed in accordance with this standard, designated for use during a severe wind storm event such as a hurricane or tornado.

Storm shelter occupant load. The occupant load intended for a room or space when that space is in use as a storm shelter.

Shelter entry system, alcove. An entry system that uses walls and passageways to allow access and egress to the shelter interior while providing shielding from windborne debris in accordance with Chapter 14.

Shelter entry system, baffled. See definition of *Shelter entry system, alcove*.

Approved agency. An established and recognized agency regularly engaged in conducting tests or furnishing inspection services, when such agency has been approved by NSSA.

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. 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.

6. DESIGN INFORMATION

Site built shelters. For the areas of a building designed for occupancy as a storm shelter, the following information shall be provided within the construction documents:

1. A statement that the design of the shelter conforms to the provisions of the NSSA Standard for the Design, Construction, and Performance of Storm Shelters, with the edition and date specified and that all components have received testing in accordance with Appendix A by an NSSA approved agency or by a nationally recognized approved agency. Alternatively, a prescriptive design from a recognized FEMA publication such as FEMA 320 shall be cited.
2. The storm shelter type – tornado, hurricane, or combined tornado and hurricane.
3. The shelter design wind speed, mph.
4. The importance factor, I (equals 1 for all cases).
5. The wind exposure category (C; indicate if more than one is used.)
6. The internal pressure coefficient, (GC_{pi})
7. The topographic factor ($K_{zt;}$ for hurricane shelter only).
8. The occupant load of the storm shelter.
9. The usable storm shelter floor area (square feet).
10. Area and locations of natural ventilation (square inches).
11. A floor plan drawing or image indicating location of the storm shelter on a site or within a building or facility; including drawing or image indicating the entire facility and showing at least one elevation of the storm shelter.
12. The Design Flood Elevation and Base Flood Elevation for the site (if applicable)
13. A statement that the shelter has/has not been constructed within an area susceptible to flooding in accordance with **Chapter 16. SITING**.

Exceptions:

1. Construction documents for manufactured shelters which are assembled on-site need not include items 11 through 13.

Manufactured shelters. Manufactured shelters shall contain the following information within the construction documents:

1. A statement that the design and testing of the shelter conforms to the provisions of the NSSA Standard for the Design, Construction, and Performance of Storm Shelters, with the edition year specified.
2. The storm shelter type – tornado, hurricane, or combined tornado and hurricane.
3. The shelter design wind speed, mph.
4. The importance factor, I (equals 1 for all cases).
5. The wind exposure category (C; indicate if more than one is used.)
6. The internal pressure coefficient, (GC_{pi})
7. The topographic factor ($K_{zt;}$ for hurricane shelter only).
8. The occupant load of the storm shelter.
9. The usable storm shelter floor area (square feet).
10. Area and locations of natural ventilation (square inches).
11. A floor plan and at least one elevation of the shelter.

7. STRUCTURAL DESIGN CRITERIA

Design criteria for this Standard are based on FEMA Publications 320 and 361 and on the ICC/NSSA *Standard for the Design and Construction of Storm Shelters* (Comment Draft), and are consistent with the provisions of ASCE 7.

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.

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 chapter of this Standard. Only Method 2 – Analytical Procedure (Section 6.5, ASCE 7) shall be used with coefficients and load factors specified in the DESIGN LOADING COMBINATIONS section of the Standard. 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”.

Shelter anchorage to slabs on grade. 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 residential 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 **8.** SHELTER ANCHORAGE & STABILITY].

Labeling of storm shelters. All shelters shall be labeled on or within the shelter with the name of the producer of the shelter and for the storm type and design wind speed. The label shall remain legible and visible.

8. SHELTER ANCHORAGE & STABILITY

Stability. In addition to structural stability requirements herein, the structural stability of a storm shelter shall also be determined for wind speeds below the shelter design wind speeds where forces in connections of portions of the host building to the storm shelter are equal to the nominal capacities of the connections.

Connection of storm shelters to foundations or slabs. Shelters shall be designed to resist the combined uplift, and lateral forces of the design wind speed and transfer those forces into the ground.

Structural stability of storm shelter foundations. Other than host buildings designed for the shelter design wind forces in accordance with Chapter 10, foundations and slabs that provide structural stability for storm shelters shall be designed to resist the combined uplift and lateral forces of the shelter design wind speed assuming the host building is totally destroyed by the windstorm.

Calculation of resistance to uplift and sliding of shelters. Structural stability of storm shelters shall be determined by engineering calculations for design wind pressures determined in accordance with Chapter 10. For storm shelters anchored to foundations or slabs-on grade whose top surfaces extending outward from the shelter walls are at grade, the slab on grade shall not be considered to have wind uplift forces acting on the slab top surfaces.

Slabs on grade for anchorage. Slabs on grade shall be designed for the applicable loads as a component of the shelter in accordance with Chapter 10. Where a slab on grade is being used to assist in providing uplift or overturning resistance, the minimum thickness of concrete to which storm shelters are anchored–shall be 3½ inches (88.9 mm). Unless otherwise supported by engineering calculations, the minimum steel welded wire reinforcement for concrete slabs on grade resisting combined uplift and lateral forces on the storm shelter shall be 6 x 6 – W1.4 x W1.4. Fiber reinforced slabs without minimum steel reinforcing shall not be used for anchorage.

Joints in concrete slabs on grade. Where contraction joints or construction joints are placed in concrete slabs on grade supporting storm shelters, the flexural strength of the concrete slab shall be considered zero at the joint. At joints where shear transfer is provided, the dead load of the slab beyond the joint which is tributary to the shelter foundation slab shall be permitted to be considered as resisting combined uplift and lateral forces.

Elevated storm shelter foundations. Where storm shelters are constructed with the top of the supporting foundation structure located at an elevation higher than the surrounding finished grade level, the structural stability of the storm shelter and elevated supporting foundation structure shall be computed assuming that both are fully exposed to the shelter design wind forces. Where applicable, the impacts of windborne and flood-borne debris on stability of the foundation shall be considered.

9. REFERENCED STANDARDS

Design of storm shelters shall be based on the referenced standards listed in Chapter 35 – Referenced Standards, International Building Code 2006.

10. DESIGN WIND LOADS

Wind pressures and loads on shelters shall be determined using ASCE 7 with coefficients and load factors specified in the DESIGN LOADING COMBINATIONS chapter of the Standard.

Tornado shelters. Tornado shelters shall be designed, tested, and labeled for wind speeds shown in Figure 10-1, taken from FEMA 361, and wind pressures calculated in accordance with ASCE 7.

Figure 10-1, Tornado Wind Speed Map

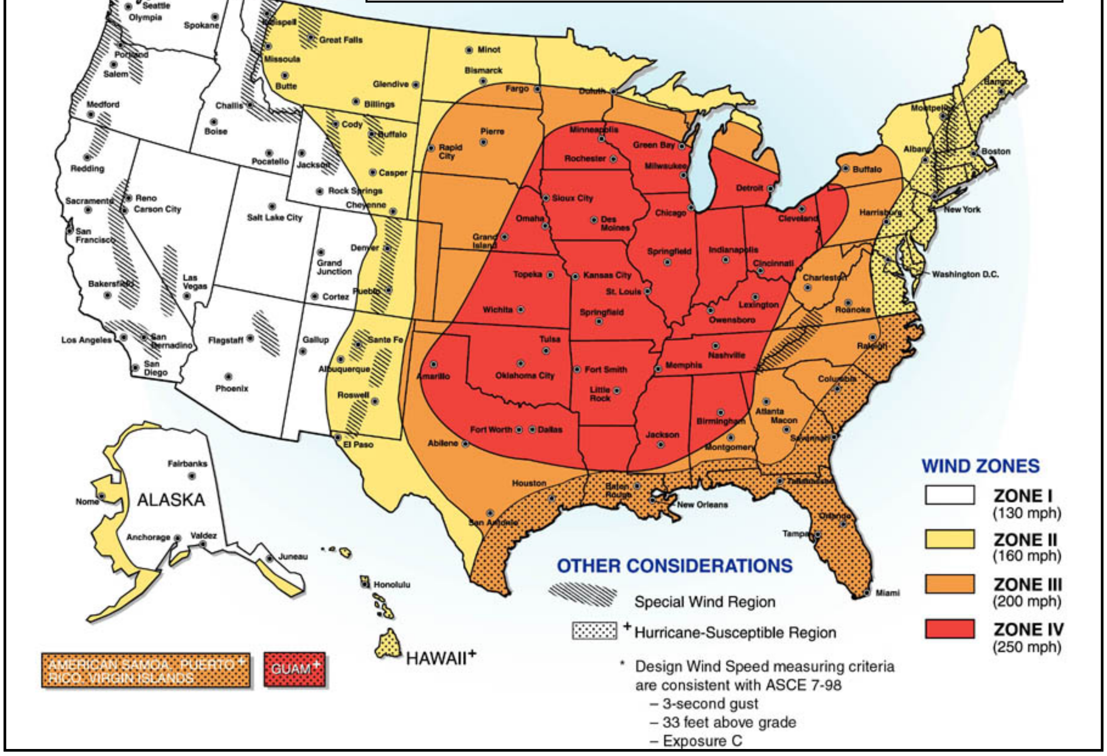


Table 10-1

Design Wind Speeds for Tornadoes

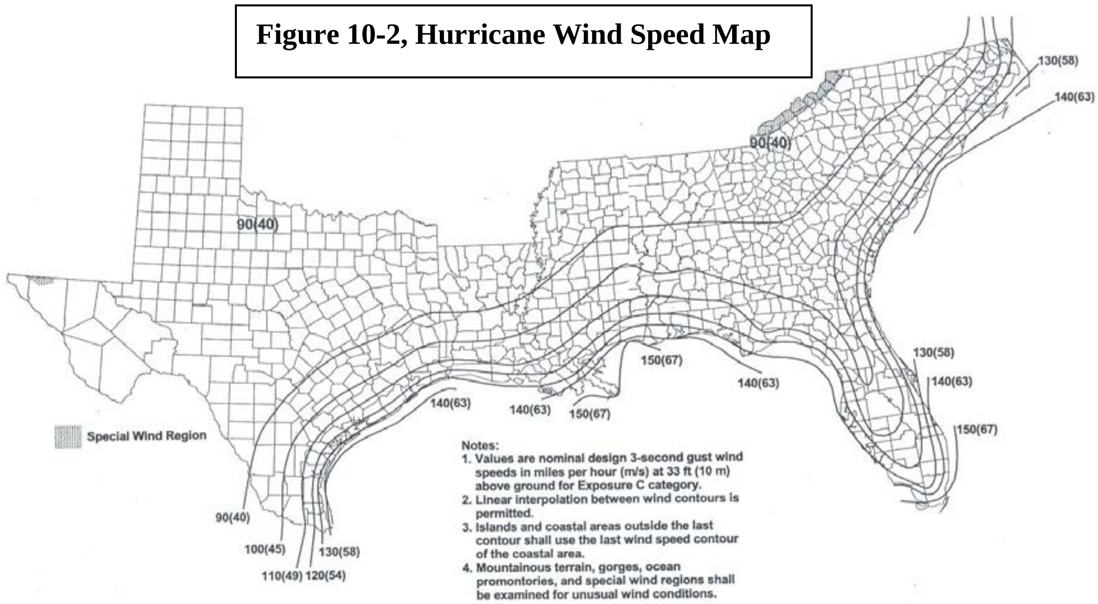
Wind Zone	Design Wind Speed (miles per hour)
I	130
II	160
III	200
IV	250

Hurricane shelters. Hurricane shelters shall be designed, tested, and labeled for the hurricane design wind speed for the specific location in which they are built or installed. Until shelter design wind speeds for hurricane shelters are defined by a storm shelter standard approved by the American National Standards Institute (ANSI), the wind speeds designated by Figure 6-1, Basic Wind Speeds, of ASCE 7 (Figure 10-2 below) plus 50 mph shall be used for design of hurricane shelters.

Storm shelters shall be labeled with storm type and design wind speed in accordance with Chapter 7, *Labeling of storm shelters.*

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) 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 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). 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).

Figure 10-2, Hurricane Wind Speed Map

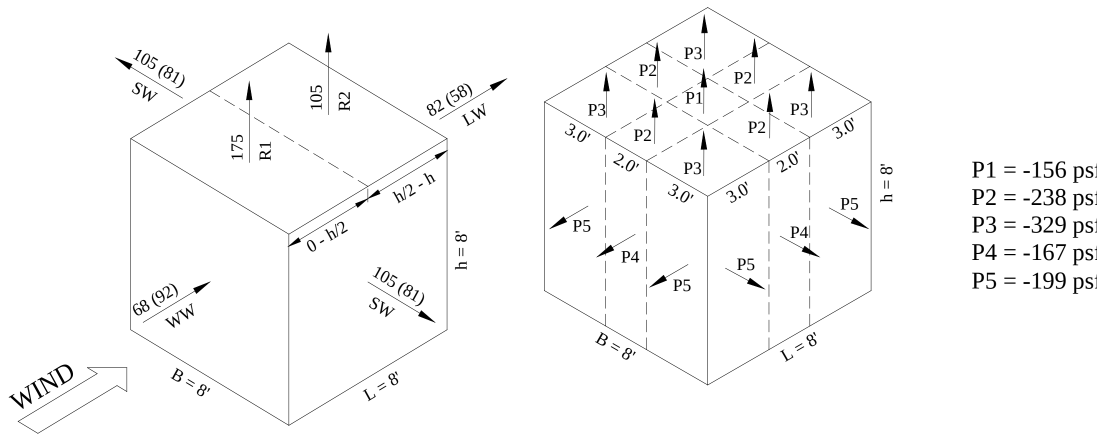


Atmospheric pressure change (APC). For tornado shelters classified as enclosed buildings the additional internal pressures due to atmospheric pressure change shall be considered. The internal pressure coefficient, $GC_{pi,}$ shall be taken as ±0.18 when APC venting area of 1 square foot (0.0929 m^2) per 1,000 cubic feet (28.3 m^3) of interior shelter volume is provided. APC venting shall consist of openings in the shelter roof having a pitch not greater than 10 degrees from the horizontal or openings divided equally (within 10 percent of one another) on opposite walls. A combination of APC venting meeting the above requirements is permitted.

