# 3 Design Criteria for Tornado and Hurricane Safe Rooms

This chapter provides the design and performance criteria for the structural systems and envelope systems (including openings and protection systems for openings and windows) for tornado and hurricane safe rooms. The performance criteria includes detailed guidance on debris impact-resistance criteria. Other engineering factors and concepts involved in the design of a safe room are also identified in this chapter, but will be discussed in detail in later chapters. This chapter presents the information in the following order (and each section provides cross-references as to which criteria are the same or different from the criteria presented in the ICC-500 Storm Shelter Standard):

- General approach to the design of safe rooms.
- Load combinations.
- Tornado community safe room wind design and debris impact performance criteria (including the Tornado Safe Room Design Wind Speed Map).
- Hurricane community safe room wind design and debris impact performance criteria (including the Hurricane Safe Room Design Wind Speed Map).
- Residential safe room wind design and debris impact performance criteria.
- Guidance on flood hazard design criteria.
- Guidance on product testing, permitting, code compliance, professional design oversight, peer review, construction documents, signage, labeling, and quality assurance/quality control, and special inspections issues are addressed at the end of the chapter.

## 3.1 General Approach to the Design of Safe Rooms

The design criteria presented in this chapter are based on the best information available at the time this manual was published and rely heavily on the ICC-500 Storm Shelter Standard. However, FEMA has identified a few design and performance criteria that are consistent with the previous FEMA guidance on safe room design and construction that remain more restrictive than some of the requirements found in the ICC-500. Chapters 5 to 9 of this publication provide a detailed commentary on these criteria and are intended to provide supplemental guidance to the design professional for the safe room criteria set forth in this chapter. The key differences affecting design of the FEMA safe room and the ICC shelter, by hazard and classification, are as follows:

- Tornado community safe rooms per FEMA 361 (see Sections 3.3.1, 3.3.2, and 3.6.1):
  - Should be designed for all cases as partially enclosed buildings, for Exposure C
  - Should be sited out of specific flood hazard areas and designed to the flood design criteria of this chapter
  - Should have life-safety protection elements of the design peer reviewed when safe room occupancy is 50 persons or more
- Hurricane community safe rooms per FEMA 361 (see Sections 3.4.1, 3.4.2, and 3.6.1):
  - Should be designed using Exposure C (may not use Exposure B as with ICC-500)
  - Should be designed as partially enclosed buildings (to account for uncontrolled openings of doors and windows)
  - Should be designed to resist the 9-lb 2x4 wood board missile traveling horizontally at 0.5 x hurricane safe room design wind speed (may not use 0.4 x hurricane safe room design wind speed)
  - Should be sited out of specific flood hazard areas and designed to the flood design criteria of this chapter
  - Should have life-safety protection elements of the design peer reviewed when safe room occupancy is 50 persons or more
- Residential safe rooms per FEMA 361/320 (see Sections 3.5.1, 3.5.2, and 3.6.2):
  - Should be designed using 250 mph as the safe room design wind speed
  - Should be designed to resist the 15-lb 2x4 wood board missile traveling horizontally at 100 mph and vertically at 67 mph
  - Should be sited out of specific flood hazard areas and designed to the flood design criteria of this chapter

The design of a safe room to resist wind loads relies on the approach to wind load determination taken in ASCE 7-05, Chapter 6, Section 6.5, Method 2 – Analytical Procedure. The International Building Code (IBC) 2006 and International Residential Code (IRC) 2006 also reference ASCE 7-05 for determining wind loads. For consistency, the designer may wish to use ASCE 7-05 to determine other loads such as dead, live, seismic, flood, and snow loads that may act on the safe room. Note: The ICC-500 provides rain and

**ICC-500 CROSS-REFERENCE**

As part of the ICC-500, rain and roof live loads for safe room designs are different and higher than as prescribed by ASCE 7-05 and the IBC and IRC.

roof live loads for safe room design that are above the requirements of ASCE 7-05 and the IBC. Wind loads should be combined with the gravity loads and the code-prescribed loads acting on the safe room in load combinations presented in Sections 3.2.1 and 3.2.2. When wind loads are considered in the design of a building, lateral and uplift loads must be properly applied to the building elements along with all other loads.

The FEMA safe room design and construction criteria are presented in this chapter without detailed discussion or guidance. The remaining chapters of this publication provide both discussion and guidance on the design and construction criteria presented in this chapter. These criteria are based on codes and standards available for adoption by any jurisdiction. Specifically, the criteria are based on the ICC-500, ASCE 7-05 and ACSE 24-05, and the 2006 IBC and IRC unless otherwise noted. For design and construction criteria not provided in this publication, or in the ICC-500, the 2006 IBC and IRC (as appropriate) should be used to determine the required criteria to complete the safe room. Should a designer, builder, or manager have any questions regarding design criteria presented in this standard, the following approach should be taken:

1. When questions arise pertaining to the difference between FEMA 361 criteria and another code or standard (such as the ICC-500), the criteria in FEMA 361 should govern. If not, the safe room cannot be considered to be a FEMA safe room.
2. When questions arise pertaining to design and construction criteria not presented in FEMA 361, but provided in the ICC-500, the criteria of the ICC-500 should be used.
3. Where the purpose of a safe room is to provide life-safety protection from both tornadoes and hurricanes, the entire safe room should be designed and constructed using the most restrictive of the two sets of criteria.
4. When a questions arise pertaining to a criteria or requirements not addressed by this publication or the ICC-500, the 2006 IBC and 2006 IRC (with references to ASCE 7-05 and ASCE 24-05) should be used to provide the necessary design and construction criteria. When these codes or standards provide conflicting criteria, the most conservative criteria should apply.

## 3.2 Load Combinations

Model building codes and engineering standards are the best available guidance for identifying the basic load combinations that should be used to design buildings. The design professional should determine the loads acting on the safe room using the load combinations and conditions for normal building use as defined in the building code in effect or as presented in Section 2 of ASCE 7-05.

The designer should then calculate the ultimate-wind loads that will act on the safe room using the design coefficients and criteria from this chapter and in the design method from Section 6.5 of ASCE 7-05. For an extreme ("ultimate") wind load ($W_x$) for a tornado, hurricane, or combined hazard, the designer should use the design parameters presented later in this chapter. However, it is important to remember that the safe room design wind speed selected from this guidance manual is for an extreme-wind event and the load combinations from ASCE 7-05 are based on design level wind events (with velocity, V). Therefore, the wind coefficients in the load combinations from ASCE 7-05 for design level wind events should be modified for the ultimate wind load. The load combinations provided in Sections 3.2.1 and 3.2.2 are for Strength Design (also termed Load and Resistance Factor Design [LRFD]) and Allowable Stress Design (ASD), respectively. These load combinations are the load combinations from ASCE 7-05 for the design level event, except where bolded. The bolded load combinations have been revised to appropriately account for the use of ultimate wind load ($W_x$) in safe room design that must be calculated using the wind design parameters specified in Sections 3.3.1, 3.4.1, and 3.5.1. The revisions are based on the guidance given in the Commentary of ASCE 7-05 for extreme-wind events and, as such, incorporate different load multipliers (specifically the wind load, $W_x$) from those used in either the model codes or ASCE 7-05 (Section 2). These load combinations should be used for the safe room design and construction.

Flood hazard design criteria for safe room design are provided in Section 3.6. Note that these criteria define where a safe room may be placed and how to design a safe room if portions of the structure are subject to flood loads. It is possible, and preferred, that there may be no flood loads to consider because a safe room has been sited outside areas subject to flooding.

The load combinations presented in Sections 3.2.1 and 3.2.2 for Strength Design and Allowable Stress Design, respectively, are the same as those presented in the ICC-500. They have been peer reviewed by the Project Team and the Review Committee. It is important to note that these load combinations are different from those presented in the first edition of FEMA 361.

### 3.2.1 Load Combinations Using Strength Design

For the design of a safe room using Strength Design Methods, the designer should use the load combinations of Section 2.3.2 of ASCE 7-05 to ensure that a complete set of load cases is considered. For the main wind force resisting system (MWFRS), components and cladding (C&C), and foundations of safe rooms designed for extreme- (ultimate-) wind loads, designers should also consider the following load cases (using $W_x$) so that the design strength equals or exceeds the effects of the factored loads in the following combinations (LRFD):

a) In load combination 3, replace 0.8W with $0.5W_x$.

b) In load combinations 4 and 6, replace 1.6W with $1.0W_x$.

c) Exception 1 from ASCE 7-05, Section 2.3.2 should not apply.

Implementing these modifications of the Strength Design Load Cases from ASCE 7-05 results in the following cases to be used for ultimate wind loads in FEMA 361 (see ASCE 7-05 for definitions of all terms, but note that $W_x$ = ultimate wind load is based on wind speed selected from the appropriate safe room design wind speed map in Sections 3.3 or 3.4):

Load Combination 1: 1.4($D$ + $F$)

Load Combination 2: 1.2($D$ + $F$ + $T$ ) + 1.6($L$ + $H$) + 0.5($L_r$ or $S$ or $R$)

**Load Combination 3:** 1.2$D$ + 1.6($L_r$ or $S$ or $R$) + ($L$ or **0.5 $W_x$**)

**Load Combination 4:** 1.2$D$ + **1.0$W_x$** + $L$ + 0.5($L_r$ or S or $R$)

Load Combination 5: 1.2$D$ + 1.0$E$ + $L$ + 0.2$S$

**Load Combination 6:** 0.9$D$ + **1.0$W_x$** + 1.6$H$

Load Combination 7: 0.9$D$ + 1.0$E$ + 1.6$H$

**Exceptions:**

1. N.A.
2. The load factor on $H$ shall be set equal to zero in load combinations 6 and 7 if the structural action due to $H$ counteracts that due to $W$ or $E$.
3. In combinations 2, 4, and 5, the combination load $S$ shall be taken as either the flat roof snow load or the sloped roof snow load.

The designer should also consider the appropriate seismic load combinations from Section 2.3.2 of ASCE 7-05. Where appropriate, the most unfavorable effects from both wind and seismic loads should be investigated. Wind and seismic loads should not be considered to act simultaneously (refer to Section 9.2 of ASCE 7-05 for the specific definition of earthquake load, E). From the load cases of Section 2.3.2 of ASCE 7-05 and the load cases listed above, the combination that produces the most unfavorable effect in the building, safe room, building component, or foundation should be used.

