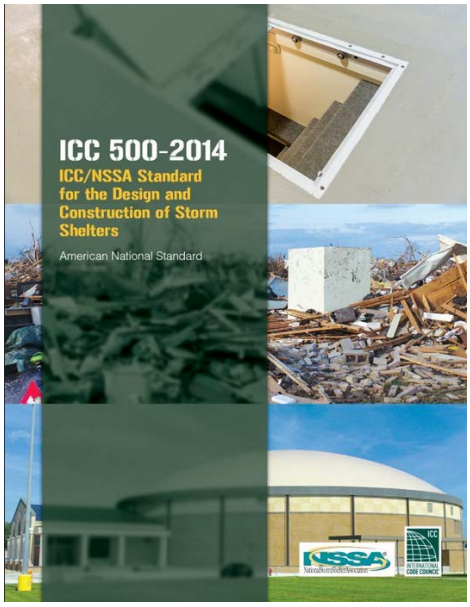
Highlights of ICC 500-2014, *ICC/NSSA Standard for the Design and Construction of Storm Shelters*

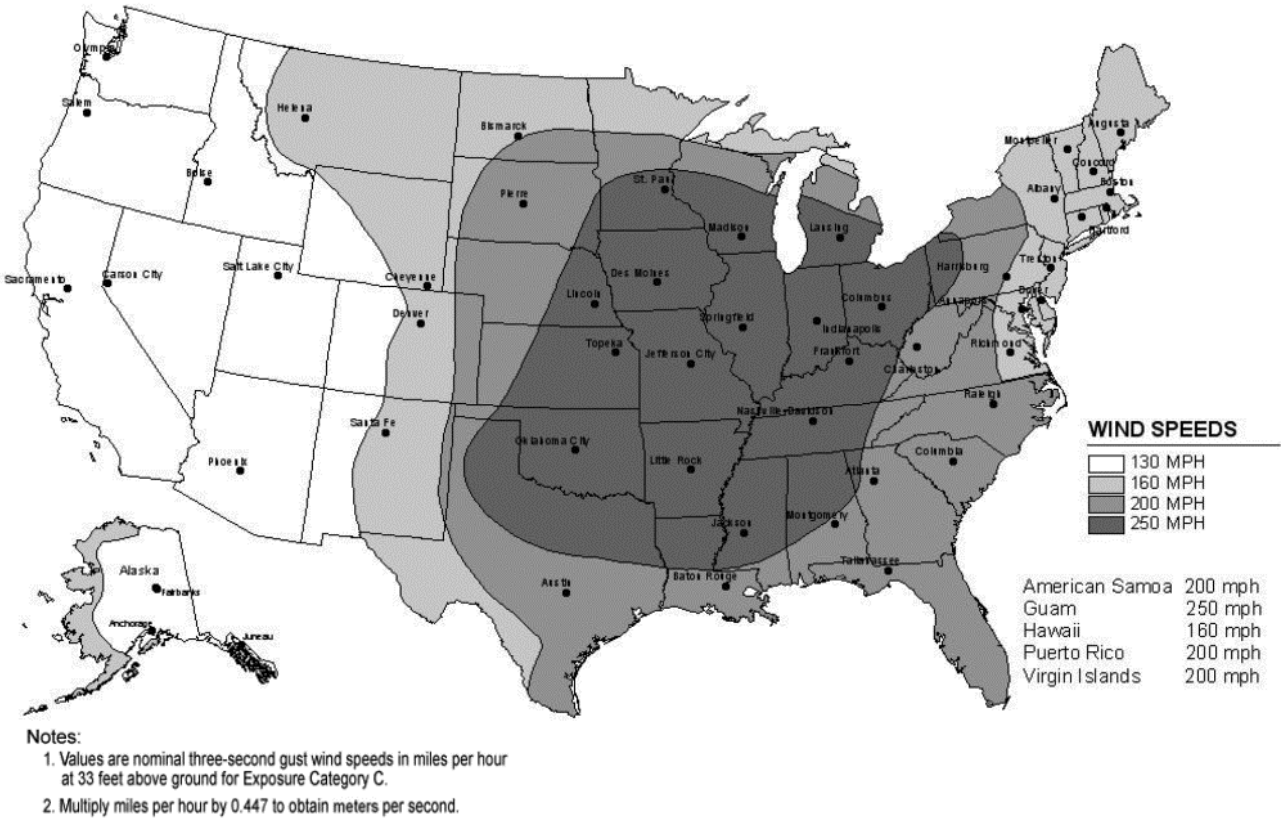


Published by the International Code Council (ICC), *ICC/NSSA Standard for the Design and Construction of Storm Shelters* (ICC 500), is a referenced standard in the International Codes (I-Codes). The ICC, in partnership with the National Storm Shelter Association (NSSA), formed a national committee in 2003 that developed and released a consensus standard to codify the design and construction requirements of tornado and hurricane storm shelters. The ICC 500 was first published in the summer of 2008 and updated in 2014. ICC 500 provides the minimum requirements to safeguard public health, safety, and general welfare relative to the design, construction, and installation of storm shelters constructed for protection from high winds associated with tornadoes and hurricanes. This standard is intended for adoption by government agencies and organizations for use in conjunction with model codes to achieve uniformity in the technical design and construction of storm shelters.

ICC 500 applies to the design, construction, installation, and inspection of both residential and community storm shelters. Residential storm shelters serve occupants of dwelling units and have an occupant capacity not exceeding 16 people. Community storm shelters are storm shelters that are not residential storm shelters. Storm shelters are permitted to be either separate, detached buildings, or enclosed or partially enclosed within a host building.

ICC 500 is referenced in the 2009, 2012, and 2015 editions of the ICC's *International Residential Code* (IRC) and *International Building Code* (IBC) as the governing standard for the design and construction of storm shelters. Since 2009, the IRC and IBC have included a section titled "Storm Shelters," which is Section R323 of the IRC and Section 423 of the IBC. Additionally, the 2015 edition of the IBC Section 423 requires buildings with certain types or functions and geographic locations to be built with a storm shelter. The following structures must include a storm shelter constructed in accordance with ICC 500 when located in a 250 mph wind speed zone for tornadoes per Figure 304.2(1) of ICC 500 (refer to Figure 1):

- 911 call stations
- Emergency operations centers
- Fire, rescue, and ambulance stations
- Police stations
- K-12 school buildings with a capacity of 50 or more occupants, with certain exceptions



Source: ICC 500, Figure 304.2(1) used with permission

Figure 1: Shelter design wind speeds for tornadoes