Exception. Calculation of venting area to relieve APC is not required for hurricane shelters or for tornadoes classified as partially enclosed buildings. An internal pressure coefficient of GCpi = ±0.55 shall be used for tornado shelters where APC venting meeting the requirements of this section is not provided, or where APC venting area requirements are not calculated.

Figure 10-1 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 $GC_{pi}= \pm 0.18$.

Wind loads on shelter doors may be taken from Figure 10-1 for small shelters or, in all cases, calculated with procedures outlined in FEMA 361, based on ASCE-7. Horizontal doors or those inclined less than 10º with the horizontal shall be designed for –329 psf or –2.28 psi, the highest pressure shown in Figure 10-3 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 10-3
Pressures on an 8' x 8' x 8' Shelter for Design Wind Speed of 250 mph

11. OTHER DESIGN LOADS & 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 as follows:

Hurricane shelters – 50 pounds per square foot
Tornado shelters – 100 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.

Hydrostatic loads. Underground portions of storm shelters shall be designed for buoyancy forces and hydrostatic loads assuming that the groundwater level is at the surface of the ground at the entrance to the storm shelter, unless adequate drainage is available to justify design for lower groundwater level.

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.

Community shelters must be designed for seismic loads for the applicable seismic zone as well as for wind and other loads. Residential 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.

Connection of shelter elements to a host building. Where the host building does not otherwise qualify as a storm shelter under the provisions of this Standard, connection of shelter elements shall be permitted to host building framing which is designed for wind forces equal to or greater than the design wind forces for the storm shelter.

Electrical grounding of shelters and internal fixtures. 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 (1) covered to prevent occupant contact, (2) grounded by means of connections to a grounded metal structure, or (3) individually grounded to the building external ground.

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]).

When LRFD is used for storm shelter design, the following combinations should be considered:

Load Combination 1: 1.2D + 0.5W + 1.6L
Load Combination 2: 1.2D + 1.0W + 0.5L
Load Combination 3: 0.9D + 1.0W

Where D = Dead Load
W = Wind Load
L = Live Load on Roof

When ASD is used for storm shelter design, the following combinations should be considered:

Load Combination 1: 1.0D + 0.6W
Load Combination 2: 1.0D + 0.45W + 0.75L
Load Combination 3: 0.6D + 0.6W

13. MINIMUM FACTORS OF SAFETY

This Association Standard recognizes the margins of safety embodied in allowable stress for materials permitted by **9. REFERENCED 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 1.15 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

Tornado shelters. Tornado shelters shall meet the requirements of this Standard and applicable building codes. All shelters shall be able to withstand design loads and be able to resist impacts of the design missile, a 15-pound sawn lumber 2x4 board striking normal (perpendicular) to the enclosure surface at speeds specified in the paragraphs that follow. Test procedures are explained in Appendix A – Test Procedures for Debris Impacts.

Walls, doors, and other enclosure surfaces inclined 30°or more from the horizontal shall be tested as vertical surfaces. The design missile speed is shown in Table 14-1.

Walls, doors, and other enclosure surfaces inclined less than 30° from the horizontal shall be tested as horizontal surfaces. The design missile speed is shown in Table 14-1.

Table 14-1
Tornado Shelter Missile Design Speeds

Zone	Design Wind Speed (mph)	Type Surface	Missile Design Speed (mph)
I	130	Vertical	80
		Horizontal	53
II	160	Vertical	84
		Horizontal	56
III	200	Vertical	90
		Horizontal	60
IV	250	Vertical	100
		Horizontal	67

Hurricane shelters. Hurricane shelters shall be designed to resists the impacts of the design missile, a 9-pound sawn lumber 2x4 board striking normal (perpendicular) to the enclosure surface at speeds specified in the paragraphs that follow. Test procedures are explained in Appendix A – Test Procedures for Debris Impacts.

Walls, doors, and other enclosure surfaces inclined 30°or more from the horizontal are tested as vertical surfaces: the design missile speed is 0.40 times the hurricane design wind speed.

Walls, doors, and other enclosure surfaces inclined less than 30° from the horizontal are considered horizontal surfaces: the design missile speed is 0.10 times the hurricane design wind speed.

Shielding of shelter surfaces. 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 shall 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 of a design missile impacting perpendicular to the surface at two-thirds the design missile velocity for that surface.

Missile impact requirements:

1. Test missiles shall 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, loose fragments detached 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.

Shelter component testing:

Shelters meeting tornado impact test requirements. Shelter envelope components meeting missile impact test requirements for tornadoes shelters shall be considered acceptable for hurricane shelters provided they meet structural design load requirements for hurricane shelters.

Wall and roof openings. All openings into the shelter envelope shall be protected or baffled to prevent windborne debris from entering the shelter protected occupant area.

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Testing of shelter door assemblies. Door assemblies for use in the shelter envelope shall be tested in accordance with missile impact and pressure test procedures described in Appendix A, Test Procedure for Pressure and Debris Impacts.

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Door assemblies without glazing. Door assemblies without glazing shall be tested in accordance with Appendix A with static pressure on the push side of the door.

Door assemblies for tornado shelters. Door assemblies for use in tornado shelters shall be tested in accordance with Appendix A. Door assemblies for use in tornado shelters shall meet static pressure criteria described in Appendix A.

Door assemblies without glazing for hurricane shelters. Door assemblies without glazing for use in hurricane shelters shall be tested in accordance with Appendix A. Door assemblies without glazing for use in hurricane shelters shall meet static pressure criteria and cyclic pressure tests defined in Appendix A.

> *Exception*: Cyclic testing of doors without glazing is not required for doors that have been static pressure tested to a pressure equal to or greater than 1.5 times the shelter design wind pressure prior to debris testing.

Door assemblies with glazing, sidelights, or transoms. Door assemblies with glazing, sidelights, or transoms shall be tested for debris impacts and cyclic pressure tests in accordance with Appendix A.

Alcove or baffled entry systems. All protective elements of alcove or baffled entry systems shall be designed to meet the requirements of Chapter 10. DESIGN WIND LOADS and the debris impact test requirements of Chapter 14. WINDBORNE DEBRIS IMPACT CRITERIA. Where a door is employed as part of the protection in such an entry system, the door shall meet the debris impact test requirements and the pressure testing requirements of Appendix A. The enclosure classification for shelters with baffled or alcove entries shall be determined in accordance with ASCE 7.

Exception: When the entry system for a residential shelter is equipped with a door assembly that meets the pressure requirements of Appendix A, the enclosure classification shall remain unchanged by the alcove or baffled entry system.

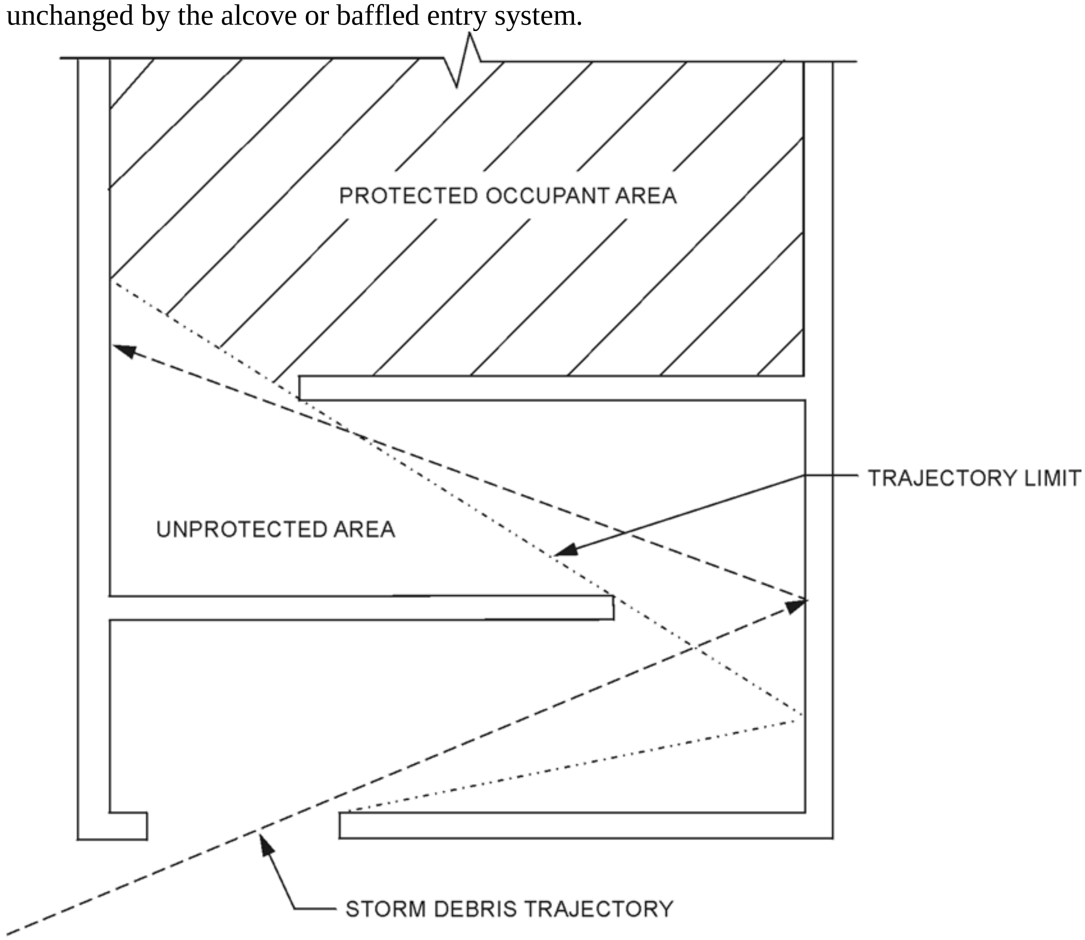

Figure 804.9.7

Figure 14-1 Alcove or Baffled Entry System

Soil-covered portions of shelters: Soil-covered shelters or portions of them with less than 12 in. of soil cover protecting shelter horizontal surfaces or with less than 36 inches of soil cover protecting shelter vertical surfaces shall be tested for resistance to missile perforation as though the surfaces were exposed. To qualify for shielding from 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. See Figure14-2.

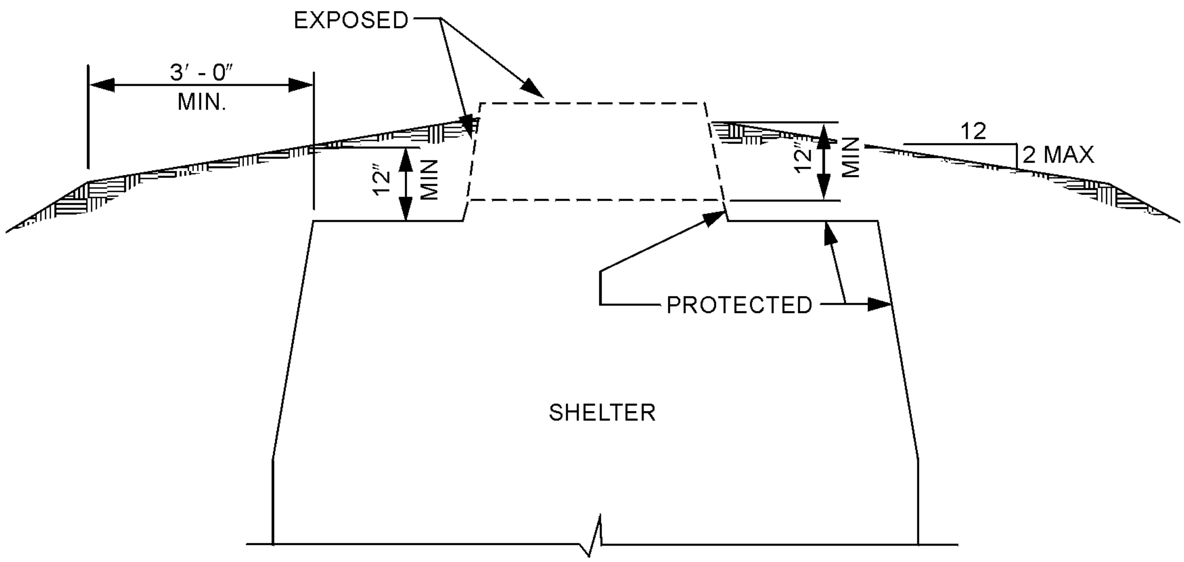

Figure 14-2

Penetrations of storm shelter envelope by systems and utilities. Penetrations through the storm shelter envelope for systems and utilities larger than 3.5 sq. inches (2258 mm^2), for any purpose, shall be considered openings and shall be protected in accordance with Chapter 14. Penetrations of the storm shelter envelope shall not degrade the structural integrity of the storm shelter and missile impact resistance of the storm shelter envelope.

Penetrations of the shelter envelope by hazardous gas or liquid lines shall have automatic shutoffs for threshold movements which are defined by the codes and standards governing such utility lines.

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 shall 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.

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 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 **15.2-1**

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.