**NOTE**

When a safe room is located in a flood zone, the following load combinations in Section 3.2.1 should be considered:

- In V zones and coastal A zones, the 1.0$W_x$ in combinations 4 and 6 should be replaced by 1.0$W_x$ + 2.0$F_a$.
- In non-coastal A zones, the $W_x$ in combinations 4 and 6 should be replaced by 1.0$W_x$ + 1.0$F_a$.

### 3.2.2 Load Combinations Using Allowable Stress Design

For the design of a safe room using Allowable Stress Design Methods, the designer should use the load combinations of Section 2.4.1 of ASCE 7-05 to ensure that a complete set of load cases is considered. For the MWFRS, C&C, and foundations of extreme-wind safe rooms, designers should also consider the following load cases (using $W_x$) so that the design strength equals or exceeds the effects of the factored loads in the following ASD load combinations:

a) In load combinations 5, 6, and 7, replace W with 0.6$W_x$.

Implementing these modifications of the Allowable Stress Design Load Cases from ASCE 7-05 results in the following cases to be used for ultimate wind loads in FEMA 361 (see ASCE 7-05 for definitions of all terms, but that $W_x$ = ultimate wind load is based on wind speed selected from the appropriate safe room design wind speed map in Sections 3.3 or 3.4):

Load Combination 1: $D + F$

Load Combination 2: $D + H + F + L + T$

Load Combination 3: $D + H + F + (L_r \text{ or } S \text{ or } R)$

Load Combination 4: $D + H + F + 0.75(L + T) + 0.75(L_r \text{ or } S \text{ or } R)$

**Load Combination 5:** $D + H + F + (\mathbf{0.6W_x} \text{ or } 0.7E)$

**Load Combination 6:** $D + H + F + 0.75(\mathbf{0.6W_x} \text{ or } 0.7E) + 0.75L + 0.75(L_r \text{ or } S \text{ or } R)$

**Load Combination 7:** $0.6D + \mathbf{0.6Wx} + H$

Load Combination 8: $0.6D + 0.7E + H$

The designer should also consider the appropriate seismic load combinations from Section 2.4.1 of ASCE 7-05. Where appropriate, the most unfavorable effects from both wind and seismic loads should be investigated. Wind and seismic loads should not be considered to act simultaneously (refer to Section 9.2 of ASCE 7-05 for the specific definition of earthquake load, E). From the load cases of Section 2.4.1 of ASCE 7-05 and the load cases listed above, the combination that produces the most unfavorable effect in the building, safe room, building component, or foundation should be used.

**NOTE**

When a safe room is located in a flood zone, the following load combinations in Section 3.2.2 should be considered:

- In V zones and coastal A zones, $1.5F_a$ should be added to load combinations 5, 6, and 7.
- In non-coastal A zones, $0.75F_a$ should be added to load combinations 5, 6, and 7.

### 3.2.3 Other Loads and Load Combination Considerations

The ICC-500 provides specific guidance on loads in addition to wind loads. The rain (R) and roof live load ($L_r$) guidance provided in the ICC-500 applies to the design and construction of safe rooms.

Concrete and masonry design guidance is provided by the American Concrete Institute International (ACI), American Society of Civil Engineers (ASCE), and The Masonry Society (TMS). *Building Code Requirements for Structural Concrete* (ACI 318-08) and *Building Code Requirements and Specifications for Masonry Structures* (ACI 530-08/ASCE 5-08/TMS 402-08, and ACI 530.1-08/ASCE 6-08/TMS 602-08) are the most recent versions of the concrete and masonry design codes. The load combinations for these codes may differ from the load combinations in ASCE 7-05, the IBC, and other model building codes.

When designing a safe room using concrete or masonry, the designer should use load combinations specified in the concrete or masonry codes, except when the safe room design wind speed is taken from Sections 3.3, 3.4, or 3.5 of this manual. For the safe room design wind speed, the ultimate wind load ($W_x$) should be determined from the wind pressures acting on the building, calculated according to ASCE 7-05 and the provisions and assumptions stated in Sections 3.3, 3.4, or 3.5.

## 3.3 Tornado Community Safe Room Design Criteria

The first step in designing and constructing a safe room is the identification of the hazard. If there is a need for the design and construction of a safe room to protect lives during a tornado or if tornado hazards have been identified, the following design criteria are recommended. The next step in the design process is to identify the appropriate tornado safe room design wind speed from the map presented in Figure 3-1.

In this map, four zones have corresponding safe room design wind speeds of 250 mph, 200 mph, 160 mph, and 130 mph. These wind speeds should be used to determine the wind forces that act on either the structural frame (i.e., the load-bearing elements – MWFRS) of a building to be used as a safe room, the exterior coverings of the safe room (C&C), and openings or opening protectives (such as doors and windows). Additional discussion on the origin and content of this map is provided in Chapter 6 of this publication.

**ICC-500 CROSS-REFERENCE**

The tornado community safe room design criteria presented in this section of FEMA 361 are the same as the tornado community shelter design criteria presented in the ICC-500 Storm Shelter Standard unless otherwise noted.

### 3.3.1 Wind Design Parameters for Tornado Community Safe Rooms

As previously mentioned, the wind loads on the safe room should be calculated using the wind load provisions in Section 6.5 of ASCE 7-05, Method 2 – Analytical Procedure (except when modified by this guidance). The design recommendations for tornado safe rooms do not meet the requirements for using Method 1 – Simplified Procedure. In addition, all doors, windows, and openings should be protected with devices that comply with the design wind pressures as calculated by ASCE 7-05. The safe room provides life-safety protection from wind events and therefore should be capable of resisting ultimate wind loads without failure, although some damage may occur and serviceability of the safe room may be an issue after an event.

The coefficients and parameters used in the ASCE 7-05 pressure calculations in the design of a safe room are different from those listed for regular buildings or even essential facilities. This is because detailed wind characteristics in tornadoes are not well understood and the wind event

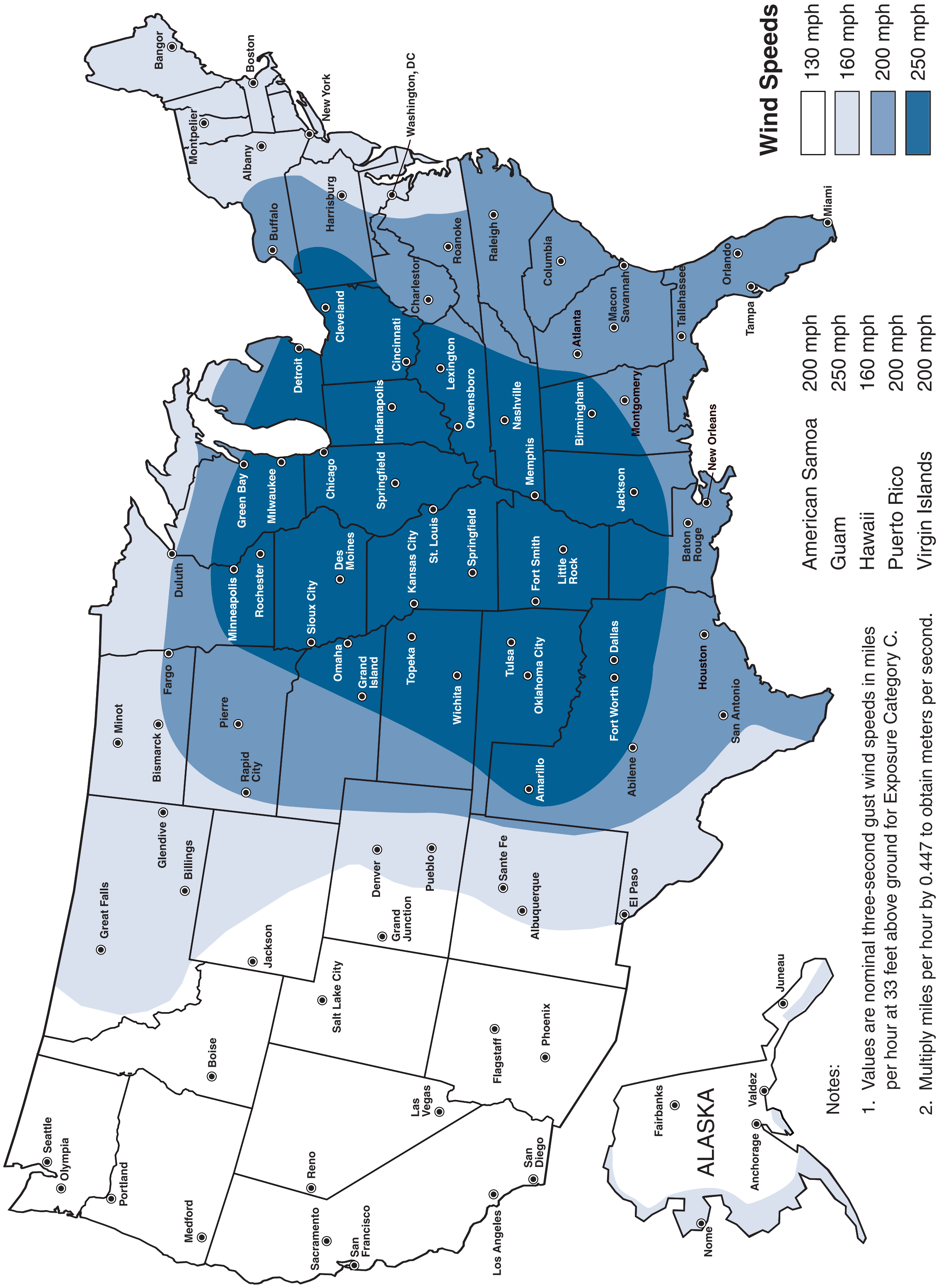


Figure 3-1. Tornado Safe Room Design Wind Speed Map (consistent with ICC-500 Tornado Hazard Map)

should be considered an "ultimate-level" event and not a "design-level" event. After selecting the tornado community safe room design wind speed from Figure 3-1, the following wind design parameters should be used when calculating wind pressures acting on tornado safe rooms:

> The design criteria discussed in this chapter pertain to the protection of the safe room space via the structural system, wall and roof assemblies, and doors and windows (and opening protectives). The design of architectural treatments on the exterior of safe room that do not provide protection of occupants within the safe room are not required to meet the design criteria presented in this publication. Should such elements or assemblies be used to improve the aesthetics of the safe room, the loads acting on those elements or assemblies should comply with requirements of the ICC-500 as applicable and, where not addressed by the ICC-500, as identified by model building code in effect or ASCE 7-05. See Chapter 7 for additional information on this topic.

a) **Select Safe Room Design Wind Speed.** This is the first component of the safe room design process. Select either $V_x$ = 250, 200, 160, 130 mph (3-second gust).

b) **Importance Factor (I)** I = 1.0

c) **Exposure Category** C

d) **Directionality Factor** $K_d$ = 1.0

e) **Topographic Effects** $K_{zt}$ need not exceed 1.0.

f) **Enclosure Classifications.** Enclosure classifications for safe rooms should be determined in accordance with ASCE 7-05, Section 6.2. For determining the enclosure classification for community safe rooms, the largest door or window on a wall that receives positive external pressure should be considered as an opening. As such, the internal pressure coefficient may be appropriate for either an enclosed or partially enclosed building, depending upon the openings in the safe room and whether the atmospheric pressure change (APC) has been calculated or estimated.

g) **Atmospheric Pressure Change.** The potential for APC should be considered in the design of tornado community safe rooms. For tornado community safe rooms, the internal pressure coefficient, $GC_{pi}$, may be taken as ±0.18 when a venting area of 1 square foot per 1,000 cubic feet of interior safe room volume is provided to account for the effect of APC. The APC venting should consist of openings in the safe room 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 criteria is permitted (see ICC-500, Section 304.8).

As an alternative to calculating the effects of APC, and designing an appropriate venting system for the safe room, the design may be completed using an internal pressure coefficient of $GC_{pi}$ = ±0.55 as a conservative means to account for the APC.

h) **Maximum Safe Room Height.** The height of a safe room is not restricted or limited.

i) **Duration of Protection.** The tornado community safe rooms are designed to provide occupants life-safety protection for storm durations of at least 2 hours.

j) **Ventilation, Sanitation, Power, and Other Non-structural Design Criteria.** Ventilation, sanitation, power, and other recommendations for tornado community safe rooms should be incorporated into the design of the safe room in accordance with ICC-500, Chapter 7. In addition, the safe room should be equipped with an electrical system with an emergency power backup system for lighting and other needs in accordance with ICC-500, Chapter 7. Additional information on these recommendations is also provided in Chapters 4 and 8 of FEMA 361.

k) **Weather Protection.** All exposed components and cladding assemblies and roof coverings of tornado community safe rooms should be designed to resist rainwater penetration during the design windstorm event, and should be designed and installed to meet the wind load requirements as prescribed by ASCE 7-05 for non-safe room wind loads at the site.

l) **Occupancy Classifications for Safe Rooms.** If a safe room is a single-use safe room, the occupancy classification per the IBC should be A-3 for the protected space. If a safe room is a multi-use safe room area, the occupancy classification for the primary use of the protected space (when not in use as a safe room) should be used.

m) **Maximum Allowable Tornado Community Safe Room Population.** From a design and construction standpoint, there is no limitation on the maximum population that a safe room may be designed to protect. However, applicants and sub-applicants who request funding support from FEMA for safe room projects should be aware that limitations do apply to the size of the safe room. Refer to FEMA safe room and benefit-cost analysis tools for guidance and criteria that can be used to define the maximum population. Any group involved in the design and construction of a tornado community safe room should obtain the latest guidance from their FEMA regional office.

n) **Maximum Population Density of a Tornado Community Safe Room.** The minimum recommended safe room floor area per occupant is provided in Table 3-1. The number of standing, seated (wheelchair-bound), or bedridden spaces should be determined based upon the needs of the safe room calculated by the designer and the applicable authority having jurisdiction. However, each community safe room should be sized to accommodate a minimum of one wheelchair space for every 200 occupants. It is also important to note that floor areas within community safe rooms should provide an access route in accordance with ICC/American National Standards Institute (ANSI) A117.1, *Standard on Accessible and Usable Buildings and Facilities*.

Table 3-1. Occupant Density for Tornado Community Safe Rooms

| Tornado Safe Room Occupant | Minimum Recommended Usable Floor Area[1] in Square Feet per Safe Room Occupant |
|---|---|
| Standing or Seated | 5 |
| Wheelchair-bound | 10 |
| Bedridden | 30 |

[1] See below for recommendations for minimum recommended usable safe room floor area.

o) **Calculation of Usable Floor Area.** The usable safe room floor area should be determined by subtracting the floor area of excluded spaces, partitions and walls, columns, fixed or movable objects, furniture, equipment, or other features that, under probable conditions, cannot be removed, or stored, during use as a safe room from the gross floor area.

An alternative method for determining the usable safe room floor area is to use the following percentages:

1. Reducing the gross floor area of safe rooms with concentrated furnishings or fixed seating by a minimum of 50 percent.
2. Reducing the gross floor area of safe rooms with unconcentrated furnishings and without fixed seating by a minimum of 35 percent.
3. Reducing the gross floor area of safe rooms with open plan furnishings and without fixed seating by a minimum of 15 percent.

p) **Number of Doors.** The number of doors as means of egress from the safe room should be determined based upon the occupant load for the normal occupancy of the space in accordance with the applicable building code. For facilities used solely for safe rooms, the number of doors should be determined in accordance with the applicable building code based upon the occupant load as calculated above in Part n). The direction of the swing of doors should be as required by the applicable building code for the normal occupancy of the space and the egress doors should be operable from the inside without the use of keys or special knowledge or effort.

Where the applicable building code requires only one means of egress door, an emergency escape opening should be provided. The emergency escape opening should be an additional door or an opening that is a minimum of 5.7 square feet in area. Such openings should have a minimum height of 24 inches and a minimum width of 20 inches. The emergency escape opening should be operable from the inside without the use of tools or special knowledge. The emergency escape opening should be located away from the means of egress door by a minimum distance of 1/3 of the length of the maximum overall diagonal dimension of the area to be served.

### 3.3.2 Debris Impact Criteria for Tornado Community Safe Rooms

The elements of the safe room structure and its components (including windows, doors, and opening protective systems) that separate the individuals therein from the event outside should resist failure from wind pressures and debris impacts. For tornado community safe rooms, the structural elements, the building envelope, and openings in the building envelope should be designed to resist wind-induced loads as well as impacts from debris.

Providing windborne debris protection for safe rooms is different from the debris impact requirements in the IBC, IRC, and ASCE 7-05. All building elements that make up the portion of the safe room that protects the occupants should resist impacts from windborne debris. As mentioned above, these include not only the openings into and out of the safe room, but the walls and roof of the safe room. No portion of the envelope (roof, wall, opening, door, window, etc.) should fail by wind pressure or be breached by the specified windborne debris (at the appropriate debris impact wind speed). The only exceptions are roof or wall coverings that provide code-compliant performance for non-safe room design features, but are not needed for the protection of the occupants within the safe room. In addition, openings for ventilation into and out of the safe room should be hardened to resist both wind loads and debris impact.

For tornado hazards, the debris impact criteria for large missiles vary with the safe room design wind speed. Specifically, the representative missile for the debris impact test for all components of the building envelope of a safe room should be a 15-lb 2x4. The speed of the test missile impacting vertical envelope surfaces varies from 100 mph to 80 mph and the speed of the test missile impacting horizontal surfaces varies from 67 mph down to 53 mph. Table 3-2 presents the missile impact speeds for the different wind speeds applicable for tornado safe room designs. This debris impact test is recommended above any other debris impact criteria that may be applicable in the local jurisdiction in which the safe room is being constructed. If the tornado safe room is located in an area that already requires debris impact protection for openings to minimize damage to buildings and contents, it is important to note that the code mandated requirements for property protection must still be adhered to and that the debris impact protection criteria which provide life-safety protection from tornadoes are additional criteria. A more detailed discussion of the debris impact recommendations is provided in Chapter 7 of this publication.

> Debris impact and extreme winds result from the same storm. However, each debris impact affects the structure for an extremely short duration, probably less than 1 second. For this reason, the highest wind load and the highest impact load are not considered likely to occur at precisely the same time.

Table 3-2. Tornado Missile Impact Criteria

| Safe Room Design Wind Speed | Missile Speed (of 15 lb 2x4 board member) and Safe Room Impact Surface |
|---|---|
| 250 mph | Vertical Surfaces: 100 mph<br>Horizontal Surfaces: 67 mph |
| 200 mph | Vertical Surfaces: 90 mph<br>Horizontal Surfaces: 60 mph |
| 160 mph | Vertical Surfaces: 84 mph<br>Horizontal Surfaces: 56 mph |
| 130 mph | Vertical Surfaces: 80 mph<br>Horizontal Surfaces: 53 mph |

Note: Walls, doors, and other safe room envelope surfaces inclined 30 degrees or more from the horizontal should be considered vertical surfaces. Surfaces inclined less than 30 degrees from the horizontal should be treated as horizontal surfaces.

To show compliance with the criteria to provide life-safety protection from windborne debris, the following guidance is provided:

a) **Testing for Missile Impacts.** Missile impact resistance of all components of the safe room envelope (including doors and opening protectives) should be tested in accordance with ICC-500, Section 305.

b) **Wall and Roof Assemblies.** All wall assemblies, roof assemblies, window assemblies, door assemblies, and protective devices used to cover openings and penetrations in the wall/roof that are recommended to protect occupants should be tested as identified in Part a) above and ICC-500, Section 306. The testing procedures that are used to comply with these criteria are provided in ICC-500, Section 804.

c) **Openings and Opening Protectives in Tornado Safe Rooms.** The openings in the safe room envelope should be protected by doors complying with ICC-500, Section 306.3.1; windows complying with ICC-500, Section 306.3.2; other opening protectives complying with ICC-500, Section 306.4; or baffled to prevent windborne debris from entering the safe room protected occupant area in accordance with ICC-500, Section 306.5. The testing procedures that are used to show compliance with these criteria are provided in ICC-500, Section 804; this also includes skylight assemblies and other glazed openings. Opening protectives in tornado safe rooms should be permanently affixed, and manually operable from inside the safe room.