ICC 500 sets forth requirements for a range of topics related to the design and construction of storm shelters, including administrative items, structural design criteria, siting requirements, occupancy and egress requirements, essential features, and test methods for impact and pressure testing. Highlights of ICC 500 (2014 edition) are described below.

Administration and Oversight

- ICC 500 includes provisions for peer review and special inspection, structural observations during construction, quality assurance plans, and contractor responsibilities. The standard also specifies the information that should be provided on construction documents, which gives designers a more standardized approach to plan development.
- Labeling requirements are provided, including that labels required on impact-protective devices must be clear. Signage requirements for storm shelters are also provided.

Structural Design Criteria

- Loads and load combinations in the American Society of Civil Engineers (ASCE) standard ASCE 7, *Minimum Design Loads for Buildings and Other Structures* (2010), with modifications, are used for storm shelter design. Coefficients and factors that are different for the design of shelters as compared to conventional buildings may include items such as wind speed, exposure category, directionality factor, and enclosure classification. These

modifications are provided in ICC 500 for the designer to use in the load determination process as defined by ASCE 7-10. Additionally ICC 500 also covers rain loads, roof live loads, and flood loads requirements that differ from those found in ASCE 7.

- Requirements for the connections between a storm shelter and its host building are also defined. If the host building is destroyed, the storm shelter must be able to resist any loads that could be transmitted through connections between the host building and the shelter, in addition to the full wind loads on the shelter.
- Changes in internal pressures due to atmospheric pressure change must be considered for tornado shelters.
- Wind-borne debris hazards are defined with representative test missiles for both tornadoes and hurricanes. The standard defines when component design and testing is required, what the size and speed of the missile must be, and the type of pressure testing required.
- Foundations and slabs that support a storm shelter must be designed for all applicable loads in accordance with ICC 500. Minimum requirements for slabs-on-grade are provided. Slabs shall have a minimum thickness of 3½ inches with a minimum of 6 x 6, W1.4 x W1.4 welded wire reinforcement or No. 4 bars spaced at a maximum of 18 inches on center in two perpendicular directions and must have the capacity to resist all applicable loads.