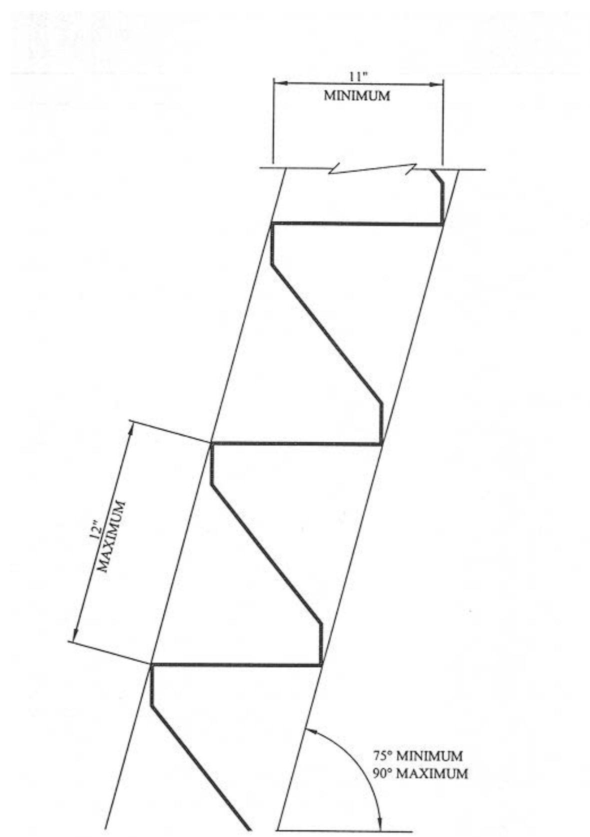

Figure 15.2-1
Ladder with Continuous Treads and Risers

Cages or ladder wells are required for stairs extending more than 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 shall 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 Chapter 13. MINIMUM FACTORS OF SAFETY).

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 for hurricanes are markedly increased by airflow over steep hills or escarpments, these locations should be avoided in siting hurricane shelters. If a large site-constructed hurricane shelter is located on an escarpment or upper half of a hill, the Topographic Factor, $K_{ZT,}$ shall be taken from ASCE 7. When manufactured hurricane shelters are installed on escarpments, the design wind speed for the shelter shall be a minimum of 1.3 times the design wind speed specified for hurricane shelters in Chapter 10, DESIGN WIND LOADS. The Topographic Factor, K_{zt}, does not apply to tornado shelters.

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 required to meet the requirements of Chapter 19, ENGINEERING TESTING AND EVALUATION and Chapter 18, ESSENTIAL STORM SHELTER FEATURES & ACCESSORIES.

Construction of in-residence shelters based on FEMA Publications 320 and 361 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. This Standard dictates only limited features or accessories that are required to be included in storm shelters. These are:

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

2. *Natural ventilation.* All storm shelters shall be provided with openings to facilitate minimum natural ventilation in accordance with this section. Ventilation area for tornado shelters shall be in accordance with Table18-1. Openings used for atmospheric pressure change (APC) are permitted to be counted as ventilation.

Ventilation area for hurricane shelters shall be in accordance with Table 18-2.

Table 18-1
Venting Area Required for Tornado Shelters

Tornado Shelter Type	Venting Area (per Occupant)
Residential	2* sq. in.
Community (≤50 persons)	5 sq. in.

Community (>50 persons)	6 sq. in.

* See Alternative following Section 2a below

2a. *Location of ventilation openings*. Configuration of natural ventilation openings required for tornado shelters shall be such that a minimum of 25 percent of the required area is located within 46 inches of the floor, or in the lower 1/2 of the height of the shelter, whichever is less, with the balance, but not less than 50 percent of the required area located a minimum of 72 inches above the floor, or in the upper ¼ of the height of the shelter, whichever is greater.

Alternative: Air intake openings for residential tornado shelters shall be permitted to be located entirely in the upper half of the shelter provided that the venting area provided is increased to 4 sq. inches per shelter occupant.

Table 18-2

Venting Area Required for Hurricane Shelters

Shelter Type	Venting Area (per Occupant)
Residential	4 sq. in.
Community (≤50 persons)	8 sq. in.
Community (>50 persons)	12 sq. in.

2b. *Location of ventilation openings*. Configuration of natural ventilation openings required for hurricane shelters shall be such that a minimum of 25 percent of the required area is located within 46 inches of the floor, or in the lower 1/2 of the height of the shelter, whichever is less, with the balance, but not less than 50 percent of the required area located a minimum of 72 inches above the floor, or in the upper ¼ of the height of the shelter, whichever is greater.

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 unless tests conducted in accordance with Appendix A prove that door failure does not occur when the door is tested with two hinges. The lock side shall include three deadbolts or other positive latching devices unless tests conducted in accordance with Appendix A prove that door failure does not occur when the door is tested with two deadbolts or other positive locking 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 independently engaged chain latches or slide bolts may be used for positive closure provided they act simultaneously to resist external forces tending to open the door. Doors in public shelters shall meet access/egress requirements of applicable building codes.

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

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

6. Interior floor, seat, and other finishes shall be Class I as determined by NFPA 101, Section 6-5.6 (See 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. Occupant density.

7.A *Community Shelters*. The minimum required shelter floor area per occupant for community shelters shall be determined in accordance with Table 18-3 and this section. The number of standing, seating, wheelchair, or bedridden spaces shall be determined based upon the needs of the shelter determined by the applicable authority having jurisdiction and the designer.

Table 18-3

Occupant Density – Community Shelters

Type of Shelter	Minimum Required Usable Shelter Floor Area[1] Sq. Ft. Per Occupant
Tornado	
Standing or seated	5
Wheelchair	10
Bedridden	30
Hurricane	
Standing or seated	20
Wheelchair	20
Bedridden	40

[1] See Section 7.A.1 below for determining minimum required usable shelter floor area

7.A.1 *Usable storm shelter floor area*. The usable storm shelter floor area shall be determined by one of the two following methods.

7.A.1.1 *Calculation of usable floor area*. The usable shelter floor area shall be determined by subtracting from the gross floor area, the floor area of excluded spaces, partitions and walls, columns, fixed or movable objects, furniture, equipment or other features that under probable conditions can not be removed or stored during use as a storm shelter.

7.A.1.2 *Alternate calculation of usable floor area*. The usable shelter floor area shall be determined by:

7.A.1.2.1 Reduce the gross floor area of shelter areas with concentrated furnishings or fixed seating by a minimum of 50 percent.

7.A.1.2.2 Reduce the gross floor area of shelter areas with un-concentrated furnishings and without fixed seating by a minimum of 35 percent.

7.A.1.2.3 Reduce the gross floor area of shelter areas with open plan furnishings and without fixed seating by a minimum of 15 percent.

7.A.2 *Wheelchair spaces*. Each storm shelter shall be sized to accommodate a minimum of one wheelchair space for every 200 shelter occupants or portion thereof.

7.B *Residential shelters*. The minimum required shelter floor area per occupant for residential shelters shall be determined in accordance with Table 18-4.

Table 18-4

OCCUPANT DENSITY—RESIDENTIAL SHELTERS

Type of Shelter	Minimum Required Usable Shelter Floor Area[1] Sq. Ft. Per Occupant
Tornado	
1&2 Family Dwelling	3
Other residential	5
Hurricane	
1&2 Family Dwelling	7
Other residential	10

[1] See Section 7.B.1 below for determining minimum required usable shelter floor area

7.B.1 Usable shelter floor area shall be the gross floor area, minus the area of sanitary facilities, where required, and shall include the protected occupant areas between shelter walls at the level of fixed seating.

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 of storm shelters which have been previously tested and evaluated by NSSA-approved agencies and new shelter designs which derive from previously tested and evaluated designs shall be submitted to NSSA in accordance with Chapter 21, STORM SHELTER DESIGN DOCUMENTATION, except where shelter sizes and performance fall between the smallest and largest shelters previously tested and evaluated as described in Chapter 19, ENGINEERING TESTING AND EVALUATION. 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 statically 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. This Standard requires testing to pressures higher than design wind pressures. Cyclic pressure testing is required for hurricane shelter doors with glazing and for glazing systems for shelter applications.

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 A -- ***Test Procedures for Debris Impacts*** **and Pressure Testing** presents requirements 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.

Texas Tech has alliances with certified testing agencies to achieve certification of products or components in cases where certification is desired or required.

21. STORM SHELTER DESIGN DOCUMENTATION

All storm shelters shall be documented by an NSSA-approved third party engineering company 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 presented with clarity and detail. To minimize third-party engineering time and costs, submittals should include design information (see **6. Design Information),** 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, 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 in Section 10, DESIGN WIND LOADS, and elsewhere in the Standard.

Al-Menyawi, Y., Carter, R., Kiesling, E., and Mehta, K., "Wind pressure on storm shelters according to FEMA 361 and ASCE 7-98," *Proceedings, America's Conference on Wind Engineering*, Clemson University, Clemson, S.C., 4-6 June 2001.

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

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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.

ICC/NSSA, (2006), "Standard for the Design and Construction of Storm Shelters" (Comment Draft), International Code Council, 2006, (www.icc.org).

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

NSSA, (2001), "Standard for the Design, Construction, and Performance of Storm Shelters", April 2001.

APPENDICES

Appendix A - Test Procedures for Debris Impacts and Pressure Testing

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.

APPENDIX A

Test Procedures for Debris Impacts and Pressure Testing

<u>*Introduction*</u>

The primary objective in pressure and debris impact testing of storm shelters is to assure compliance with a high standard of performance in protecting shelter occupants from injury structural failures or from wind-borne debris. Performance criteria include maintaining structural integrity of all shelter components when subjected to design wind pressure and preventing perforation of the shelter by the design missile or deformations of the shelter envelope sufficient to cause injury to occupants.

This appendix of the Standard provides guidance on the pressure and debris impact tests that shall be performed on shelters or components. This section is taken from Chapter 8 – Test Methods for Impact and Pressure Testing of the October 2006 draft of the ICC/NSSA Standard for Design and Construction of Storm Shelters expected to be published in 2007

A1
General

A1.1 Scope This testing protocol covers procedures for conducting impact and pressure testing of components of the shelter envelope required to meet windborne debris impact provisions, as detailed in section 14 of this standard.

A1.2 Referenced documents

ASTM E 1886 *Standard Test Method for the Performance of Exterior Windows, Curtain Walls, Doors and Impact Protective Systems Impacted by Missile(s) and Exposed to Cyclic Pressure Differentials.*

ASTM E 330 *Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights and Curtain Walls by Uniform Static Air Pressure Difference.*

ASTM E 631 *Terminology of Building Constructions*

American Lumber Standard Committee, Voluntary Product Standard DOC PS 20, *American Softwood Lumber Standard.*

Testing Application Standard (TAS) 201-94, *Florida Building Code*

Appendix I, Test Procedure for Debris Impact, ANSI Standard A250.13, Testing of Severe Windstorm Resistant Components for Swinging Door Assemblies

A2
Terminology

A2.1 General terminology. General terminology of building construction used in this test method is defined in ASTM E 631.

A2.2 Definitions of terms specific to this test method

Specimen - The entire assembled unit submitted for test, including but not limited to anchorage devices and structure to which product is to be mounted.

Test chamber - An airtight enclosure of sufficient depth to allow unobstructed deflection of the specimen during pressure cycling, including ports for air supply and removal, and equipped with instruments to measure test pressure differentials.

Opening protective Device–Shutter, door or other device mounted on the inside or outside of the exterior wall of a shelter.

A3
Test Specimens

A3.1 Test specimen. All parts of the test specimen shall be full size, using the same materials, details, methods of construction and methods of attachment as proposed for actual use. Large scale shelters shall be tested as components consisting of wall, roof, door, and window assemblies. Wall sections shall be a minimum of 4-feet (1219 mm) wide by 4-feet (1219 mm) high except where dimensions of the actual assembly are less than these dimensions. Doors and windows shall be tested at the maximum size proposed for use. Operable doors or windows shall be tested for the conditions of swing and latching as specified for use of the product. The specimen shall consist of the entire assembled unit and shall, when practical, be mounted as it will be installed in a shelter, and shall contain all devices used to resist wind forces and windborne debris. When it is not practical to install for testing a door or window frame as it will be mounted in a shelter, then the unit or assembly shall be mounted in a test buck to connect the specimen to the test frame/stand/chamber. Details of the mounting shall be described in the test report.

A3.2 Number of test specimens. Where both pressure and impact tests are required, two test specimens shall be submitted for testing, one for pressure tests and one for impact tests. For small manufactured residential shelters, only one specimen need be tested. Should failure occur on any element of the shelter, complete retesting of the shelter is required.

A3.3 Locks and latching mechanisms. Locking and other latching mechanisms shall be permanently mounted on the specimen. Such mechanisms shall require no tools to be engaged in the locked position. Devices such as pins shall be permanently secured to the specimen through the use of chains or wires which must be of corrosion resistant material.

A3.4 Multi-latching systems. Products that are not categorized as means of egress/escape and are provided with more than one single action locking mechanism shall be provided with permanently posted instructions on latching.

A3.5 Specimen conditioning. Samples shall be conditioned at ambient temperature (59º to 95º F) for a minimum of two hours prior to testing.

A3.6 Specifications/Drawings. The manufacturer or constructor shall provide test laboratory with applicable product specifications and/or drawings detailing materials of construction and applicable installation details. The test laboratory shall also be provided with applicable specifications and/or drawings detailing construction of proposed test assemblies which differ from the completed shelter. The laboratory shall determine the design(s) to be tested based on engineering judgment. The laboratory shall verify the accuracy of the design documentation by examining the test specimen or by witnessing construction of the test assembly if necessary.