   Also, window assemblies (operable and non-operable) and other glazed openings (including skylights, side lights, and transoms) should be tested using the procedures for missile impact resistance in accordance with ICC-500, Section 804; pressure in accordance with ICC-500, Section 805; and cyclic pressures in accordance with ASTM E 1996.

**Exceptions:**

1. Missile impact testing for the life-safety missile impact criteria is not necessary for window assemblies and other glazed openings where the opening is protected by a device located on the exterior or interior sides of the opening and meeting the criteria of Part a) above.

2. Missile impact and pressure testing for life-safety missile impact criteria is not necessary for window assemblies and other glazed openings where the opening is protected by a device located on the interior side of the opening and meeting the criteria of Part a) above.

d) **Soil-covered Portions of Safe Rooms.** Should all or portions of safe rooms be below ground or covered by soil, missile impact resistance criteria may not need to be addressed. Safe rooms with at least 12 inches of soil cover protecting horizontal surfaces, or with at least 36 inches of soil cover protecting vertical surfaces, do not need to be tested for resistance to missile impact as though the surfaces were exposed. Soil in place around the safe room as specified above can be considered to provide appropriate protection from the representative, tornado safe room missile impact.

e) **Alcove or Baffled Entry Systems.** All protective elements of alcove or baffled entry systems to safe rooms (when used) should be designed to meet the wind load criteria of Section 3.3.1 and the debris impact test criteria of Section 3.3.2 of this publication. Where a door is employed as part of the protection in such an entry system, the door should meet the debris impact test requirements of ICC-500, Section 804.9.7 and the pressure testing requirements of ICC-500, Sections 805 and 806.6. The enclosure classification for safe rooms with alcove or baffled entries should be determined in accordance with Section 3.3.1 of this publication.

f) **Other Debris Hazards.** Lay down, rollover, and collapse hazards (i.e., trees, other structures, rooftop equipment, etc., that have a reasonable chance of adversely impacting the safe room) should be considered by the design professional when determining the location of safe rooms on the site.

g) **Other Hazards.** Fuel tanks, fueling systems, fuel pipes, or any other known hazards near the safe room should be taken into account in the siting and design of the safe room.

## 3.4 Hurricane Community Safe Room Design Criteria

The first step in designing and constructing a safe room is the identification of the hazard. If there is a need for the design and construction of a safe room to protect lives during a hurricane or from hurricane hazards, the following design criteria are recommended. The next step in the design process is to identify the appropriate hurricane safe room design wind speed from the map presented in Figure 3-2 (including 3-2a through 3-2c).

In these maps, hurricane safe room design wind speeds are not provided by wind zones, but by wind contours and range from 160 mph to 255 mph. These wind speed contours were developed using the same model used to develop the wind speed contours for ASCE 7-05 and represent an "ultimate" design wind speed for the hurricane hazards in these areas. These wind speeds should be used to determine the wind-generated forces that act on either the structural frame (i.e., the load-bearing elements) of a building or shelter to be used as a safe room (MWFRS), the exterior coverings of the safe room (C&C), and openings or opening protectives (such as doors and windows). Additional discussions on the origins and contents of these maps are provided later in Chapters 5 and 6 of this publication.

**ICC-500 CROSS-REFERENCE**

The hurricane community safe room design criteria presented in this section of FEMA 361 differ from the tornado community safe room design criteria presented in the ICC-500 Storm Shelter Standard in several key areas. These areas are exposure classification, debris impact criteria, and flood protection. Flood design criteria are presented in Section 3.6.

The difference between the hurricane safe room wind design speed map presented in Figure 3-2 (including 3-2a through 3-2c) and the hurricane shelter design wind speed map in the ICC-500 is the landward limit line for hurricane safe rooms. The FEMA 361 map contains an additional contour line that depicts the inland geographic boundary of the area in which FEMA hurricane community safe room design criteria are deemed appropriate. Should a safe room be constructed landward of this line, the tornado community safe room recommendations presented in Section 3.3 should be used. This inland boundary is defined as the extent of the hurricane-prone region, as mapped by ASCE 7-05.

### 3.4.1 Wind Design Parameters for Hurricane Community Safe Rooms

As previously mentioned, the wind loads on the portions of the safe room that experience wind pressures (including MWFRS, C&C, and openings) should be calculated using the wind load provisions in Section 6.5 of ASCE 7-05, Method 2 – Analytical Procedure (except as modified by this section). The design recommendations for hurricane safe rooms do not meet the requirements for using Method 1 – Simplified Procedure. In addition, all doors, windows, and openings should be protected with devices that comply with the design wind pressures as calculated by ASCE 7-05. The safe room provides life-safety protection from wind events and therefore should be capable of resisting ultimate-wind loads without failure, although some damage may occur and serviceability of the safe room may be an issue after an event.

For additional information on the definition of "hurricane-prone regions," see Chapters 6 and C6 of ASCE 7-05, *Minimum Design Loads for Buildings and Other Structures.*

The coefficients and parameters used in the ASCE 7-05 pressure calculations in the design of a safe room should be different from those listed for regular buildings or even essential facilities because detailed wind characteristics in hurricanes are complex and the wind event should be considered an "ultimate-level" event and not a "design-level" event. Based on the wind speed selected from Figure 3-2, the following wind design parameters should be used when calculating wind pressures acting on hurricane safe rooms:

a) **Select Safe Room Design Wind Speed.** This is the first component of the safe room design process. Select $V_x$ = 255-160 mph (3-second gust).

b) **Importance Factor (I)** I = 1.0

c) **Exposure Category** C

d) **Directionality Factor** $K_d$ = 1.0

e) **Topographic Effects** $K_{zt}$ need not exceed 1.0.