Siting and Flood Criteria

- Minimum floor elevation requirements based on flood hazards are provided.
- Siting requirements include proximity to hazardous materials, travel distance, and high-risk flood hazard areas. Residential shelters should be located a maximum travel distance of 150 feet from an exterior door of the residence that the shelter is intended to serve.

Occupancy, Means of Egress, and Access

- Minimum required usable shelter floor area is specified in square feet per occupant. Designers must determine occupant load using the minimum usable area per occupant in conjunction with the total usable area, which is calculated by reducing unusable area from gross floor area.
- Provisions for number of doors, emergency escape openings, stair specifications, and locks and latching are provided, among other items.

Fire Protection, Essential Features, and Accessories

- The standard provides requirements on fire resistant construction and fire extinguishers. Community storm shelters must have a 2-hour fire resistance rating for any fire barriers and horizontal assemblies separating spaces between the storm shelter and host building.
- Ventilation, both mechanical and natural, is covered for tornado and hurricane storm shelters. Tornado storm shelters must have at least natural ventilation, while hurricane storm shelters must have mechanical ventilation if they have an occupant capacity greater than 50.
- Other requirements, such as emergency lighting, standby lighting, and standby power, are also covered in the standard. Power for critical systems (such as mechanical ventilation) must be protected to the same level as the storm shelter.

- The section on sanitation requirements includes tables showing the number of required hand-washing and toilet facilities for both hurricane and tornado storm shelters.

Test Methods

- The standard specifies testing requirements on storm shelters and components for both missile impact (wind-borne debris) and wind pressure.

Significant Changes in the 2014 Edition of ICC 500

The 2014 edition of ICC 500 significantly increases the level of quality control and quality assurance required for the design and construction of storm shelters. The 2008 edition of ICC 500 required that peer reviews of storm shelters be performed only for storm shelters designed for more than 300 occupants. The 2014 edition of ICC 500 requires a peer review to be conducted for community storm shelters protecting 50 occupants or more, Group E classified structures with more than 16 occupants, and shelters in Risk Category IV structures. Additionally, a peer review report must be submitted to the Authority Having Jurisdiction, in conjunction with the construction documents, during permit review.

ICC 500-2014 has special inspection requirements for post-installed anchors (anchors installed in masonry or concrete that has already hardened) and foundation elements. Post-installed anchor capacities are highly dependent on the installation; therefore, the anchor installation and capacity must be verified and certified. To ensure a complete load path from roof to ground, special inspections are now required to verify the adequacy of the foundation slab to transfer loads from the storm shelter to the subgrade below. The requirements for design information to be provided on the construction documents have also been expanded in ICC 500-2014.

ICC 500-2008 required construction documents to include details for Main Wind Force Resisting System (MWFRS) connections to the roof and foundation, and wall connections to the roof and foundation. ICC 500-2014 goes further to specify that construction documents must include details on wall cladding and wall cladding connections, foundation design and capacity, and shelter installation methods, including anchor locations and minimum required capacity of each anchor. These additional details will help peer reviewers and the Authority Having Jurisdiction verify that a proper load path exists that can withstand the extreme forces storm shelters may encounter.

ICC 500-2014 clarifies provisions that account for the effects imposed by a structure that encloses the storm shelter or by neighboring structures that may shield/connect to the storm shelter. If the storm shelter is enclosed inside a host structure, the storm shelter must be designed to resist the loads that would be generated if the surrounding structure collapsed. If components of the host building structurally connect to the storm shelter, the storm shelter must be designed to resist the maximum load that could be transferred by the connection simultaneously with all loads imposed on the shelter assuming it is fully exposed.

The list below provides a brief representation of the most significant changes by chapter.