A4
Missile Impact Testing

A4.1 Apparatus. The general description of the apparatus for performing the missile impact testing requirements of this standard is detailed in Section 6 of ASTM E-1886. Any equipment, properly certified, calibrated and approved by a qualified lab, capable of performing this test, within the allowable tolerance, is permitted

A4.2 Calibration. Calibration of the speed measuring system shall be performed per the procedure detailed in Section 9 of ASTM E 1886.

A4.3 Missile impact procedure. Test specimens shall be impact tested with test missiles of size and speed as specified in Section 14 of this Standard. Impact procedure shall be performed as detailed in Sections 11.1 through 11.3 of ASTM E 1886. Minimum impact locations shall be as detailed in Section A4.9. The test lab shall apply additional impacts at locations considered vulnerable to missile impacts.

A4.4 Missile properties. The test missile weight shall be selected to meet the requirements of Section 14 of this standard and shall comply with the following:

A4.4.1 Wood species. Any common softwood lumber species as defined by DOC PS 20 shall be permitted to be used provided it meets length tolerances detailed below. The lumber shall be grade stamped No. 2 or better and be free of splits, checks, wane or other significant defects. The 2 x 4's used shall be straight such that any bow or warp measured by stretching a string or wire on the side of the board from end to end is within 0.5 inches of the 2 x 4's surface over its entire length.

A4.4.2 Missile length and weight tolerance. The wood density, including moisture content, shall be such that the required 15 ± 0.25 pound (6.8 ± 0.11 kg) weight is met with a length of 13.5-feet (4115 mm) ± 6-inches (152 mm) and the 9 ± 0.25 pound (4.1 ± 0.11 kg) weight is met with a length of 8-feet (2438 mm) ± 4-inches (102 mm). The sabot and attachment screws shall be included in the missile weight when it is permanently attached. Missile weights shall be confirmed within 2 hours prior to their use.

A4.4.3 Conditioning. The test missile shall be conditioned at ambient temperature [59ºF (15ºC) to 95º F (35 ºC)] for a minimum of two hours prior to testing.

A4.5 Sabot size and weight. Where the missile launching system requires the use of a sabot for the effective launching of the missile, the sabot shall weigh no more than 0.5-lb. (0.226 kg), and shall be included in the weight of the missile, unless it is stripped away during flight prior to impact.

A4.6 Missile Speed. Missile speed measurement and speed tolerances shall be in accordance with the following.

A4.5.1 Missile speed measurement The missile speed shall be measured by a light gate with a known separation using an interval timing system capable of measuring the missiles velocity to within ±1 ft/sec (0.14 m/s). One of the following three options shall be followed in positioning the measuring gates.

Option 1. The light gate is positioned so that it measures speed of the missile entirely outside the cannon barrel so that there is no additional acceleration while the missile is in the timing gate.

Option 2. An in-barrel light gate is used. The relationship shall be established between the indicated missile speed and the velocity measured in free flight.

Option 3. Two sets of in-barrel gates are used that are staggered along the axis of the barrel by at least one foot and mounted beyond vents in the barrel to verify constant speed of the missile at exit.

A4.5.2 **Missile speed tolerance.** The missile test speed tolerance is four mph above and zero mph below the missile speed prescribed in Section 14.

A4.7 Impact angle. Missile impacts shall be within 5 degrees of normal to the primary plane of the test specimen. This requirement is deemed to be met when the barrel of the cannon is aligned within ± 2º of perpendicular in the horizontal plane and between level and a 3 º upward incline in the vertical plane.

A4.8 Testing temperature. The testing shall be conducted at ambient temperature in the range of 59ºF (15ºC) to 95º F (35 ºC) .

A4.9 Impact locations and the number of impacts. Impacts are to be located as indicated in the following sections.

A4.9.1 Panel or framed walls/roofs: Panel or framed wall and roof sections shall be impacted in the center of the wall/roof section, and at one interface corner as detailed in Figure A4.9.1-1 and A4.9.1-2.

When an interior stud or support is present, additional impacts shall be performed near the stud/support, and directly on the stud support as detailed in Figures A4.9.1.-1 and -2.

Interface joints used for attachment or joining at corners, at panel-to-panel sections, or at panel-to-roof shall be impacted, directly on the interface joints as detailed in Figure A4.9.1-2 for each type of joint.

When a section contains lapped materials, the centered impact shall be adjusted to strike the center of any lap, and an additional impact shall be performed beside the lap on the panel that laps behind the seam as detailed in Figure A4.9.1-2.

No more than three impacts shall be made on one specimen. Where more than three impacts are required, multiple identical test specimens shall be provided.

Exception: More than three impacts may be made on a test specimen by mutual consent of owner and test laboratory.

When specific locations on a test specimen are judged by the test agency to be more vulnerable to missile impact than one or more of those specified in the figure below, then the test agency shall have the discretion to select those locations as alternates to those shown in the figure.

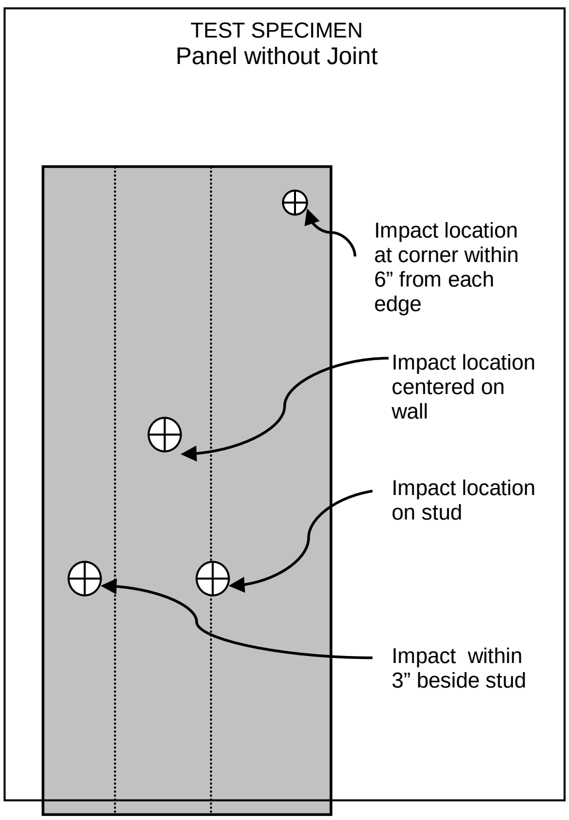


Figure A4.9.1-1

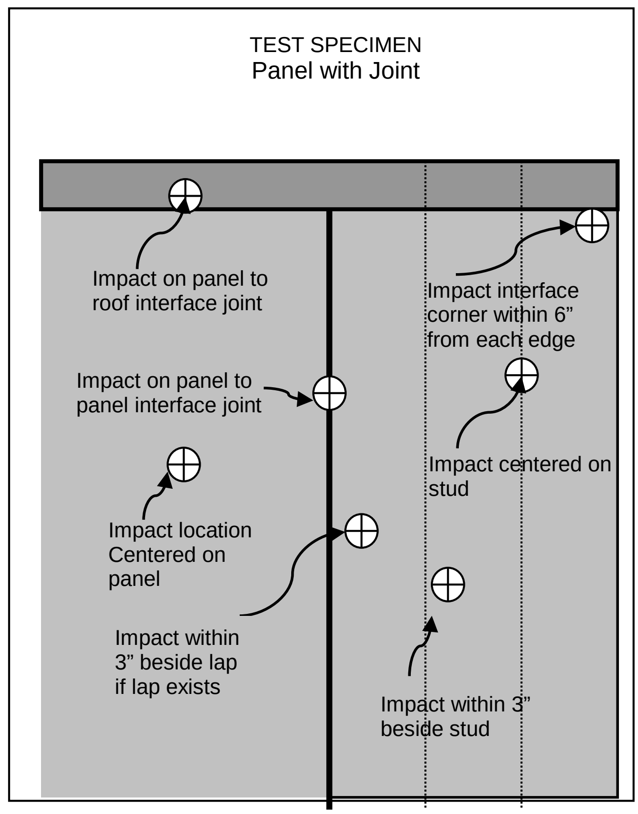


Figure A4.9.1-2

Panel or Framed Walls/Roofs

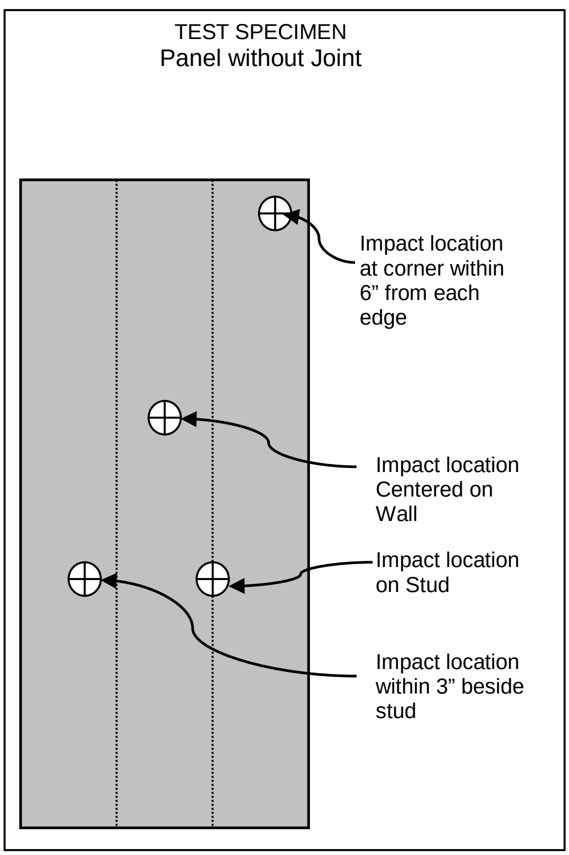
A4.9.2 Solid wall/roof sections of concrete or other materials. Wall and roof sections of solid concrete or other solid material shall be impacted in the center of the wall/roof section, and at one interface corner as detailed in Figure A4.9.2-1 and A4.9.2-2. When interface joints are used for joining at corners or panel-panel joints, an additional section shall be impacted directly on the interface joints as detailed in Figure A4.9.2-2.

Where an interior stud or support is present, additional impacts shall be performed within 3" of the stud/support, and directly on the stud support as detailed in Figures A4.9.2-1 and -2.

No more than three impacts shall be made on one specimen. Where more than three impacts are required, multiple identical test specimens shall be provided.

Exception: More than three impacts may be made on a test specimen by mutual consent of owner and test laboratory.

When specific locations on a test specimen are judged by the test agency to be more vulnerable to missile impact than one or more of those specified in the figure below, then the test agency shall have the discretion to select those locations as alternates to those shown in the figure.



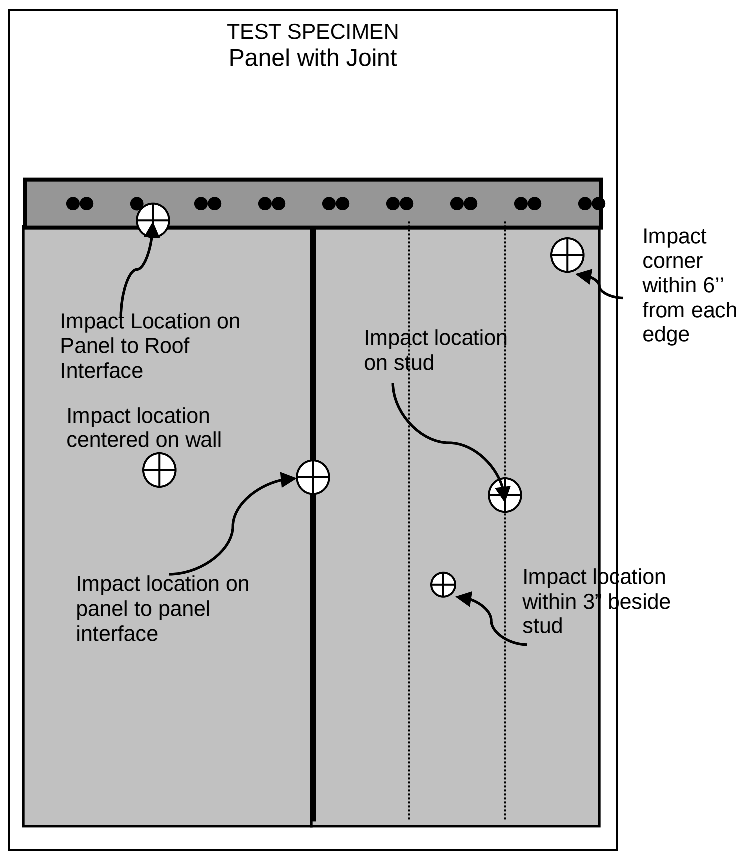


Figure A4.9.2-1 **Figure A4.9.2-2**

A4.9.3 Masonry unit walls/roofs. Walls and roof sections of masonry units shall be impacted in the center of the wall/roof section, and at one interface corner or joint as detailed in Figure A4.9.3-1. Mortared joints shall be impacted directly on the interface joints as detailed in Figure A4.9.3-2.

No more than three impacts shall be made on one specimen or specimen panel. Where more than three impacts are required, multiple identical test specimens shall be provided.

Exception: More than three impacts may be made on a test specimen by mutual consent of owner and test laboratory.

When specific locations on a test specimen are judged by the test agency to be more vulnerable to missile impact than one or more of those specified in the figure below, then the test agency shall have the discretion to select those locations as alternates to those shown in the figure.