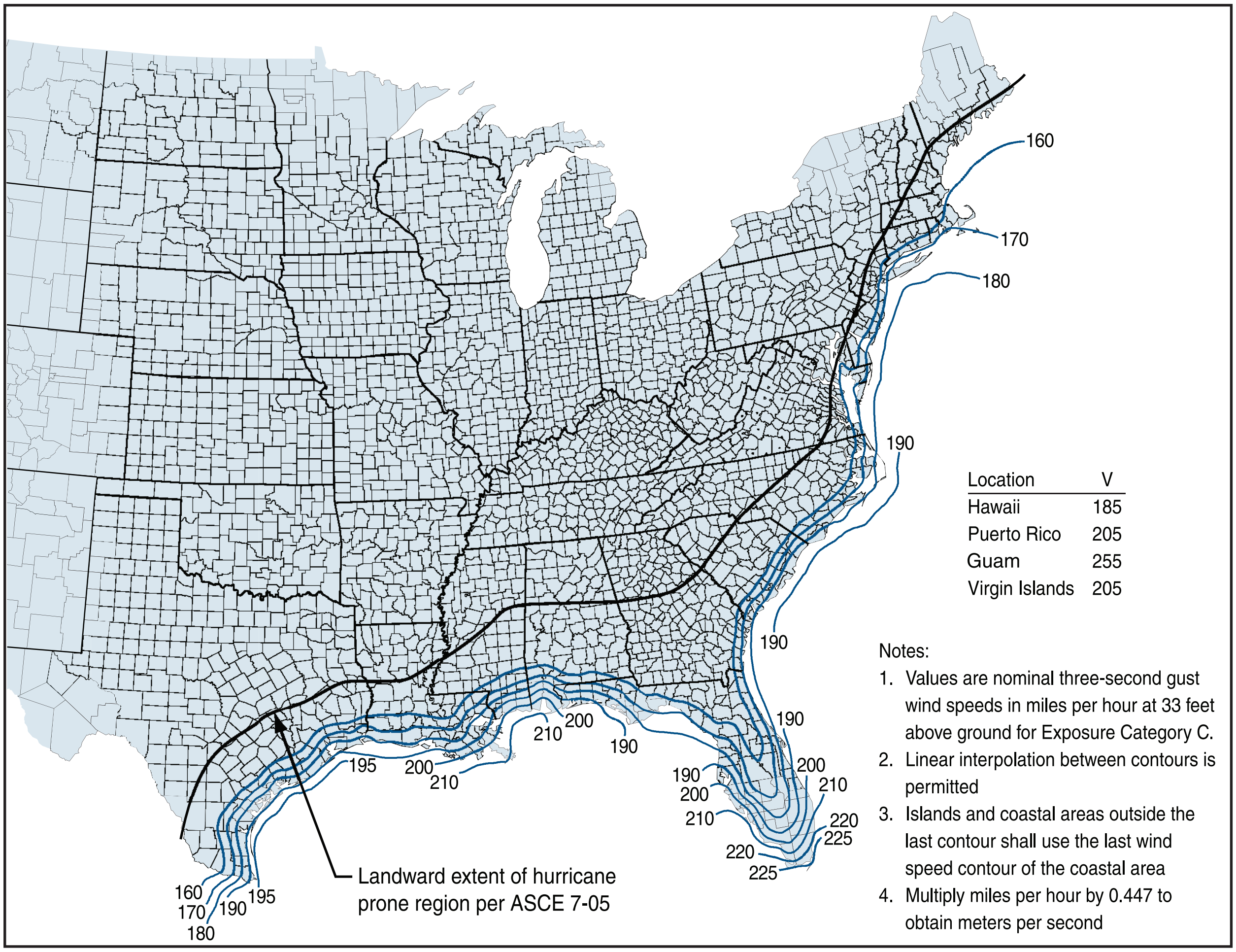


**Figure 3-2. Hurricane Safe Room Design Wind Speed Map from the ICC-500**

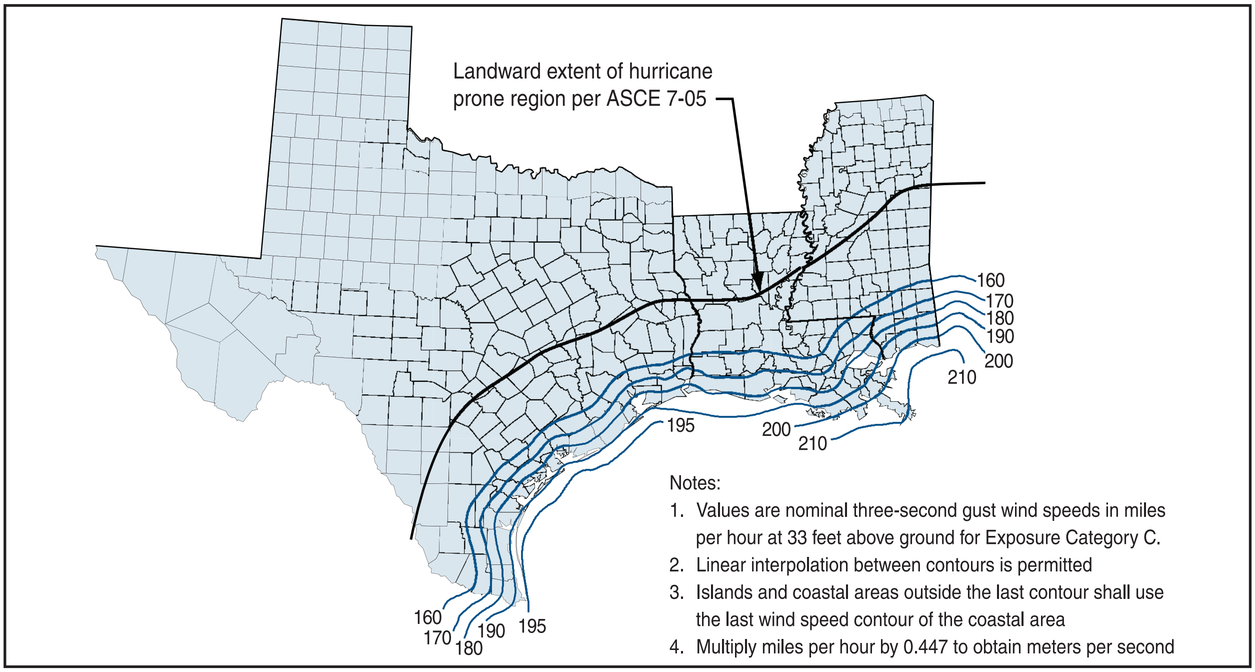


**Figure 3-2a. Hurricane Safe Room Design Wind Speed Map from the ICC-500 – Western Gulf of Mexico Detail**



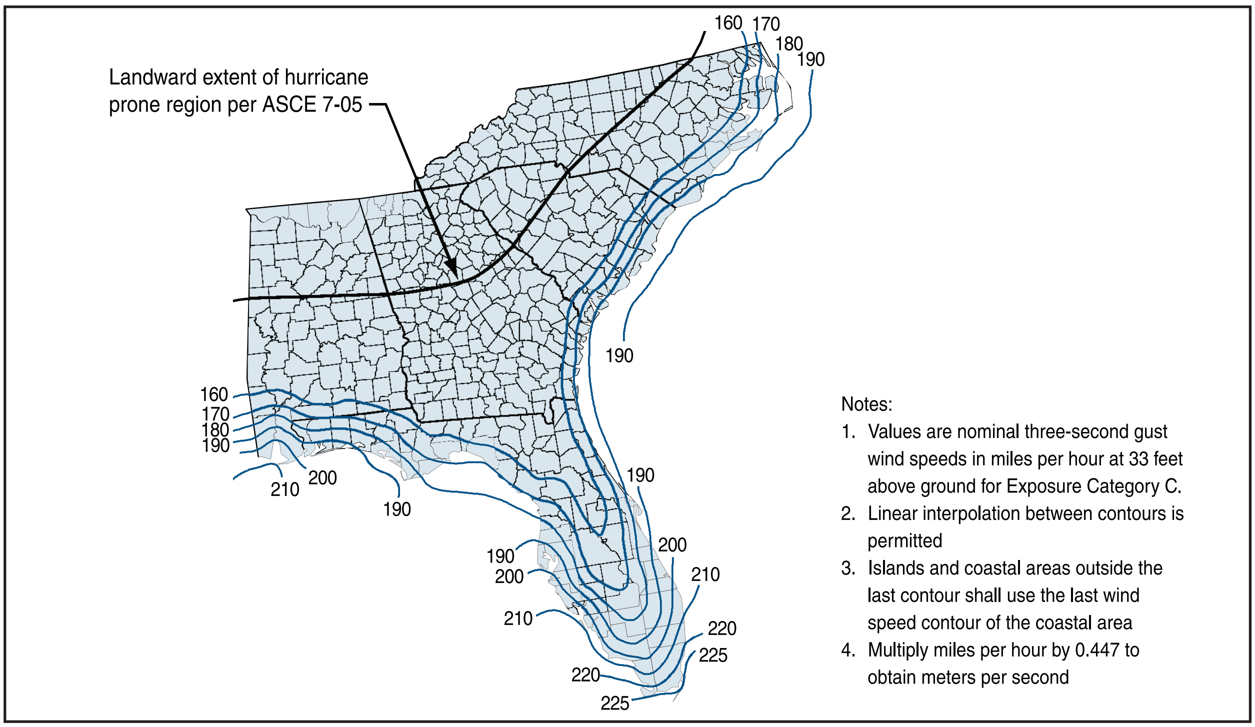


**Figure 3-2b. Hurricane Safe Room Design Wind Speed Map from the ICC-500 – Eastern Gulf of Mexico Detail**

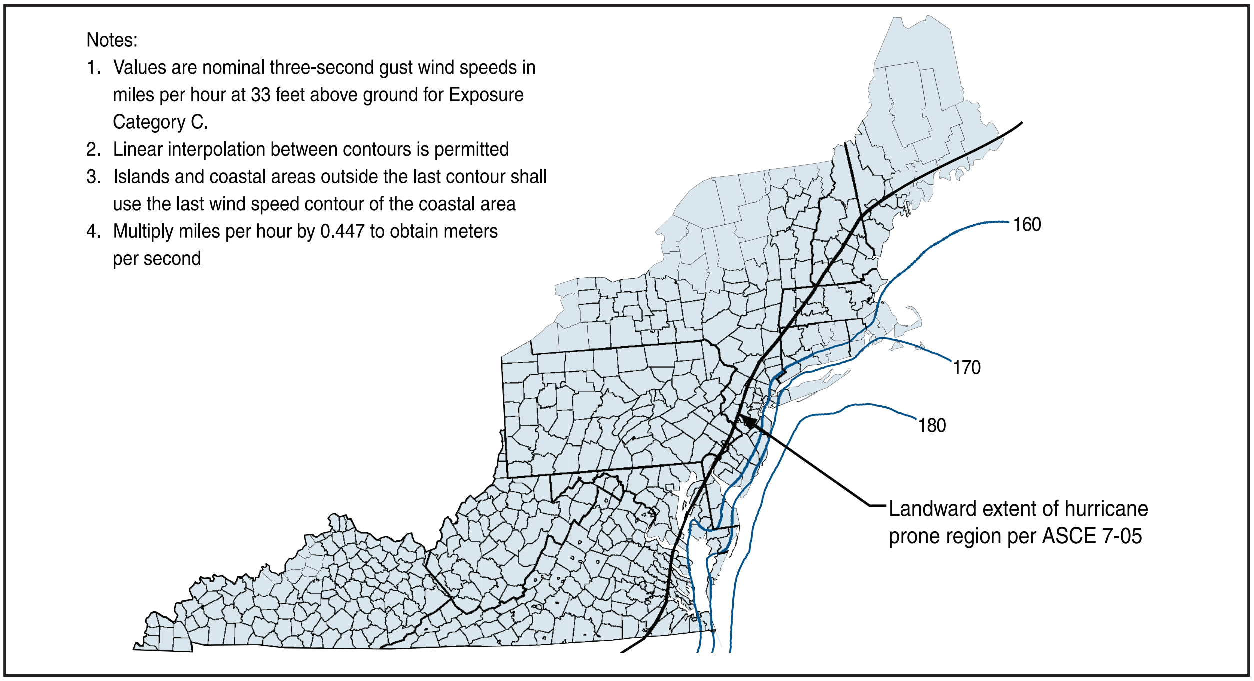


**Figure 3-2c. Hurricane Safe Room Design Wind Speed Map from the ICC-500 – Mid-Atlantic and Northeast Detail**



f) **Enclosure Classifications.** Enclosure classifications for safe rooms should be determined in accordance with ASCE 7-05, Section 6.2. For determining the enclosure classification for hurricane community safe rooms, the largest door or window on a wall that receives positive external pressure should be considered as an opening. As such, the internal pressure coefficient may be appropriately taken for either enclosed or partially enclosed buildings, depending upon the openings in the safe room.

g) **Atmospheric Pressure Change.** The potential for APC is considered negligible for hurricane hazards and therefore need not be considered in the design of hurricane community safe rooms.

h) **Maximum Safe Room Height.** The height of a safe room is not restricted or limited.

i) **Duration of Protection.** The hurricane community safe rooms are designed to provide occupants life-safety protection for storm durations of at least 24 hours.

j) **Ventilation, Sanitation, Power, and Other Non-structural Design Criteria.** Ventilation, sanitation, and other recommendations for hurricane community safe rooms should be incorporated into the design of the safe room in accordance with ICC-500, Chapter 7. In addition, the safe room should be equipped with an electrical system with an emergency power system for lighting and other needs in accordance with ICC-500, Chapter 7.

Emergency lighting recommendations may be met through means other than generators (i.e., flashlights may be used to meet this recommendation). Additional information is also provided in Chapters 4 and 8 of FEMA 361.

k) **Weather Protection.** All exposed C&C assemblies and roof coverings of hurricane safe rooms should be designed to resist rainwater penetration during the design windstorm and should be designed and installed to meet the wind load criteria of Section 3.4.1.

l) **Occupancy Classifications for Safe Rooms.** If a safe room is a single-use safe room, the occupancy classification per the IBC should be A-3 for the protected space. If a safe room is a multi-use safe room area, the occupancy classification for the primary use of the protected space (when not in use as a safe room) should be used.

m) **Maximum Allowable Hurricane Community Safe Room Population.** From a design and construction standpoint, there is no limitation on the maximum population that a safe room may be designed to protect. However, applicants and sub-applicants who request funding support from FEMA for safe room projects should be aware that limitations do apply to the size of the safe room. Refer to FEMA safe room and benefit-cost analysis tools for guidance and criteria that can be used to define the maximum population. Any group involved in the design and construction of a hurricane community safe room should obtain the latest guidance from their FEMA regional office.

n) **Maximum Population Density of a Hurricane Community Safe Room.** The minimum recommended safe room floor area per occupant is provided in Table 3-3. The number of standing, seated, or bedridden spaces should be determined based upon the needs of the safe room determined by the designer and the applicable authority having jurisdiction. However, each community safe room should be sized to accommodate a minimum of one wheelchair space for every 200 occupants or portion thereof. It is also important to note that floor space (areas) within community safe rooms should provide an accessible route in accordance with ICC/ANSI A117.1.