CHAPTER 1 APPLICATION AND ADMINISTRATION

- **Section 106.1.1 Peer review:** A peer review shall be conducted by an independent registered design professional for compliance with the requirements of Chapters 3, 5, 6, and 7 for

community shelters with an occupant load greater than 50 people, storm shelters in elementary schools, secondary schools, and day care facilities with an occupant load greater than 16 people, and for storm shelters in Risk Category IV (essential facilities) as defined in Table 1604.5 in the IBC. ICC 500-2008 required peer review only for storm shelters with an occupant load greater than 300 people, and only for requirements in Chapter 3. Conducting peer reviews on safe rooms will allow inadequacies in the design to be found and resolved, resulting in improved performance.

- **Section 106.1.2 Peer review report:** A signed and sealed report, fully describing the items reviewed, their compliance or non-compliance with applicable codes and standards, and recommendation of acceptance or rejection of the storm shelter design, or modifications to render the design acceptable, shall be submitted to the Authority Having Jurisdiction prior to issuance of a permit for construction. ICC 500-2008 did not require a peer review report. The peer review report confirms in writing that the peer review was performed and that any design issues were resolved.
- **106.3.1 Special inspection to verify anchor installation:** A special inspection shall be provided to verify the post-installed anchor installation and capacity in accordance with Section 107.2.1. For post-installed anchorage to foundations, a special inspection shall be provided to verify foundation adequacy in accordance with Section 107.2.1 and 308. ICC 500-2008 did not require a special inspection of post-installed anchors or verification of the adequacy of the foundation. Verifying anchor and foundation capacity will ensure there is a continuous load path to anchor the storm shelter.
- **Section 107.2.1 Design information:** Under ICC 500-2014, additional design information is required to be included in the construction documents to improve the information provided to reviewers or the Authority Having Jurisdiction. The additional information allows for easier confirmation that the proper design loading and criteria were used for the design of the storm shelter. The following additional design information is required to be included with the construction documents:
    - A storm shelter section or elevation showing the height of the storm shelter relative to the finished grade, finished floor, and host building, where applicable.
    - For community shelters, calculations for the number of sanitation facilities.
    - Minimum foundation capacity requirements.
    - Shelter installation requirements including anchor locations and minimum required capacity for each anchor.
    - For hurricane shelters, the rainfall rate of the roof primary drainage system.
    - For hurricane shelters, the rainfall rate of the roof secondary (overflow) drainage system, where required.
    - For hurricane shelters, the rainwater drainage design rainfall rate for facilities subject to rainwater impoundment.

The ICC 500-2008 requirement to indicate the importance factor has been removed because wind pressure is calculated using ASCE 7-10, which no longer uses importance factors.

- **Section 107.3.1 Detailed requirements:** Under ICC 500-2014, additional detailed requirements for quality assurance plans must be included in the construction documents for community shelters in an effort to improve the load path performance. The following have been added to the list of detailed requirements for quality assurance plans:
    - Foundation design.
    - Pre-fabricated shelter installation requirements including anchor locations and minimum required capacity for each anchor.
    - Pre-fabricated shelter minimum foundation capacity requirements.