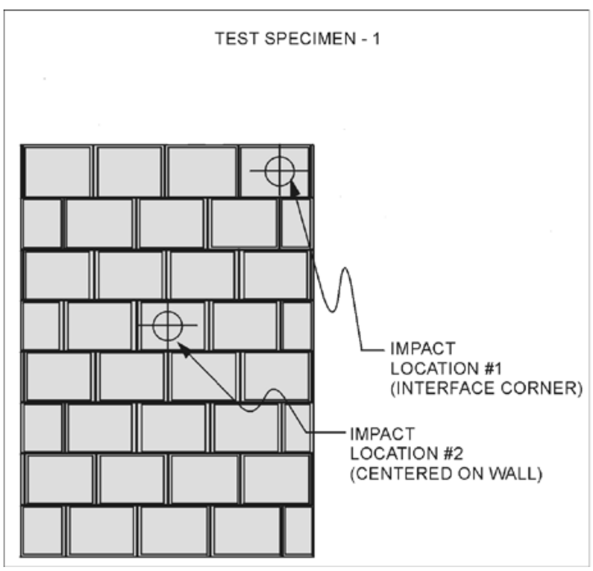


Figure A4.9.3-1

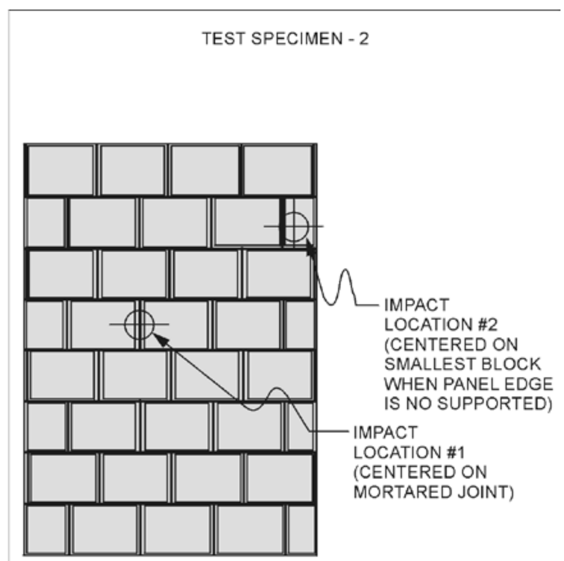


Figure A4.9.3-2

Masonry Unit Walls/Roofs

A4.9.4 Windows and other glazed openings. All window assemblies and other glazed openings shall be impacted in the center of the smallest glazed section, and at one interface corner as detailed in Figure A4.9.4-1. Where interior mullions or other glazed section joints and/or latches are present, an additional sample shall be impacted on these features as shown in Figure A4.9.4-2.

No more than two impacts shall be made on one specimen. Where more than two impacts are required, multiple identical test specimens shall be provided.

Exception: More than two impacts may be made on a test specimen by mutual consent of owner and test laboratory.

When specific locations on a test specimen are judged by the test agency to be more vulnerable to missile impact than one or more of those specified in the figure below, then the test agency shall have the discretion to select those locations as alternates to those shown in the figure.

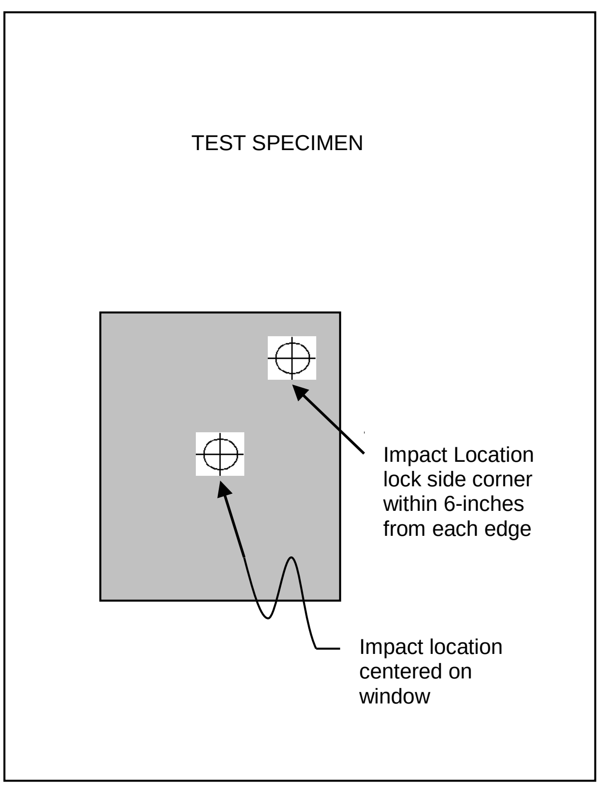


Figure A4.9.4-1

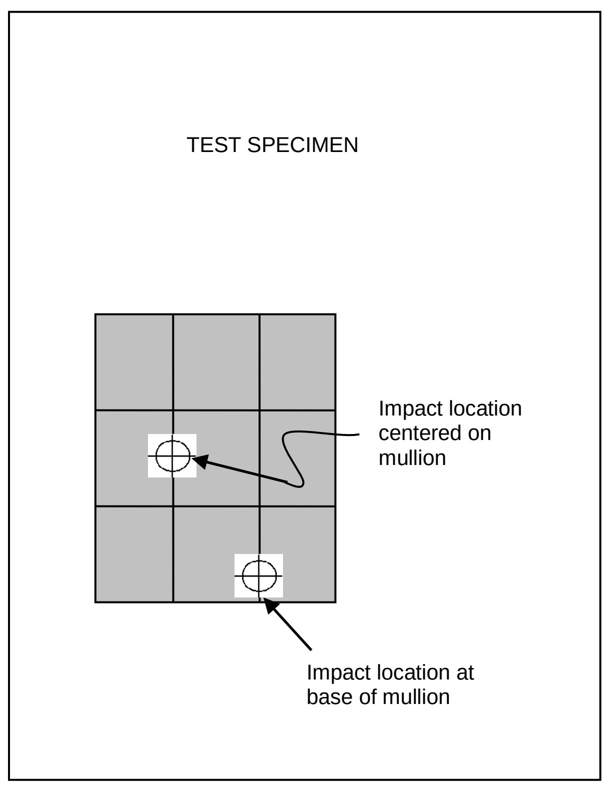


Figure A4.9.4-2

A4.9.5 Doors or other entry/egress systems. All door assemblies and other Entry/Egress Systems shall be impacted near an interface hinge joint, near an upper latch point and near center primary latches or operators as shown in Figure A4.9.5-1.

For double door assemblies, a single door leaf shall receive three impacts as shown in Figure A4.9.5-2 plus an additional impact on a center meeting point or mullion.

-

Where the door contains glazed openings with a size less than or equal to 12-inches (305 mm) by 12-inches (305 mm), an additional sample shall be impacted in the center of the glazed opening. Where glazed openings have a dimension greater than 12-inches (305 mm), the glazed opening shall be treated as a window and tested in accordance with section A4.9.4 of this standard.

When specific locations on a test specimen are judged by the test agency to be more vulnerable to missile impact than one or more of those specified in the figure below, then the test agency shall have the discretion to select those locations as alternates to those shown in the figure.

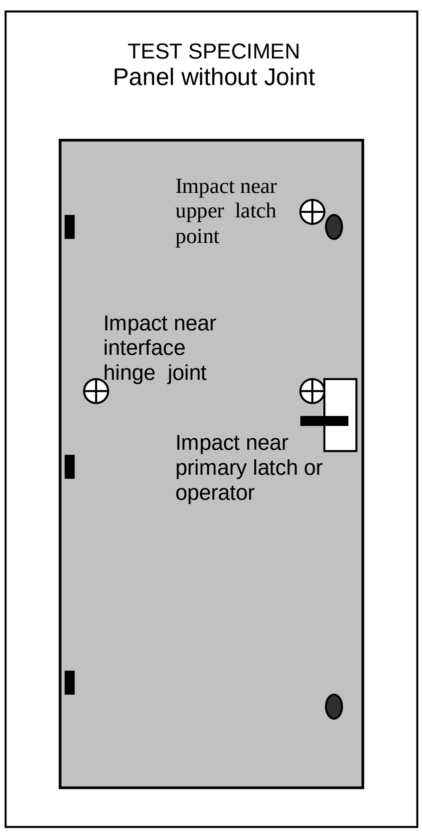


Figure A4.9.5-1

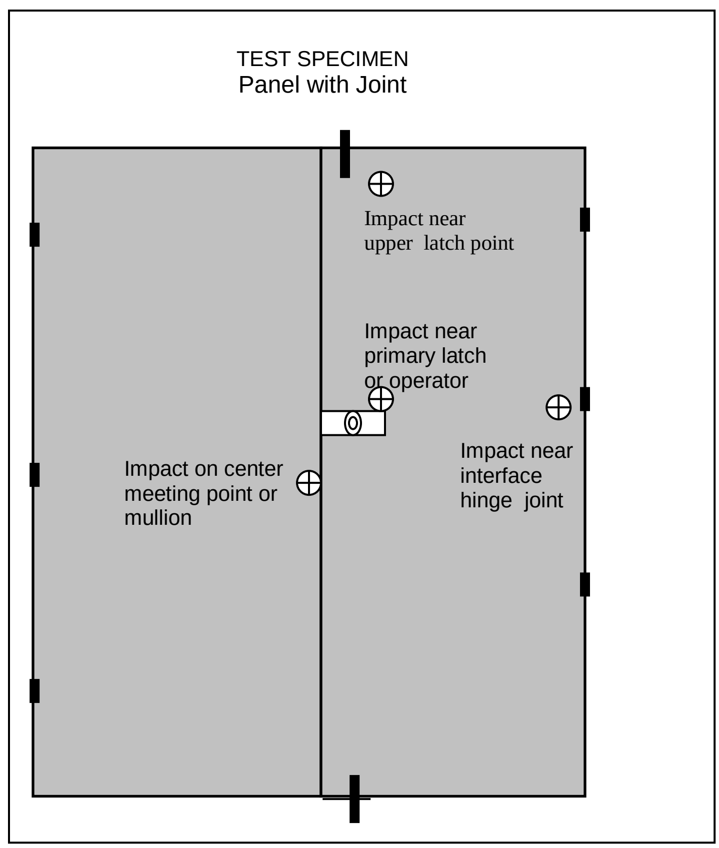


Figure A5.9.5-2

Doors or Other Entry/Egress Systems

A4.9.6 Shutters or other impact protection systems. All shutter assemblies and other Impact Protection Systems shall be impacted in the center of the closed opening, and at one interface corner as detailed in Figure A4.9.6-1. Panels and interface joints shall be impacted as shown in Figure A4.9.6-2. Interface hinge joints and primary latches, where present, shall be impacted as shown in Figure A4.9.5-2 on an additional specimen.

Where an interior stud or support is present, additional impacts shall be performed within 3" of the stud/support, and directly on the stud support as detailed in Figures A4.9.2-1 or A4.9.2-2.

When specific locations on a test specimen are judged by the test agency to be more vulnerable to missile impact than one or more of those specified in the figure below, then the test agency shall have the discretion to select those locations as alternates to those shown in the figure.

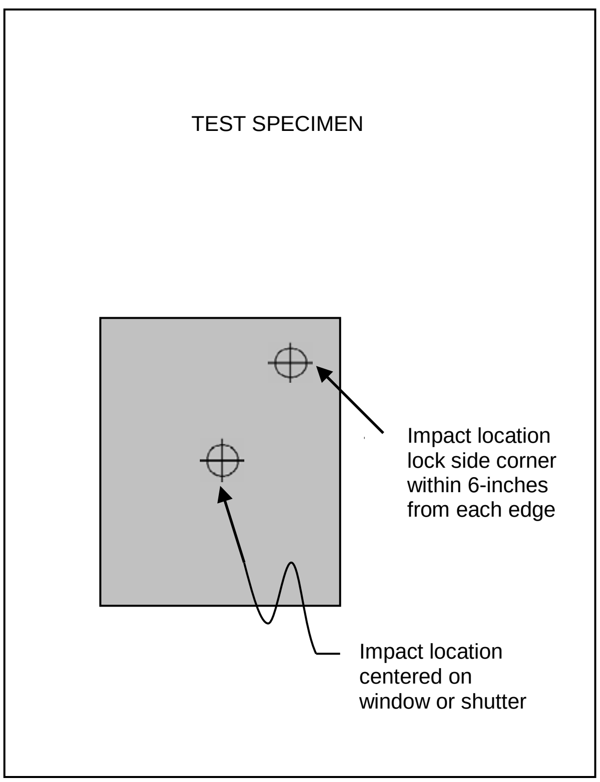


Figure A4.9.6-1

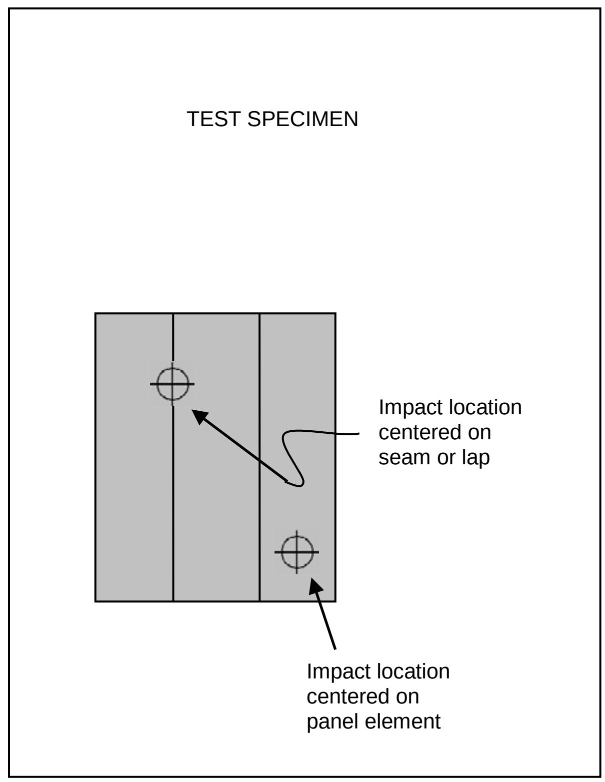


Figure A4.9.6-2

Shutters or Other Impact Protection Systems

A4.9.7 Alcove or baffled entry systems –. Debris impact testing described in this section is required for alcove/baffled access/egress systems meeting the requirements of Sections 10 and 14. Figure A4.9.7 illustrates an alcove/baffle system. Debris impact test requirements are presented for systems for which:

1. Storm debris impacts at least two shelter protective elements meeting the requirements of prior to entering the protected occupant area. Straight missile paths and elastic impacts are assumed in determining missile trajectories. Test requirements for this type of system are presented in Section A4.9.7.1. Examples of this type of system are shown in Figure A4.9.7.1. The boundary between the protected occupant area and the unprotected occupant area shall be clearly marked on the floor and walls of the shelter.