Table 3-3. Occupant Density for Hurricane Community Safe Rooms

| Hurricane Safe Room Occupant | Minimum Recommended Usable Floor Area[1] in Square Feet per Safe Room Occupant |
|---|---|
| Standing or Seated | 20 |
| Wheelchair-bound | 20 |
| Bedridden | 40 |

[1] See below for recommendations for minimum recommended usable safe room floor area.

o) **Calculation of Usable Floor Area.** The usable safe room floor area should be determined by subtracting 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 safe room from the gross floor area.

An alternative for determining the usable safe room floor area is to use the following percentages:

1. Reducing the gross floor area of safe room areas with concentrated furnishings or fixed seating by a minimum of 50 percent
2. Reducing the gross floor area of safe room areas with unconcentrated furnishings and without fixed seating by a minimum of 35 percent
3. Reducing the gross floor area of safe room areas with open plan furnishings and without fixed seating by a minimum of 15 percent

p) **Number of Doors.** The number of doors as means of egress from the safe room should be determined based upon the occupant load for the normal occupancy of the space in accordance with the applicable building code. For facilities used solely for safe rooms, the number of doors should be determined in accordance with the applicable building code based upon the occupant load as calculated above in Part n). The direction of the swing of doors should be as required by the applicable building code for the normal occupancy of the space and the egress doors should be operable from the inside without the use of keys or special knowledge or effort.

Where the applicable building code requires only one means of egress door, an emergency escape opening should be provided. The emergency escape opening should be an additional door or an opening that is a minimum of 5.7 square feet in area. Such openings should have a minimum height of 24 inches and a minimum width of 20 inches. The emergency escape opening should be operable from the inside without the use of tools or special knowledge. The emergency escape opening should be located away from the means of egress door by a minimum distance of 1/3 of the length of the maximum overall diagonal dimension of the area to be served.

### 3.4.2 Debris Impact Criteria for Hurricane Community Safe Rooms

The elements of the safe room structure and its components (including windows, doors, and opening protectives) that separate the individuals inside from the event outside should resist failure from wind pressures and debris impacts. For hurricane community safe rooms, the structural elements, the building envelope, and openings in the building envelope should be designed to resist wind-induced loads as well as impacts from debris.

Providing windborne debris protection for safe rooms is different from the debris impact requirements in the IBC, IRC, and ASCE 7-05. All building elements that make up the portion of the safe room that protects the occupants should resist impacts from windborne debris. As mentioned above, these include not only the openings into and out of the safe room, but the walls and roof of the safe room. No portion of the envelope (roof, wall, opening, door, window, etc.) should fail by wind pressure or be breached by the specified windborne debris (at the appropriate debris impact wind speed). The only exceptions are roof or wall coverings that provide code-compliant performance for non-safe room design features, but are not needed for the protection of the occupants within the safe room. In addition, openings for ventilation into and out of the safe room should be hardened to resist both wind loads and debris impact.

For hurricane hazards, the debris impact criteria for large missiles are a function of the hurricane safe room design wind speed. Specifically, the representative missile for the debris impact test for all components of the building envelope of hurricane safe rooms should be a 9-lb 2x4. The speed of the test missile impacting vertical safe room surfaces should be a minimum of 0.50 times the safe room design wind speed. The speed of the test missile impacting horizontal surfaces should be 0.10 times the safe room design wind speed. Table 3-4 presents the missile impact speeds for the different wind speeds applicable for hurricane safe room designs. This debris impact test is recommended above any other debris impact criteria that may be applicable in the local jurisdiction in which the safe room is being constructed. If the hurricane safe room is located in an area that already requires debris impact protection for openings to minimize damage to buildings and contents, it is important to note that life-safety debris impact-resistance criteria identified here should be applied in addition to the code mandated requirements because the protected area must be designed to provide near-absolute protection from hurricanes. A more detailed discussion of the debris impact criteria is provided in Chapter 7 of this publication.

To show compliance with criteria for providing life-safety protection from windborne debris, the following guidance is provided:

a) **Testing for Missile Impacts.** Testing for missile impact resistance of all components of the safe room envelope (including doors and opening protectives) should be in accordance with ICC-500, Section 305, with the exception of the missile impact speed, which should be that specified in Table 3-4.

b) **Wall and Roof Assemblies.** All wall assemblies, roof assemblies, window assemblies, door assemblies, and protective devices used to cover openings and penetrations in the wall/roof that are recommended to protect occupants should be tested as identified in Part a) above and ICC-500, Section 306. The testing procedures that are used to comply with these criteria are provided in ICC-500, Section 804.

## ICC-500 CROSS-REFERENCE

The hurricane community safe room missile impact criteria in this section of FEMA 361 differ from the hurricane community shelter design criteria presented in the ICC-500 Storm Shelter Standard. The ICC-500 Standard Committee considered several factors in determining the horizontal missile speed to be used for testing with the 9-lb 2x4 board member. FEMA, however, reviewed the same data, research, and post-storm assessments, but took a position that it is more appropriate to recommend a high impact speed for the representative missile (for the debris impact criteria) when providing near-absolute level of protection of occupants that FEMA has promulgated since the first safe room and shelter guidance in FEMA 320 and FEMA 361.

Table 3-4. Hurricane Missile Impact Criteria

| Hurricane Design Missile is a 9-lb 2x4 board member impacting the safe room at the following missile impact speed (as a function of safe room design wind speed [V]) | | | | |
|---|---|---|---|---|
| Hurricane Design Wind Speed (V) | FEMA 361 Horizontal Missile Speed – Hurricane (0.5xV) | FEMA 361 Vertical Missile Speed – Hurricane (0.1xV) | ICC-500 Horizontal Missile Speed – Hurricane (0.4xV) | ICC-500 Vertical Missile Speed – Hurricane (0.1xV) |
| 255 mph | 128 mph | 26 mph | 102 mph | 26 mph |
| 250 mph | 125 mph | 25 mph | 100 mph | 25 mph |
| 240 mph | 120 mph | 24 mph | 96 mph | 24 mph |
| 230 mph | 115 mph | 23 mph | 92 mph | 23 mph |
| 220 mph | 110 mph | 22 mph | 88 mph | 22 mph |
| 210 mph | 105 mph | 21 mph | 84 mph | 21 mph |
| 200 mph | 100 mph | 20 mph | 80 mph | 20 mph |
| 190 mph | 95 mph | 19 mph | 76 mph | 19 mph |
| 180 mph | 90 mph | 18 mph | 72 mph | 18 mph |
| 170 mph | 85 mph | 17 mph | 68 mph | 17 mph |
| 160 mph | 80 mph | 16 mph | 64 mph | 16 mph |

Note: Walls, doors, and other safe room envelope surfaces inclined 30 degrees or more from the horizontal should be considered vertical surfaces. Surfaces inclined less than 30 degrees from the horizontal should be treated as horizontal surfaces.

c) **Openings and Opening Protectives in Tornado Safe Rooms.** The openings in the safe room envelope should be protected by doors complying with ICC-500, Section 306.3.1; windows complying with ICC-500, Section 306.3.2; other opening protectives complying with ICC-500, Section 306.4; or baffled to prevent windborne debris from entering the safe room protected occupant area in accordance with ICC-500, Section 306.5. The testing procedures that are used to show compliance with these criteria are provided in ICC-500, Section 804; this also includes skylight assemblies and other glazed openings. Opening protectives in tornado safe rooms should be permanently affixed, and manually operable from inside the safe room.

Also, window assemblies (operable and non-operable) and other glazed openings (including skylights, side lights, and transoms) should be tested using the procedures for missile impact resistance in accordance with ICC-500, Section 804; pressure in accordance with ICC-500, Section 805; and cyclic pressures in accordance with ASTM E 1996.

**Exceptions:**

1. Missile impact testing for the life-safety missile impact criteria is not necessary for window assemblies and other glazed openings where the opening is protected by a device that is located on the exterior or interior side of the opening, and meets the criteria of Part a) above.

2. Missile impact and pressure testing for the life-safety wind design criteria are not necessary for window assemblies and other glazed openings where the opening is protected by a device that is located on the interior side of the opening and meets the criteria of Part a) above.

d) **Soil-covered Portions of Safe Rooms.** Should all or portions of safe rooms be below ground or covered by soil, missile impact resistance criteria may not need to be addressed. Safe rooms with at least 12 inches of soil cover protecting safe room horizontal surfaces, or with at least 36 inches of soil cover protecting safe room vertical surfaces, do not need to be tested for resistance to missile impact as though the surfaces were exposed. Soil in place around the safe room as specified above can be considered to provide appropriate protection from the representative hurricane safe room missile impact.

e) **Alcove or Baffled Entry Systems.** All protective elements of alcove or baffled entry systems to safe rooms (when used) should be designed to meet the wind load recommendations of Section 3.4.1 of this publication and the debris impact test recommendations of this section. When a door is employed as part of the protection in such an entry system, the door should meet the debris impact test requirements of ICC-500, Section 804.9.7 and the pressure testing requirements of ICC-500, Sections 805 and 806.6. The enclosure classification for safe rooms with baffled or alcove entries should be determined in accordance with Section 3.4.1 of this publication.

f) **Other Debris Hazards.** Lay down, rollover, and collapse hazards (i.e., trees, other structures, rooftop equipment, etc., that have a reasonable chance of adversely impacting the safe room) should be considered by the design professional when determining the location of safe rooms on the site.

g) **Other Hazards.** Fuel tanks, fueling systems, fuel pipes, or any other known hazards near the safe room should be taken into account in the siting and design of the safe room.

h) **Safe Rooms Meeting Hurricane Impact Test Recommendations.** Safe room envelope components meeting missile impact test recommendations for tornado safe rooms should be considered acceptable for hurricane safe rooms provided they meet structural design load recommendations for hurricane safe rooms.