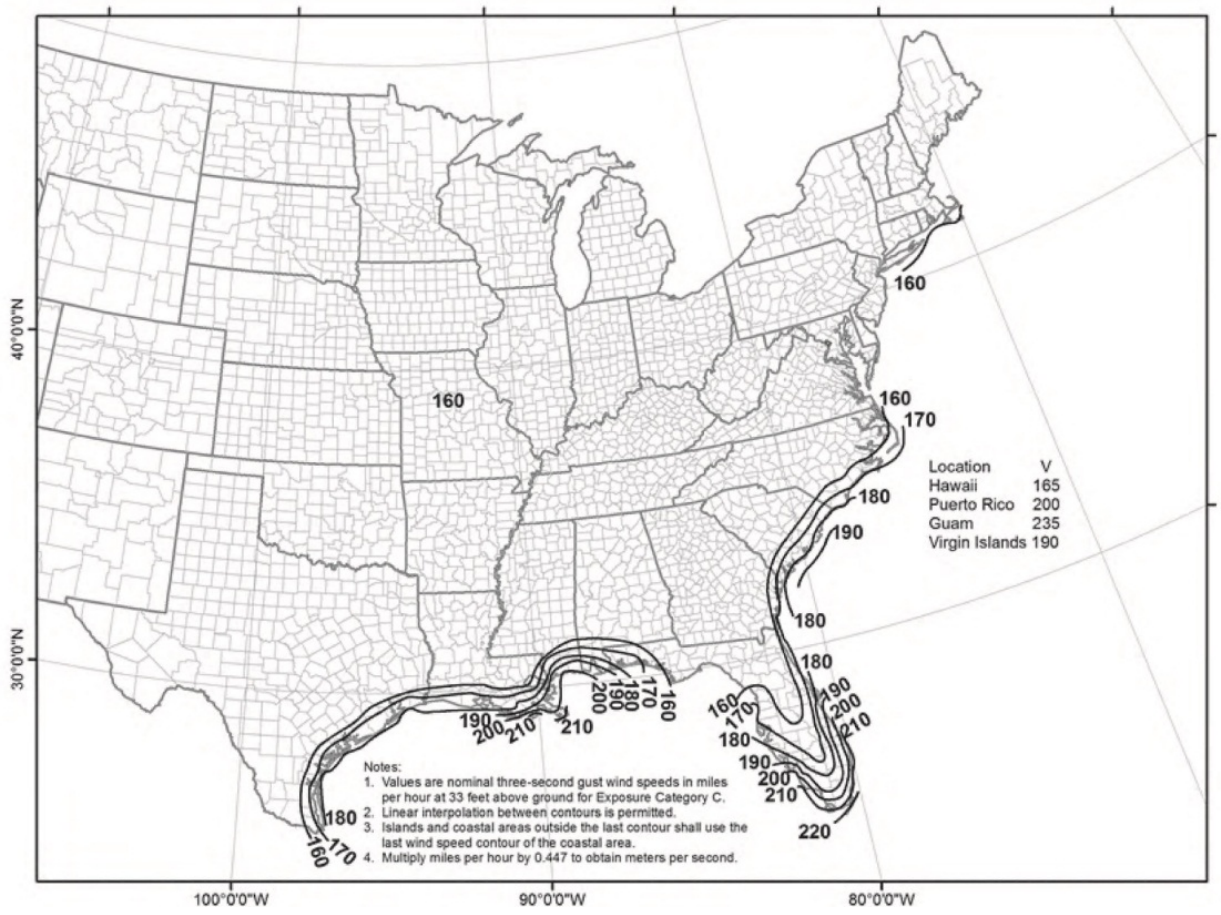
  Ensuring that the listed details are part of the quality assurance plan in the construction documents will help reviewers verify that a proper load path is provided from roof to foundation.
- **Section 107.3.3 Contractor responsibility:** The requirements of a contractor's responsibility are clarified. Before beginning work on the MWFRS or components listed in the quality assurance plan, each contractor responsible for the construction, fabrication, or installation must submit a written statement of responsibility to the Authority Having Jurisdiction, the responsible design professional, and the owner. This statement acknowledges awareness of special inspection requirements, compliance with the construction documents, and the quality assurance plan.
- **Section 108.2 Labeling:** Permanent labels that denote compliance with ICC 500-2014 must now be applied to impact-protective systems.

CHAPTER 3 STRUCTURAL DESIGN CRITERIA

The 2014 Edition of ICC 500 is now consistent with ASCE 7-10, including items such as load combinations, removal of importance factor, and terminology (e.g., "impact-protective systems" rather than "opening protective devices").

- **Section 301.1.2 Anchor calculations for doors, windows, and shutters (Section 306.6 states similar criteria):** Where anchorage of door, window, or shutter framing to the shelter structure is required by means other than those provided in the manufacturer's listing or installation instructions in accordance with Section 107, alternate anchorage shall be designed for pull-out and shear, and the anchor placement detailed in accordance with accepted engineering practice. The alternate anchorage details and calculations shall be provided as part of the construction documents. ICC 500-2008 did not discuss anchorage requirements or require that any additional information on the design of anchors be provided. These requirements will help ensure that a proper load path is provided for doors, windows, and shutters.
- **Section 302.1 Strength design (ASCE 7-10):** For strength design or load and resistance factor design (LRFD), the load combinations are now as stated in ASCE 7, Section 2.3, using loads as determined in accordance with Section 304 of this standard. Exception 1 to ASCE 7 Section 2.3.2 is still not allowed.