2. Storm debris impacts initially a shelter protective element meeting the requirements of Chapter 14 and possibly rebounds to impact an entry door. Straight missile paths and elastic impacts are assumed in determining missile trajectories. The debris test requirements for this type of system are presented in Section A4.8.7.2. Examples of this type of system are shown in Figure A4.9.7.2-1 and Figure A4.9.7-2-2.

3. Storm debris impact on an entry door is limited to an angle less than 90 degrees by a protective element. The debris test requirements for this type of system are presented in Section A4.8.7.3. Examples of this type of system are shown in Figure A4.9.7.3.

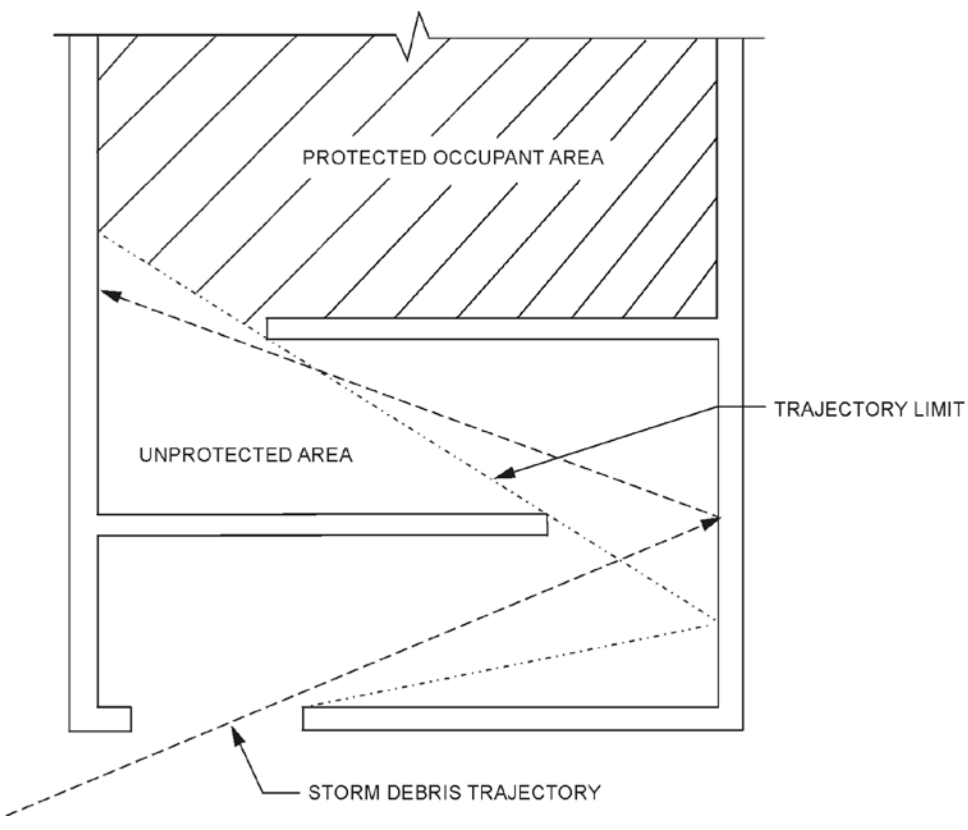


Figure A4.9.7
Alcove / Baffled Entry System

A4.9.7.1 Alcove/baffled entry systems for which testing is not required. Shelter entrances, whether provided with a door or not, that are protected by an alcove or baffled entry system that require missiles to impact at least two surfaces meeting the requirements of Chapter 14, *Alcove or Baffled Entry Systems,* prior to arriving at the protected occupant area shall not be required to undergo debris impact testing. See Figure A4.9.7.1 When a solid door is installed as a closure for this type of entry system, the door shall meet the wind load requirements of Section 10.

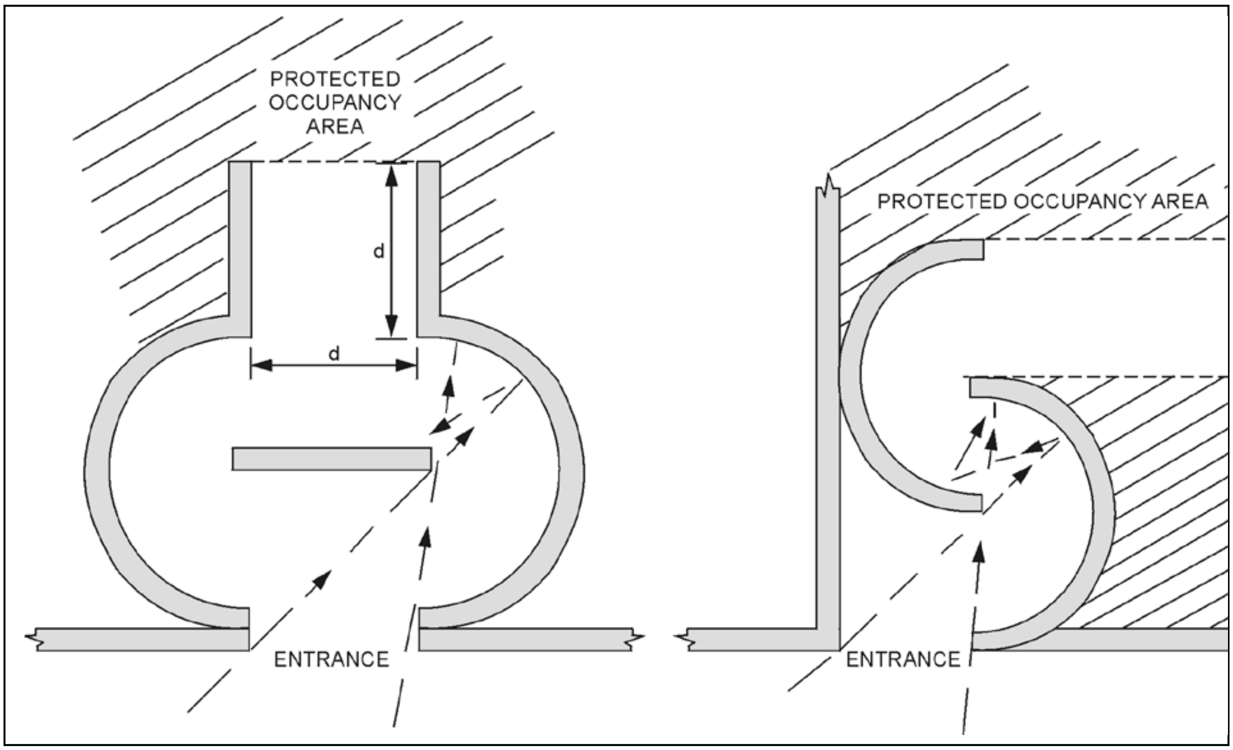


FIGURE A4.9.7.1.

Example of baffled entry systems for which no door or testing is required

A4.9.7.2 Door subject to rebound impact. Where the alcove or baffled entry system prevents a first impact of the design missile on the door but the door is subject to a rebounded impact of the design missile after it has impacted one surface meeting the requirements of Chapter 14 (See Figure A4.9.7.2), then a door assembly shall meet the wind load requirements of Section 10 and the debris impact requirements of Section 14 except that the missile shall be, at a minimum, a 9-lb sawn lumber 2x4 traveling at 50 ft/sec (15.2 m/s). Entry systems having doors that are protected from the initial and first rebounded impacts of debris shall comply with the requirements of Section A4.9.7.1.

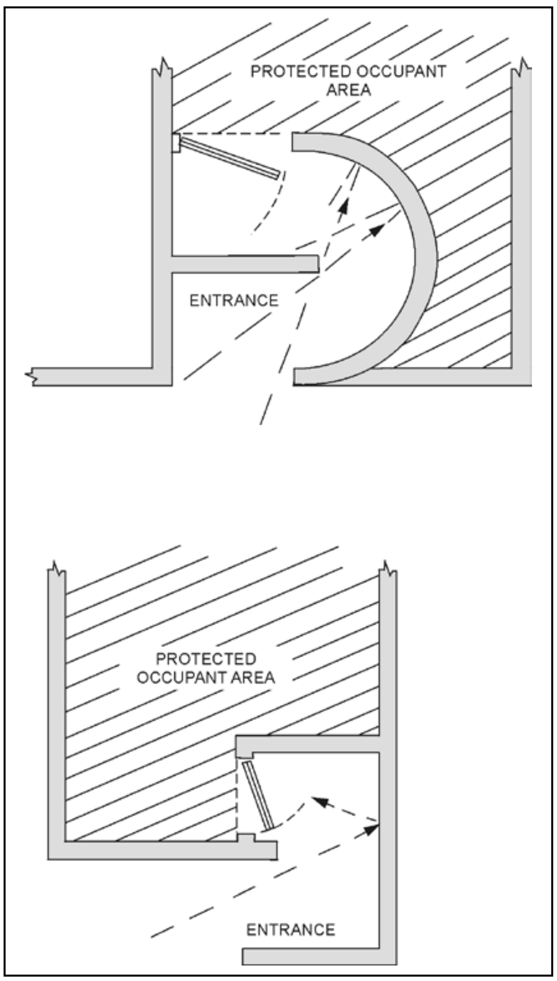


FIGURE A4.9.7.2

Examples of baffled entry system where

door Is subject to rebound impact

A4.9.7.3 Door subject to first impact. If a first-strike angle missile impact on the door is possible (See Figure A4.9.7.3) then the door is deemed suitable if the door assembly meets the wind load requirements of Section 10 and the door assembly meets one of the following debris impact criteria:

1. The door withstands the impact of a missile specified in Section 14 striking the door assembly at an angle closest to perpendicular to the plane of the door that the missile might strike in the shelter application, or
2. The door assembly is tested following procedures specified in Section 14 or a door assembly is selected that has withstood missile impacts by the design missile striking perpendicular to the surface with speed equal to or greater than the shelter design missile's velocity component perpendicular to the door assembly for the most critical angle that can occur in the application.

The minimum debris impact criterion for the door shall be an impact perpendicular to the door of a 9 lb sawn lumber 2 x 4 traveling at 50 fps (34 mph).

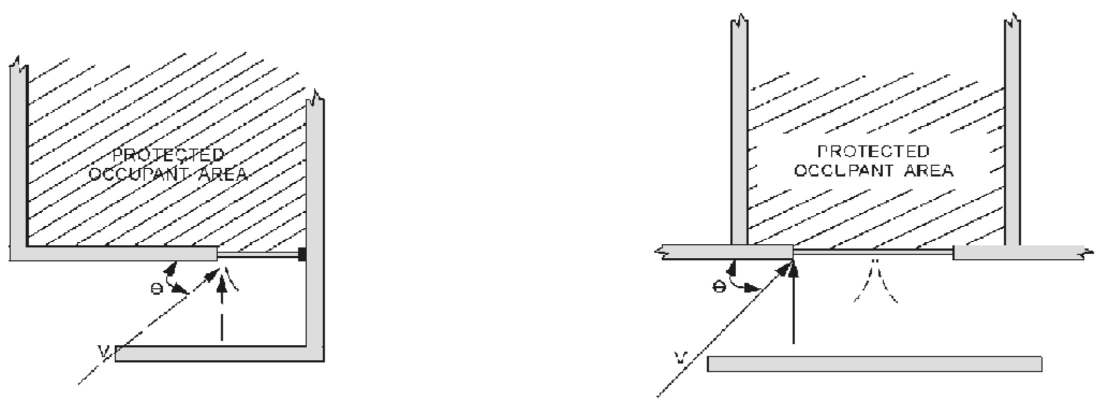


FIGURE A4.9.7.3

Example of baffled entry system where door is subject to first impact

A4.10 Pass/fail The pass/fail criteria for missile impact testing shall be in accordance with this section.

A4.10.1 Perforation. Any perforation of the interior surface of the tested component of the shelter envelope by the design missile shall constitute a failure. For shutters or other impact protection system, perforation or deflection that would result in impact of the protected component constitutes a failure.

A4.10.2. Dislodgment and disengagement*:* Specimens and load bearing fasteners, where used, shall not become disengaged or dislodged during the test procedures so as to endanger occupants. Dislodgement that occurs in a test shall be demonstrated to be harmless by failing to perforate a #70 unbleached kraft paper witness screen with its surface secured in place on a rigid frame installed within five inches of the interior surface of the shelter component. The rigid frame shall maintain tautness of the kraft paper and shall have continuous supports in one direction at intervals no greater than 3 feet (914 mm).