## 3.5 Residential Safe Room Design Criteria

This section provides the residential safe room design criteria for both tornado and hurricane safe rooms. FEMA supports the ICC-500 Storm Shelter Standard design and construction requirements for residential tornado and hurricane shelters. However, FEMA safe room guidance on the use of safe rooms in residential applications takes a different approach from the ICC-500. FEMA 320 designs are combination tornado and hurricane safe rooms that meet the most stringent criteria for each hazard. The original FEMA 320, *Taking Shelter From the Storm: Building a Safe Room Inside Your House* (1998, and revised in 1999) provided prescriptive solutions for homeowners for below- and above-ground safe rooms that could provide "near-absolute protection" without the need to obtain and hire professional design services, provided the design plans in the publication are used properly. Therefore, the intent of FEMA in the original publication, and in any revisions to FEMA 320, remains the same, to continue to provide the prescriptive solutions for sheltering from extreme-wind events for life-safety protection. As such, the FEMA 320 designs provide FEMA's interpretation of how to implement the combined tornado and hurricane residential safe room criteria based on the design criteria included in this section.

**ICC-500 CROSS-REFERENCE**

The residential safe room design criteria presented in FEMA 361 meet the design criteria presented in the ICC-500 for combined, residential tornado and hurricane shelters. The FEMA safe room criteria presented here also meet the requirements for combined, small tornado and hurricane community safe rooms (with maximum occupancies of 16 persons or less). The criteria presented here are the basis for the safe room designs presented in FEMA 320, *Taking Shelter From the Storm: Building a Safe Room For Your Home or Small Business*.

Along with these revisions and updates to FEMA 361, FEMA has updated and expanded the guidance provided in FEMA 320. The updated FEMA 320 guidance and prescriptive design plans comply not only with the residential shelter requirements of the ICC-500, but also with the community shelter requirements for small shelters (less than 16 occupants) to support the use of these safe rooms in buildings other than residences. Since FEMA 320 does not present detailed design information, this section of FEMA 361 provides designers with the criteria used for the development of the revised, prescriptive safe room plans in FEMA 320. Therefore, the revised FEMA 320, *Taking Shelter From the Storm: Building a Safe Room for Your Home or Small Business* publication (August 2008) presents simple and conservative prescriptive approaches to safe room designs that are considered compliant with both FEMA 361 criteria and the ICC-500 requirements for the design and construction of combined, residential tornado and hurricane safe rooms.

### 3.5.1 Wind Design Parameters for Residential Safe Rooms

Calculate the wind loads on the residential safe room for all sections that experience wind pressures (including MWFRS and C&C) using the wind load provisions in Section 6.5 of ASCE 7-05, Method 2 – Analytical Procedure (except as modified by this section). The design recommendations for residential safe rooms do not meet the requirements for using Method 1 – Simplified Procedure. In addition, all doors, windows, and openings should be protected with devices that comply with the design wind pressures as calculated by ASCE 7-05. The safe room provides life-safety protection from wind events and therefore should be capable of resisting ultimate wind loads without failure, although some damage may occur and serviceability of the safe room may be an issue after an event. The following wind design parameters should be used when calculating wind pressures acting on residential safe rooms:

a) **Select Safe Room Design Wind Speed.** The design wind speed for residential safe rooms should be taken as $V_x$ = 250 mph (3-second gust).

b) **Importance Factor (I)** I = 1.0

c) **Exposure Category** C

d) **Directionality Factor** $K_d$ = 1.0

e) **Topographic Effects** $K_{zt}$ need not exceed 1.0.

f) **Enclosure Classifications.** Enclosure classifications for small community safe rooms should be that used for a partially enclosed building as defined by ASCE 7-05, Section 6.2. For residential safe rooms serving one- and two-family dwellings only, the partially enclosed building classification is recommended, but the enclosed building classification may be used for the design of the safe room.

g) **Atmospheric Pressure Change (APC).** When the safe room is being designed as a partially enclosed building, it meets the alternative design criteria for considering APC in the design of the safe room. Therefore, the designer should use $GC_{pi}$ = ±0.55.

h) **Maximum Safe Room Height.** The height of the residential safe room is restricted to 8 feet of vertical wall.

i) **Duration of Protection.** The residential safe rooms are designed to provide occupants life-safety protection for storm durations of at least 24 hours.

j) **Ventilation, Sanitation, Power and Other Non-structural Design Criteria.** Ventilation, sanitation, power, and other services for tornado community safe rooms should be incorporated into the design of the safe room in accordance with ICC-500, Chapter 7. In addition, the safe room should be equipped with an electrical system with an emergency power backup system for lighting and other needs in accordance with ICC-500, Chapter 7. Emergency lighting recommendations may be met through means other than generators (i.e., flashlights may be used to meet this recommendation). Additional information is also provided in Chapters 4 and 8 of FEMA 361.

k) **Weather Protection.** All exposed C&C assemblies and roof coverings of hurricane safe rooms should be designed to resist rainwater penetration during the design windstorm and should be designed and installed to meet the wind load recommendations of Section 3.3.1.

l) **Occupancy Classifications for Safe Rooms.** A safe room serves occupants of dwelling units as defined in Section 310 of the IBC and having an occupant load not exceeding 16 persons.

m) **Maximum Allowable Residential Safe Room Population.** The maximum allowable population for the prescriptive designs provided is 16 persons (only when the design selected provides at least 80 square feet of net, usable floor space within the safe room).

n) **Maximum Population Density of a Residential Safe Room.** The minimum safe room floor area per occupant in a residential safe room is provided in Table 3-5.

Table 3-5. Occupant Density for Residential Safe Rooms

| Type of Safe Room | Minimum Recommended Usable Safe Room Floor Area in Square Feet Per Occupant |
|---|---|
| Tornado | |
| One- and Two-Family Dwelling | 3 |
| Other Residential | 5 |
| Hurricane | |
| One- and Two- Family Dwelling | 7 |
| Other Residential | 10 |

For this table, the usable tornado safe room floor area should be the gross floor area, minus the area of sanitary facilities, if any, and should include the protected occupant area between the safe room walls at the level of fixed seating, where fixed seating exists.

o) **Number of Doors.** The number of doors as means of egress from the safe room should be determined based upon the occupant load for the normal occupancy of the space in accordance with the applicable building code. A minimum of one door is recommended and an emergency escape opening, in addition to the egress door is not required.

It is important to note that use and occupancy of a residential safe room is at the discretion of the safe room occupant. Compliance with FEMA residential safe room design recommendations should not be seen as a waiver or variance from the Federal Government of disregard or to not comply with a mandatory evacuation order issued by local emergency management officials or the authority having jurisdiction (AHJ).

### 3.5.2 Debris Impact Criteria for Residential Safe Rooms

The entire safe room structure, and especially the components that separate the individuals inside from the event outside, should resist failure from wind pressures and debris impacts. For residential safe rooms, the structural elements and the building envelope should be designed to resist wind-induced loads as well as impacts from debris.

Providing windborne debris protection for safe rooms is different from the debris impact requirements in the IBC, IRC, and ASCE 7-05. All building elements that make up the portion of the safe room that protects the occupants should resist impacts from windborne debris. As mentioned above, these include not only the openings into and out of the safe room, but the walls and roof of the safe room. No portion of the envelope (roof, wall, opening, door, window, etc.) should fail by wind pressure or be breached by the specified windborne debris (at the appropriate debris impact wind speed). The only exceptions are roof or wall coverings that provide code-compliant performance for non-safe room design features, but are not needed for the protection of the occupants within the safe room. In addition, openings for ventilation into and out of the safe room should be hardened to resist both wind loads and debris impact.

For the residential safe room, the representative missile for the debris impact test for all components of the safe room envelope should be a 15-lb 2x4. The speeds of the test missile impacting vertical and horizontal safe room surfaces are presented in Table 3-6. This debris impact test is recommended above and beyond any other debris impact criteria that may be applicable in the local jurisdiction in which the safe room is being constructed. If the residential safe room is located in an area that already requires debris impact protection for openings to minimize damage to buildings and contents, it is important to note that the code mandated requirements for property protection must still be adhered to and that the debris impact protection criteria that provide life-safety protection from tornadoes and hurricanes are the additional criteria. A more detailed discussion of the debris impact criteria is provided in Chapter 7 of this publication.

**Table 3-6. Residential Safe Room Missile Impact Criteria**

| Safe Room Design Wind Speed | Missile Speed (of 15-lb 2x4 board member) and Safe Room Impact Surface |
|---|---|
| 250 mph | Vertical Surfaces: 100 mph<br>Horizontal Surfaces: 67 mph |

Note: Walls, doors, and other safe room envelope surfaces inclined 30 degrees or more from the horizontal should be considered vertical surfaces. Surfaces inclined less than 30 degrees from the horizontal should be treated as horizontal surfaces.

To show compliance with criteria pertaining to life-safety protection from windborne debris, the following guidance is provided:

a) **Testing for Missile Impacts.** Testing for missile impact resistance of all components of the safe room envelope (including doors and opening protectives) should be in accordance with ICC-500, Section 305, with the exception of the missile impact speed, which should be that specified in Table 3-6.

b) **Wall and Roof Assemblies.** All wall assemblies, roof assemblies, window assemblies, door assemblies, and protective devices used to cover openings and penetrations in the wall/roof that are recommended to protect occupants should be tested as identified in Part a) above and ICC-500, Section 306. The testing procedures that are used to comply with these criteria are provided in ICC-500, Section 804.

c) **Openings and Opening Protectives in Tornado Safe Rooms.** The openings in the safe room envelope should be protected by doors complying with ICC-500, Section 306.3.1; windows complying with ICC-500, Section 306.3.2; other opening protectives complying with ICC-500, Section 306.4; or baffled to prevent windborne debris from entering the safe room protected occupant area in accordance with ICC-500, Section 306.5. The testing procedures that are used to show compliance with these criteria are provided in ICC-500, Section 804; this also includes skylight assemblies and other glazed openings. Opening protectives in residential safe rooms should be permanently affixed and manually operable from inside the safe room.

Also, window assemblies (operable and non-operable) and other glazed openings (including skylights, side lights, and transoms) should be tested using the procedures for missile impact resistance in accordance with ICC-500, Section 804; pressure in accordance with ICC-500, Section 805; and cyclic pressures in accordance with ASTM E 1996.