- **Section 302.2 Allowable stress design (ASCE 7-10):** For allowable stress design (ASD), the load combinations are now as stated in ASCE 7, Section 2.4, using loads as determined in accordance with Section 304 of this standard.
- **Section 303.1.1 Rainfall rate:** The rainfall rate for determination of rain loads on the roof of a hurricane shelter shall be determined by adding 6 inches (152.4 mm) of rainfall per hour to the rainfall rate established from Figure 303.2. The purpose of the revision was to increase the design rainfall rate to approximate a 10,000-year recurrence interval, which is also used for wind speed. The 2008 edition of ICC 500 required that a rainfall rate of 3 inches per hour be added to the rate established in Figure 303.2.
- **Section 303.4 Flood loads:** Flood loads shall be determined in accordance with ASCE 7-10. The design flood elevation shall equal the minimum floor elevation as specified in Section 401 of this standard. ICC 500-2008 did not specify flood loading criteria.
- **Section 304.1 General:** Wind loads are allowed to be determined by any of the several applicable methods in ASCE 7-10, including the wind tunnel method. ICC 500-2008 prescribed use of the Method 2 Analytical Procedure in ASCE 7-05 (renamed the Directional Method in ASCE 7-10).
- **Section 304.2 Design wind speed:** The hurricane shelter design wind speed map, Figure 304.2(2) of ICC 500 (refer to Figure 2 below), has been updated using the same hurricane simulation method as in ASCE 7-10. The mean recurrence interval is 10,000 years (0.5 % probability of exceedance in 50 years), unchanged from ICC 500-2008. Wind speeds on the new hurricane shelter design wind speed map are slightly lower than those in the 2008 edition. The tornado shelter design wind speed map is unchanged and is shown above in Figure 1.



Source: ICC 500, Figure 304.2(2) used with permission

Figure 2: Shelter design wind speeds for Hurricanes

- **Section 304.4 Exposure category:** For hurricane shelters, use of Exposure Category B for the MWFRS is not permitted unless the following exception exists: Exposure Category B exists for all wind directions and is likely to remain Exposure Category B after a hurricane having wind speeds as great as those in Figure 2. ICC 500-2008 permitted the use of Exposure Category B for hurricane storm shelter MWFRS, but without considering possible changes in exposure due to damage during the storm. Additionally, it should be noted that the reintroduction of Exposure D in hurricane prone regions in ASCE 7-10 is carried through to ICC 500 (Exposure D did not exist in hurricane prone regions in ASCE 7-05, or by reference in ICC 500-2008).
- **Section 304.8 Shielding of storm shelters by host and adjacent buildings:** Storm shelters enclosed in, partially enclosed in, or adjacent to host buildings, or adjacent to other buildings not designed for the load requirements of Chapter 3, shall be designed considering the host building to be destroyed and the shelter to be fully exposed. ICC 500-2008 did not have any requirements on how to account for the shielding of storm shelters by the host structure or adjacent structures.
- **Section 304.9 Storm shelter connected to host buildings:** Where an element or component of the host building is connected to a storm shelter, the storm shelter shall also be designed to resist

the maximum force that could be transmitted to the shelter equal to the ultimate failure strength of the connection or element being connected, whichever is lower, concurrent with the other wind loads on the storm shelter required by Chapter 3. This section replaces and clarifies the provisions in ICC 500-2008 Section 308.1.1.