A4.10.3 Spall. Excessive spall shall not be released from the interior surface of any specimen. Excessive spall is defined as that which perforates a #70 unbleached kraft paper witness screen with its surface secured in place on a rigid frame 5 inches (127 mm) from the interior surface of the test specimen. The witness screen rigid frame shall maintain tautness of the kraft paper and shall have continuous supports in one direction at intervals no greater than 3 feet (914 mm).

Exception: Where warnings are to be provided marking the protected occupant area, beyond the 5-inch limit defined above the witness screen is permitted to be positioned at the boundary of the protected area, and excessive spall defined as that which will perforate the witness screen in this position.

A4.10.4 Permanent deformation. Permanent deformation of an interior surface of the test specimen shall be determined by measuring the distance from a straight edge held between two un-deformed points on the specimen. The maximum permanent deformation shall be measured to the nearest 1/8 inch (3.2 mm) and shall not exceed 3 inches (76.2 mm).

A5
Pressure Testing

A5.1 Apparatus*:* The general description of the apparatus for performing the pressure testing requirements of this standard is detailed in Section 6 of ASTM E-330 when performing the static pressure test, or ASTM E-1886 when performing the cyclic test. Any equipment, properly certified, calibrated and approved by a qualified lab, capable of performing this test, within the allowable tolerance, is permitted.

A5.2 Calibration. Calibration of the pressure measuring system shall be performed in accordance with the procedure detailed in Section 9 of ASTM E-330 or ASTM E-1886.

A5.3 Static pressure proof testing. Test specimens required by Section A6 to have a static pressure proof test to establish the ability to meet the wind pressure requirements set forth in section 10 of this standard, shall be pressure tested to a static proof load of 1.5 times the design wind pressure as defined in Section 10.1.

A5.4 Cyclic Pressure testing after impact. Test specimens requiring cyclic pressure testing to establish the ability to meet the wind pressure requirements set forth in section 14 of this standard, shall be cyclic tested using the loading sequence detailed in ASTM E-1886 specified to the design wind pressure as defined in Section 10.1. Pressure testing procedures shall be performed as detailed in Sections 11.1 through 11.2.11 of ASTM E 1886.

A5.5 Testing temperature. The testing shall be conducted at room temperature in the range of 59ºF (15ºC) to 95º F (35 ºC).

A6
Pressure Testing Procedures

A6.1 Pressure testing procedures Procedures for pressure testing wall assemblies, roof assemblies, door assemblies, window assemblies, shutters and other protection systems requiring pressure testing are presented in this section.

A6.2 Roof and wall assemblies When testing of roof and wall assemblies is required, they shall be pressure tested in the as-supplied condition. Required pressure testing shall be done as detailed in ASTM E 330 to the pressures specified in Section 10..

A6.3 Door assemblies. Door assemblies shall be pressure tested in the as-supplied condition, and, when required, they shall be static pressure tested or cyclically tested as specified in the following sections.

A6.3.1 Door assemblies without glazing. Door assemblies without glazing that require testing to meet qualification of Chapter 14 shall be pressure tested according to procedures specified in this section.

A6.3.1.1 Door assemblies without glazing for tornado shelters. Door assemblies without glazing for use in tornado shelters shall be static pressure tested away from the door stops to 1.2 times the pressures specified in Section 10. Pressure tests are permitted to be conducted separately from missile impact tests.

A6.3.1.2 Door assemblies without glazing for hurricane shelters. Door assemblies without glazing for hurricane shelters shall be statically pressure tested away from the stops to 1.2 times the design wind pressure, then subjected to required debris impact tests, and then to cyclic pressure tests following procedures of ASTM 1886.

Alternatively, door assemblies without glazing for hurricane shelters shall be statically pressure tested away from the door stops to a pressure 1.5 times the design wind pressure before impact tests and then to required debris impact tests. Cyclic pressure testing after impact tests is not required for these door assemblies that have been static pressure tested to pressures equal to or greater than 1.5 times the design wind pressure.

A6.3.2 Door assemblies with glazing, sidelights, or transoms. Door assemblies with glazing, sidelights, or transoms shall be pressure tested according to procedures specified in this section. Where glazed openings are present, with size less than or equal to 12-inches by 12-inches, an additional sample shall be impacted in the center of the glazed opening in accordance with Section A4 and cyclic pressure tested as detailed in Section A5.5 when cyclic testing is required Where glazed openings have a dimension greater than 12-inches, the glazed opening shall be treated as a window and tested in accordance with Section A6.5 of this standard.

A6.3.2.1 Door assemblies with glazing, sidelights, or transoms for tornado shelters Door assemblies with glazing, sidelights, or transoms for tornado shelters shall be static pressure tested away from the door stops following procedures of ASTM E 330 to 1.2 times the pressures specified in Section 10. Pressure tests are permitted to be conducted separately from debris impact tests.

A6.3.2.2 Door assemblies with glazing, sidelights, or transoms for hurricane shelters. Door assemblies with glazing, sidelights, or transoms for hurricane shelters shall be static pressure proof tested away from the stops to a pressure 1.2 times the design wind pressure. Any required debris impact tests shall follow such initial pressure testing. After impact tests the door assembly shall be subjected to cyclic pressure tests following procedures of ASTM 1886.

A6.4 Window assemblies and other glazed openings. Window assemblies and Other Glazed Openings shall be pressure tested according to procedures specified in this section.

A6.4.1 Window assemblies and other glazed openings for tornado shelters. Window assemblies and other glazed openings for tornado shelters shall be static pressure tested away from stops following procedures detailed in sections ASTM E 330 to **1.2 times** the pressures specified in Section 10. Pressure tests are allowed to be conducted separately from debris impact tests.

A6.4.2 Window assemblies and other glazed openings for hurricane shelters. Window assemblies and other glazed openings for hurricane shelters shall be static pressure proof tested away from stops to a pressure 1.2 times the design wind pressure. Any required debris impact tests shall follow pressure proof testing. After impact tests the window assembly shall be subjected to cyclic pressure tests following procedures of ASTM 1886.

A6.5 Opening protective devices. External opening protective devices such as shutters and protective screens shall be tested for ability to withstand prescribed pressures if withstanding pressure is critical to their function when installed. Devices such as non-operable, permanently affixed shields or cowlings whose only function is to protect against debris intrusion need not be pressure tested.

A6.5.1 Opening protective devices for tornado shelters. External protective devices for tornado shelters whose ability to withstand wind-induced pressure when installed is critical to their function shall be static pressure tested following procedures specified in ASTM E 330 to 1.2 times the pressures specified in Chapter 10, DESIGN WIND LOADS. Debris impact tests and pressure tests are permitted to be conducted separately.

Exception: Protective devices with a jamb or stop need be tested only with pressure away from the stop.

A6.5.2 Opening protective devices for hurricane shelters. External protective devices for hurricane shelters whose ability to withstand wind-induced pressure when installed is critical to their function shall be static pressure tested to shelter design wind pressures specified in Section 10 following the procedures specified in ASTM E 330. Cyclic pressure tests conducted according to Section A5.5 shall be conducted after debris impact tests.

A6.6 Alcove or baffled entry systems. Any element of the entry system whose ability to resist wind induced pressure is critical to the function of the entry system shall be designed to meet the requirements of Section 10 or shall be pressure tested in accordance with Section A6.

COMMENTARY

COMMENTARY

This 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 are the same as those in the text of the Standard and are presented in the same order.

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.

C6. 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]. Tornado shelter 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).

The pressures used in developing 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 ± 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 shall be provided in shelters designed as enclosed buildings to insure adequate relief of internal pressures due to atmospheric pressure changes. Such openings provide adequate ventilation to prevent health hazards. Shelters shall be vented through the roof or, if vented through the wall, venting shall be of approximately equal amounts (within 10%) on opposite sides of the shelter. Venting requirements for aboveground shelters may also be met by 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 community 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.

C7. STRUCTURAL DESIGN CRITERIA

Elevated storm 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.

C8. SHELTER STABILITY & ANCHORAGE

Stability. Where storm shelters are constructed as an integral part of host buildings, structural framing and non-structural framing may be connected to the storm shelter. Community shelters may be designed to provide some or all of the MWFRS for the host building. Interior partitions, ceilings, and finishes will typically be attached to the shelter for architectural purposes.

FEMA 320, Second Edition, Figure II.2, page 15, proposes a basis for incorporating existing building components, which are part of the continuous load path for the superstructure, as part of the storm shelter. The paragraph following Figure II.2 permits one or more of the basement walls to be used as part of the shelter enclosure, provided that they are reinforced to resist the design forces. The presumption made here is apparent – the superstructure has separated for the foundation wall at a wind velocity less than the design wind of 250 mph. However, it should be pointed out that FEMA 320, page 17, continues with the bulleted caution:

> "The walls of the shelter must be completely separate from the structure of the house. Keeping the walls separate makes it possible for the shelter to remain standing even if portions of the house around it are destroyed by extreme winds."

This provision is contradictory with the provision for basement walls on pages 15 and 17. Two designs in FEMA 320 (Details 1, Sheet AG-6 – anchorage to exiting concrete slab, and Detail 2, Sheet B-1 – connection of lean-to shelter to existing foundation wall which is partially below ground) indicate the rationale that the superstructure of the building will not add to the forces on the existing concrete slab or foundation wall when winds reach 250 mph.

Page 2-11, FEMA 361, defines "hardened shelter areas" in terms which imply that these may be "…part of a building…" capable of resisting wind pressures and impacts. Page 3-7, Section 3.3.1, states:

> "The designer should also ensure either that the destruction of the non-shelter parts of the building does not put additional loads on the shelter or that the shelter is designed for these additional loads."

On page 4-6, FEMA 361, "The roof system", poses the question:

> "Is the roof system over the proposed refuge area structurally independent of the remainder of the building? If not, is it capable of resisting the expected wind and debris loads?"

FEMA's instructions that structural analysis of the superstructure and consideration of the "break-away" capacities of connecting elements in the continuous load path are essential to successful design of storm shelters expressly imply that connectivity of elements of the superstructure at wind speeds substantially less than the design wind may exist, and that the forces from these elements must be considered in the design of the shelter.

It is recommended that the Standards Committee consider and recommend procedures whereby the "complete separation" provision of page 17, FEMA 320, may be replaced with a provision which permits "break-away" design of the non-shelter portion of the building which is connected to the shelter with attachments designed for maximum wind velocities substantially less then 250 mph tornado design wind velocity.

Connection of storm shelters to foundations or slabs. Guidance is provided for anchorage of above ground storm shelters on concrete slabs in "On-Grade Reinforced Concrete Floor Slabs for Storm Shelters", Galani, Budek, Kiesling, and Zain, *Building Safety Journal,* April 2006, pages 23 – 30.

C9. REFERENCED 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.

C10. DESIGN WIND LOADS

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Design Wind Pressures. Wind pressures and loads on shelters are determined in accordance with ASCE 7 and this Standard. 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) 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 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). Flat, open terrain is assumed with the Topographic Factor K_{ZT} = 1.0. This factor must be increased for computing wind velocity for hurricane shelters if the hurricane shelter is to be located on an escarpment or on the upper half of a hill (see Figure 6-4, ASCE 7).

Atmospheric Pressure Change (APC). APC results when the vortex of a tornado approaches a shelter or other building. The amount of pressure buildup (positive or negative) depends on the amount of venting in the building available to relieve the APC. Vents or other protected openings meeting the requirements of Chapter 14 must be provided to permit sufficient passive ventilation air transfer for occupant breathing in accordance with Chapter 18. Slots in walls and openings under and around doors that are not sealed may be counted as part of the required venting area. For tornado shelters, this ventilation provides some venting to relieve atmospheric pressure change, APC, which occurs during a tornado. Internal pressure coefficient $GC_{pi}= \pm 0.18$ may be used for tornado shelters classified as enclosed buildings where adequate venting for atmospheric pressure change is provided in accordance with Chapter 8. Residential hurricane shelters which are classified as enclosed buildings may also use an internal pressure coefficient of ± 0.18.

Figure C10-1 shows Main Wind Force Resisting System (MWFRS) pressures and Component and Cladding (C&C) pressures for a nominally 8'x 8'x 8' tornado shelter (volume $\approx$ 500 ft^3) subjected to a 250 mph design wind speed. These pressures may be used in design for this size or smaller residential tornado shelters that are enclosed and vented, permitting use of the internal pressure coefficient $GC_{pi}= \pm 0.18$, where roof slopes are less than or equal to 10 degrees. Wind loads on shelter doors may be taken from Figure C10-1 for small shelters or, in all cases, calculated with procedures outlined in ASCE 7. Horizontal doors or those inclined less than 10 degrees with the horizontal shall be designed for –329 psf or –2.28 psi, the highest pressure shown in Figure C10-1 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.

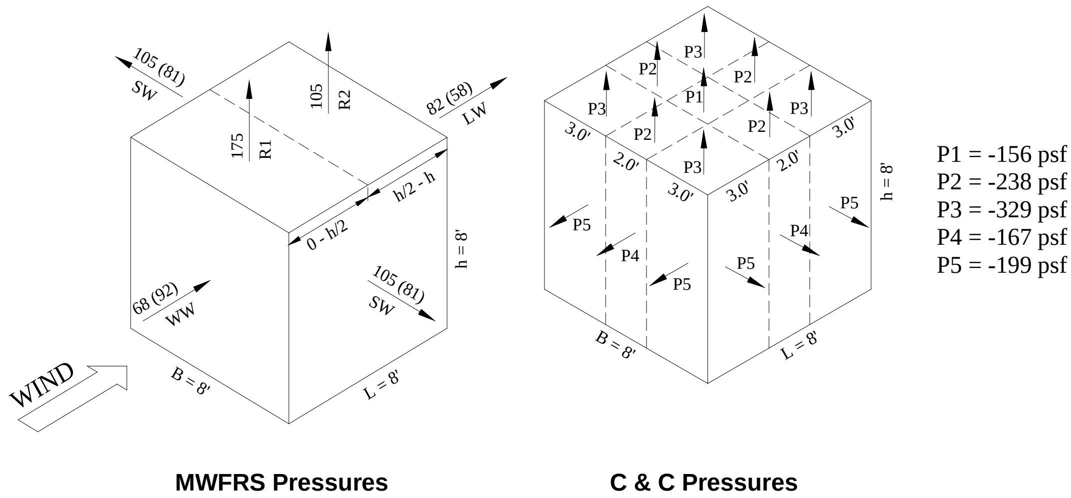

Figure C10-1 Pressures on an 8' x 8' x 8' Shelter for Design Wind Speed of 250 mph

C11. DESIGN LOADS & CRITERIA

Chapter 11 requires that connections of any or all portions of the host building which are connected to the storm shelter not result in forces being transmitted to the shelter which will produce instability of the shelter or its anchoring foundation. The assumption that all connections tending to produce instability for wind from any given direction will simultaneously reach their ultimate capacities is conservative.

C12. DESIGN LOADING COMBINATIONS

In this Standard the wind loadings resulting from tornadoes and hurricanes are deemed "catastrophic loadings". This is consistent with ASCE 7.

The LRFD Load Combination 1. is ASCE, Section 2.3 load combination 3. with the wind load factor 0.5 substituted for 0.8 in the equation. LRFD Load Combinations 2. and 3. are ASCE, Section 2.3 load combinations 4. and 6. with the wind load factor 1.0 substituted for 1.6.

The ASD Load Combinations 1., 2., and 3. are ASCE, Section 2.4 load combinations 5., 6., and 7., with the wind load factor 0.6 substituted for 1.0.

C14. WINDBORNE DEBRIS IMPACT CRITERIA

Alcove or Baffled Entry Systems. Alcove/baffled entry systems are shelter entry/egress configurations which shield the protected occupant area from straight-line travel of storm debris. A qualifying alcove/baffled entry would require a test missile to experience two impacts on shelter entry surfaces capable of withstanding the first missile impact. An alcove/baffled entry meeting this requirement shall be deemed to protect shelter occupants in the protected occupant area (hatched area of Figure 14-1) provided that the boundary between the protected area and the unprotected area is conspicuously marked on the floor and walls of the shelter.

Baffled shelter entrances with non-qualified doors. FEMA 361, pages 6-15 through 6-16 and Figure 6-8 describe a baffled entrance with non-qualified tornado doors. The plan of FEMA 361, Figure 6-8 indicates debris impact with at least two rebounds or ricochets from missile resistant barriers before the non-qualified door would be impacted.

C17. TYPES OF CONSTRUCTION

It has always been the intent of NSSA to not limit innovation in the design of storm shelters that meet requirements for safety and performance. It is expected that technical advances and engineering ingenuity will advance the science of storm shelter design. Therefore, NSSA has made every effort to remove the constraints on the advancement of shelter design by developing a procedure which permits professionals to design storm shelters which have limited strength connectivity with building components which are not part of the protective shelter.

C18. ESSENTIAL FEATURES & ACCESSORIES

Natural ventilation. Natural or passive ventilation is the non-powered, natural flow of air into, through, and out of a building envelope which is caused by air leakage or intentional openings in the building envelope. The degree of natural ventilation depends on numerous factors, but is controlled primarily by the area of openings to the outside of the building. This Standard specifies the minimum venting areas (square inches per occupant) to assure adequate breathing air and comfort in storm shelters in the event of loss of power. The amount of air necessary for breathing and comfort depends primarily on occupant density and duration of occupancy. Openings which provide venting of tornado shelters for atmospheric pressure change (APC) and the cracks around and under doors contribute to the venting area for breathing air and comfort.

Natural ventilation results from differential wind pressures as airs flow around and over a building and from differential temperatures between the inside and outside of a building. Factors affecting the air exchange rates from natural ventilation include areas of ventilation openings to the outside, differential air pressures at vent openings across the building, differential temperatures between the inside and outside of the building at vent openings, wind velocity, and occupant activity (internal air turbulence).

Minimum total venting areas per shelter occupant which will provide acceptable air exchange rates to provide comfort and safety for tornado shelters (maximum anticipated occupancy of 2 hours) are specified in Table 18-1 and for hurricane shelters (maximum anticipated occupancy of 24 hours) in Table 18-2. Occupant densities for tornado shelters and hurricane shelters differ by a factor of approximately five. Times of confined occupancy for storm shelters vary for hurricane shelters and tornado shelters. Occupants of residential hurricane shelters may not close doors for more than a few hours, whereas managers of community hurricane shelters may require shelter closure for much longer periods of time. Minimum venting areas take into consideration probable durations of confinement of occupants and the effects longer durations might have on the physiology and state of mind of the occupants.

Studies to determine acceptable air exchange rates for storm shelters have not been published. Numerous studies regarding natural ventilation have been published, however, and the use of natural ventilation in residential and office buildings has been accepted in many countries. The 2003 IBC, Section 1203.4.1 requires that natural ventilation for residences shall be 4% of the floor area being ventilated. A recent publication in the ASHRAE Journal indicates that persons in naturally ventilated environments are more tolerant to temperature changes than they are in mechanically ventilated buildings[1]. Minimum air exchange rates have been established for occupancies other than storm shelters. Methods of analysis currently exist for designing natural ventilation [2, 3, 4, 5].

Natural ventilation of storm shelters is caused when cooler outside air flows in through openings in the shelter envelope and settles toward the bottom of the shelter. Body-heated air and expired air combined with exhaled carbon dioxide rise toward the top of the shelter interior and exhaust from the shelter through openings at or near the ceiling of the shelter (stack ventilation). The convection created by this process causes uncontaminated air at the bottom of the shelter to rise into the occupied zone where the process is repeated. Additional air exchange occurs as the result of outside air movement which causes air to flow into and out of the building (wind effect ventilation).

The area of vent openings includes cracks around doors. Vent area requirements for residential shelters are smaller because at least one door will be available for a reasonably small occupancy shelter and openings around the door will typically comprise about one-third of the venting area to the outside. Even if the threshold of the door is above the bottom of a small residential shelter, cooler outside air will flow downward into the enclosure around the occupants.

REFERENCES

1. G. S. Brager and R. de Dear ,"A Standard for Natural Ventilation" , ASHRAE Journal, October 2000.

2. W. Dols and S. Emmerich, "LoopDA – Natural Ventilation Design and Analysis Software", NISTIR 6967, Building Environmental Division, Building and Fire Research Laboratory, National Institute of Standards and Technology, April 2003.

3. G. Tan and L. Glicksman, "Study of Natural Ventilation Design by Integrating the Multi-zone Model with CDF (Computational Fluid Dynamics) Simulation", Department of Building Technology, MIT.

4. "Air Movement and Natural Ventilation", Beer Lecture Series, Hong Kong University, April 2003.

5. "Hawaii Commercial Building Guidelines for Efficiency, 2. Natural Ventilation Guidelines", Eley Associates, 2003.

Literature Review on Natural Ventilation

"While some might suggest that all standards development be put on hold until these questions (required levels of ventilation to achieve acceptable indoor air quality) are fully resolved, others argue that the standards are needed and must be developed based on the best science available and the practical experience of the thousands of engineers, designers, and building operators who are successfully designing, building and operating buildings. Present standards are a mixture of scientifically validated findings and professional experience (sometimes "guess"), though the user is not always aware of the source of particular standard requirements" [A. Persily, NIST, M. Liddament, AIVC, and J. Railio, AFMAHE, Finland, "Ventilation Standards – Research Needs and Natural Ventilation", Healthy Buildings 2000 Workshop Report, International Energy Agency, 2000].

"ASHRAE Standard 62-1999, "Ventilation for Acceptable Indoor Quality", requires that homes receive 0.35 air changes per hour (ach), but not less than 15 cubic feet per minute (cfm) per person." "A common rule of thumb is the 15 cfm is multiplied by the number of bedrooms in the house plus one [(3 bedrooms + 1) x 15 cfm = 60 cfm]." [U. S. Environmental Protection Agency, "Indoor Air Quality (IAQ) and Home Remodeling – Addressing Indoor Environmental Concerns During Remodeling", January 27, 2005].

Hurricane forward speeds average approximately 9 mph along the Southeast Atlantic and Gulf coasts and approximately 16 mph in coastal areas of Virginia and to the north. Tornado forward speeds average 30 mph as the tornado passes over [NOAA].

"When the air in a room is stirred, three effects on the human body result, all adding up to a feeling of greater comfort. One is a purely sensory effect, another affects humidity, and the third affects room temperature. The three are closely related and depend upon the velocity of the air motion." "When the air has a gentle motion, a velocity of 20 to 50 feet per minute, the tactile sensory nerves in the skin are stimulated, and a feeling of greater comfort is experienced than when air is completely still." "The body is always giving off heat to the air around it by conduction. If the air is still, the air is carried away by convection and not permitted to build up." "(When) air is stirred, the convection currents thus formed carry away (body) moisture as rapidly as it is given off, and a normal rate of evaporation is restored." "Up to an air motion of about 60 feet per minute, a person is conscious only of the stimulating effect, that is, the air close to the body becomes more heated, and this heat is not carried away by convection currents in the air." "The upper limit of 100 feet per minute is suitable for persons at rest or doing light work, as is the case in a submarine." ["Submarine Refrigeration and Air-Conditioning Systems", NavPers 16163, Bureau of Naval Personnel, U. S. Navy, 1945].

"The traditional definition of comfort published in ANSI/ASHRAE Standard 55-1992 (Thermal Environmental Conditions for Human Occupancy) does not distinguish between spaces with and without natural ventilation. But recent research by Gail Brager of the University of California – Berkeley shows that in naturally ventilated buildings, people adapt to changes in mean outdoor temperatures and are comfortable in – and may even prefer – a broader range of thermal conditions." "Brager's research is at the heart of changes to ASHRAE Standard 55 that are currently under consideration."

The following is excerpted from Hawaii Commercial Building Guidelines for Energy Efficiency:

Cross Ventilation. "Provide equal area of operable openings on the windward and leeward side. Ensure that the windward side is well shaded to provide cool air intake. Locate openings on the windward side at the occupied level." "The air pressure on the windward side rises above atmospheric pressure, creating a high pressure zone. The pressure on the leeward side drops, creating pressure stratification across the building. To equalize pressure, outdoor air will enter through available openings on the windward side and eventually be exhausted through the leeward side." "The airflow is directly proportional to the effective area of inlet openings, wind speed, and direction."

Stack Ventilation. "At least two ventilation apertures need to be provided – one closer to the floor and the other high in the space." Warmed by internal loads (people, lights and equipment), the indoor air rises. This creates a vertical pressure gradient within the enclosed space. If an aperture is available near the ceiling, the warmer air at the upper levels will escape as the cool outside air is drawn in through the lower aperture." "…the indoor temperature must be higher than the outdoor temperature for the stack ventilation to occur." "The airflow induced by thermal force is directly proportional to the inlet-outlet height differential, the effective area of the aperture, and the inside-outside temperature differential." "Allow for at least 5 feet (center-to-center) height difference between the inlet and the outlet. Increasing the height differential further will produce better airflow." "Use architectural features like solar chimneys to effectively exhaust the hot indoor air." ["Hawaii Commercial Building Guidelines for Energy Efficiency, 2. Natural Ventilation Guidelines", Eley Associates, 2003]

"Many researchers and designers have argued…that reliance on Standard 55 has allowed important cultural, social and contextual factors to be ignored, leading to an exaggeration of the "need" for air conditioning. Others have argued that allowing people greater control of indoor environments, and allowing temperatures to more closely track patterns in the outdoor climate, could improve levels of occupant satisfaction with indoor environments and reduce energy consumption." ["A Standard for Natural Ventilation" by G. S. Brager and R. de Dear, ASHRAE Journal, October 2000].

"…Brager's model means that people in naturally ventilated buildings can be comfortable at higher indoor temperatures as the outdoor air temperature increases." [Brager and de Dear, "A Field-Based Thermal Comfort Standard for Naturally Ventilated Buildings," Collaborative for High Performance Schools (CHPS) Best Practices Manual, Appendix C (Eley Associates, 2001)].

Electrical Grounding of 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.

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 lightning 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."

Bulletin of the American Meteorological Society, Vol. 80, No. 10, Oct. 1999, Updated Recommendations for Lightning Safety – 1998, by Ronald L. Holle & Raul E. Lopez, National Sever Storm Laboratory, NOAA and Christoph Zimmerman, Global Atmospherics, Tucson, states

> "In general, fully enclosed metal vehicles such as cars, trucks, buses, vans, fully enclosed farm vehicles, etc. with the windows rolled up provide good shelter from lightning. Avoid contact with metal or conducting surfaces outside or inside the vehicle."

The National Lightning Safety Institute Technical Information (NSLI), November 20, 2001, Section 5.1.6, states

> "A fully enclosed metal vehicle – van, car, or truck – is a safe place because of the (partial) Faraday Cage effect. A large permanent building can be considered a safe place. In all situations, people should avoid becoming a part of the electrical circuit."

NLSI, Section 5.1.6 further states:

> "Building structural steel also may be used in place of down conductors where practical as a beneficial subsystem emulating the Faraday Cage concept."
>
> "All metallic conductors entering structures … should be electrically referenced to the same ground."
>
> "Equipotential grounding is achieved when all equipment within the structure(s) are referenced to a master bus bar which is in turn bonded to the external grounding system."

Emergency shelter supplies. 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 (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.