- **Section 305.1.2 Missile criteria for hurricane shelters:** The speed of the test missile impacting vertical shelter surfaces shall be a minimum of 0.50 times the shelter design wind speed. The 2008 edition of ICC 500 directed that the speed of the test missile impacting vertical shelter surfaces shall be a minimum of 0.40 times the shelter design wind speed. This modification represents a more conservative approach, which is more consistent with post-storm observations of debris impacts during hurricane events and recent research on the aerodynamics of wind-borne debris.
- **Section 306.7 Door undercut:** Door or shutter assemblies for use in the shelter envelope with a threshold at the level of exit discharge shall be limited to a ¾-inch maximum undercut. A weather seal at the door undercut where doors are exposed to weather shall be provided. ICC 500-2008 did not have any requirements on door undercuts.
- **Section 306.8 Joints, gaps, or voids in shelter envelope:** Joints, gaps, or voids in the shelter envelope that open into the protected occupant area similar to masonry control joints, expansions joints, opening protective device shim spaces, air louver blades, grates, grilles, screens, or pre-cast panel joints shall be considered openings and shall be protected in accordance with Sections 306.3 and 306.4. Masonry control joints, masonry or concrete expansion joints, or precast concrete panel joints ⅜-inch or less in width shall be sealed with joint material that is in accordance with TMS 602 for masonry or ASTM C920 for concrete. Additionally, joints, gaps, or voids that do not allow a direct debris path through the shelter envelope into the protected occupant area are not required to be protected. ICC 500-2008 did not have any requirements on joints, gaps, or voids in the shelter envelope other than those required for systems and utilities.

CHAPTER 4 SITING

- **Section 401.1.1 Minimum floor elevation of community shelters and Section 401.1.2 Minimum floor elevation of residential shelters:** Text was extensively revised to clarify the minimum floor elevations of community and residential storm shelters for flood hazards.
- **Section 403.1 Residential shelter siting:** ICC 500-2014 has added clarification that residential storm shelters are to be located so that the maximum travel distance along one path from the residence to the storm shelter is 150 feet. ICC 500-2008 specified a 150-foot radius.
- **Section 404.1 Community shelter siting:** ICC 500-2014 specifies that community shelters are not permitted to be sited in floodways or flood hazard areas subject to high velocity wave action (Zone V). ICC 500-2008 did not address shelter siting with respect to flood hazards.

CHAPTER 5 OCCUPANCY, MEANS OF EGRESS, ACCESS AND ACCESSIBILITY

- **Section 501.2 Number of doors:** ICC 500-2014 provides an exception stating that shelters having an occupant load of 16 or less are not required to have an emergency escape opening.

CHAPTER 7 SHELTER ESSENTIAL FEATURES AND ACCESSORIES

- **Section 702.1.1.1 Location of ventilation:** ICC 500-2014 specifies that the lower and upper openings shall be horizontally located on an opposite wall or roof surface to cross-ventilate the shelter. The location of ventilation openings in storm shelter walls was not stated in the 2008 edition.
- **Section 703.8 Rainwater drainage for hurricane shelter facilities:** ICC 500-2014 specifies that primary roof drainage systems shall be designed to drain a rainfall rate of 3 inches more than the rate established in Figure 303.2. Secondary roof drainage systems shall be designed to drain a rainfall rate of 6 inches more than the rate established in Figure 303.2. Rainwater drainage for the site must be provided by adding 6 inches per hour to the rainfall rate from the rate established in Figure 303.2 to prevent flooding of occupied areas, critical support systems, and access routes. The 2008 edition did not address design of the drainage system.

CHAPTER 8 TEST METHODS FOR IMPACT AND PRESSURE TESTING

- **Section 803.1 Test assembly:** ICC 500-2014 specifies that the tests for doors, windows, and impact-protective systems shall be performed on the maximum and minimum size listed for use. The 2008 edition required that testing be performed only on the maximum size listed for use.
- **Section 806.4.1 Window assemblies and other glazed openings for tornado shelters:** ICC 500-2014 requires the static test pressure to be 1.2 times the design wind pressure. This modification corrects a typographical error in ICC 500-2008, where the 1.2 factor had been left out.

REFERENCES

- ASCE (American Society of Civil Engineers) 7-10. 2010. *Minimum Design Loads for Buildings and Other Structures*. ASCE/SEI 7-10. American Society of Civil Engineers. Reston, VA.
- ASCE (American Society of Civil Engineers) 7-05. 2005. *Minimum Design Loads for Buildings and Other Structures*. ASCE/SEI 7-05. American Society of Civil Engineers. Reston, VA.
- ICC (International Code Council). 2014. *Standard on the Design and Construction of Strom Shelters*. International Code Council & National Strom Shelter Association. ICC 500. Country Club Hills, IL
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