**Exceptions:**

1. Missile impact testing for the life-safety missile impact criteria is not necessary for window assemblies and other glazed openings where the opening is protected by a device located on the exterior or interior sides of the opening and meeting the criteria of Part a) above.
2. Missile impact testing and pressure testing for the life-safety missile impact criteria are not necessary for window assemblies and other glazed openings where the opening is protected by a device located on the interior side of the opening and meeting the criteria of Part a) above.

d) **Soil-covered Portions of Safe Rooms.** Should all or portions of a safe room be below ground or covered by soil, missile impact resistance criteria may not be to be addressed. Safe rooms with at least 12 inches of soil cover protecting horizontal surfaces, or with at least 36 inches of soil cover protecting vertical surfaces, do not need to be tested for resistance to missile impact as though the surfaces were exposed. Soil in place around the safe room as specified above can be considered to provide appropriate protection from the representative residential safe room missile impact.

e) **Alcove or Baffled Entry Systems.** All protective elements of alcove or baffled entry systems to safe rooms (when used) should be designed to meet the wind load recommendations of Section 3.5.1 of this publication and the debris impact test recommendations of Section 3.5.2 of this publication. Where a door is employed as part of the protection in such an entry system, the door should meet the debris impact test requirements of ICC-500, Section 804.9.7 and the pressure testing requirements of ICC-500, Sections 805 and 806.6. The enclosure classification for safe rooms with alcove or baffled entries should be determined in accordance with Section 3.5.1 of this publication.

f) **Other Debris Hazards.** Lay down, rollover, and collapse hazards (i.e., trees, other structures, equipment, etc., that have a reasonable chance of adversely impacting the safe room) should be considered by the design professional when determining the location of safe rooms on the site.

## 3.6 Flood Hazard Design Criteria for Safe Rooms

The design of safe rooms to resist wind forces and wind loads was identified in the previous section. It is also important to address the flood hazards that may exist at a safe room site. This section outlines the flood design criteria for community and residential safe rooms. This process, like the wind design, can be accomplished and completed by a design professional using the processes presented in ASCE 7-05 as modified in this publication for the flood hazard (if it exists). If the flood hazard does not exist at the site, a statement identifying that there is not a flood hazard should be included on the project plans.

### SAFE ROOMS AND TSUNAMI HAZARDS

Tsunami hazards may exist in some jurisdictions where safe rooms are designed and constructed to provide protection from hurricanes. Flood Insurance Rate Maps (FIRMs) will exist for these areas, but tsunami inundation maps may or may not.

The tsunami hazard in the U.S. is the greatest along the coasts in Washington, Oregon, California, Alaska, and Hawaii, and along the coasts of the U.S. territories in the Caribbean. Most areas considered to have a high tsunami risk have been studied, and tsunami inundation areas associated with the credible worst-case scenario have been mapped. These maps were prepared as part of the National Tsunami Hazard Mitigation Program (NTHMP) in cooperation with affected states and communities. FEMA has also recently started to evaluate tsunami hazards through its Map Modernization Program, by performing Probabilistic Tsunami Hazard Assessments (PTHAs). Currently, FEMA's Tsunami Pilot Study Working Group is developing a methodology that identifies relevant tsunami events and then maps the corresponding 500-year inundation area and tsunami elevations.

Until a unified set of tsunami hazard maps is available, FEMA recommends that the existing maps be used to identify the extents of the tsunami hazard in a given jurisdiction. Once a tsunami hazard has been identified to exist, FEMA recommends that both community and residential safe rooms be constructed outside of tsunami inundation areas. This is similar to the approach used for the flood design criteria in this Section 3.6, which recommends that safe rooms not be sited in Velocity (V) Zones shown on FIRMs or in storm surge inundation zones shown on Sea, Lake, and Overland Surges from Hurricanes (SLOSH) maps.

For additional information on the mapping of tsunami inundation zones, see the NTHMP web site at http://nthmp.tsunami.gov/. For additional information on the design and construction of structures in tsunami inundation areas, see FEMA P646, *Guidelines for the Design of Structures for Vertical Evacuation from Tsunamis* (June 2008), available at http://www.atcouncil.org/atc64.shtml.

## 3.6.1 Flood Design Criteria for Community Safe Rooms

Flood hazards should be considered when designing a community safe room. Flood loads acting on a structure containing a safe room will be strongly influenced by the location of the structure relative to the flood source. It is for this reason that safe rooms should be located <u>outside</u> of the following high-risk flood hazard areas:

a. The Coastal High Hazard Area (VE zones) or other areas known to be subject to high-velocity wave action; or

b. Areas seaward of the Limit of Moderate Wave Action (LiMWA) where mapped, also referred to as the Coastal A Zone in ASCE 24-05; or

c. Floodways.

Structures containing community safe rooms should be located in areas at low risk to flooding and mapped as unshaded Zone X or Zone C (outside the 500-year [0.2 percent annual change] floodplain) wherever possible. Where not possible, the structures should be located in the least hazardous portion of the area subject to flooding during the 0.2 percent annual chance flood (shaded Zone X or Zone B), or if that is not possible, then in the least hazardous portions of the 1 percent annual chance floodplain (i.e., within SFHA, Zones AO or AH, or Zones AE or A1-30). Siting of structures containing safe rooms in SFHAs is not a desirable option, and should be avoided except in special circumstances where consultation with local and state emergency management officials and with FEMA concludes there is no other feasible option.

For the purposes of this guidance, the lowest floor used for safe room space and/or safe room support areas should be elevated to the higher of the following elevations, which should be used as the design flood elevation (DFE) for flood load calculations:

1. Two feet above the base flood elevation (BFE), i.e., 2 feet above the flood elevation having a 1 percent annual chance of being equaled or exceeded in any given year (100-year event); or

2. The stillwater flood elevation associated with the 0.2 percent annual chance of being equaled or exceed in any given year (500-year event); or

3. The lowest floor elevation required by the community's floodplain ordinance, if such ordinance exists; or

4. Two feet above the highest recorded flood elevation in an area, if the area is designated as Zone D on a FIRM or Flood Hazard Boundary Map, or if the area has not been evaluated as part of a NFIP flood study (or equivalent flood study); or

5. If the community safe room is in an area subject to coastal storm surge inundation:

    a. The maximum stillwater inundation elevation associated with a Category 5 hurricane

    b. The wave crest elevation having a 0.2 percent annual chance of being equaled or exceeded in any given year.

> In areas where Category 5 storm surges are not mapped, references in this document to "Category 5" storm surge inundation area should be taken to mean the area inundated by the highest storm surge category mapped. See Chapter 10, References, for a list of some web sites that provide state-specific storm surge inundation maps.

**DEFINITION**

In this publication, the term **storm surge** means an abnormal rise in sea level accompanying a hurricane or other intense storm, and whose height is the difference between the observed level of the sea surface and the level that would have occurred in the absence of the cyclone. Storm surge (see Figure 3-3) is usually estimated by subtracting the normal or astronomic high tide from the observed storm tide.

Safe rooms subject to flooding, including any foundation or building component supporting the safe room, should be designed in accordance with the provisions of this chapter, ASCE 7-05, Section 5, and ASCE 24-05.

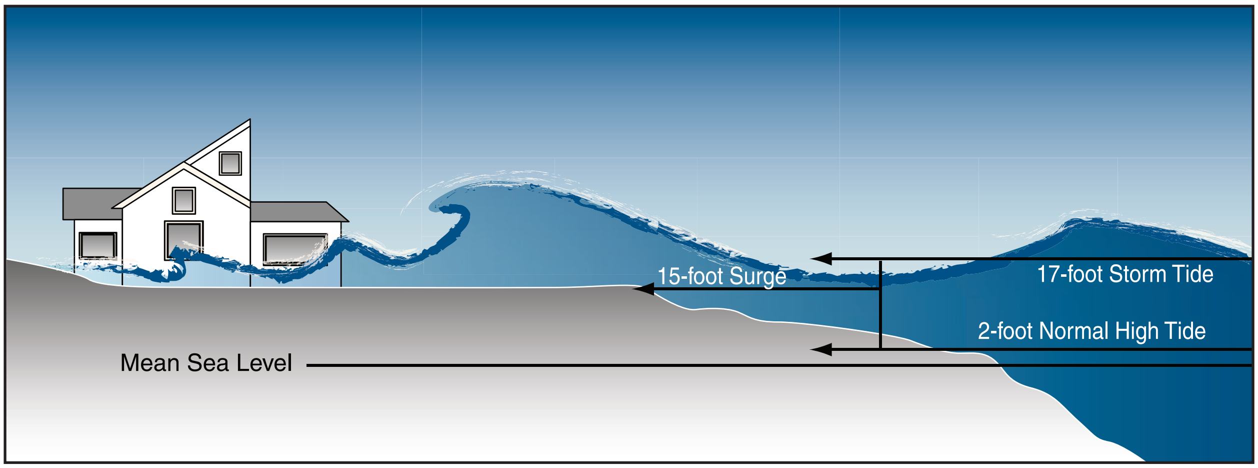


Figure 3-3. Storm surge

When at all possible, a community safe room should be located outside the influence of coastal storm surge and outside of any areas subject to flooding. When a safe room is installed in a Special Flood Hazard Area (SFHA) or other flood-prone area, the top of lowest floor for the safe room should be elevated at or above the highest flood elevation defined in Section 3.6.1.

## 3.6.2 Flood Design Criteria for Residential Safe Rooms

Flood hazards should be considered when designing and constructing a residential safe room. A tornado or hurricane residential safe room should be located outside of the high-risk flood hazard areas listed in this section. If the safe room needs to be located within the SFHA, the lowest floor of the safe room should be elevated to the highest of flood hazard elevations identified in this section.

Flood loads and conditions acting on a structure containing a safe room will be strongly influenced by the location of the structure relative to the flood source. It is for this reason that residential safe rooms should be located outside of the following high-risk flood hazard areas:

a. The Coastal High Hazard Area (VE zones) or other areas known to be subject to high-velocity wave action; or

b. Areas seaward of the LiMWA where mapped, also referred to as the Coastal A Zone in ASCE 24-05; or

c. Floodways; or

d. Areas subject to coastal storm surge inundation associated with a Category 5 hurricane (where applicable, these areas should be mapped areas studied by the U.S. Army Corps of Engineers [USACE], NOAA, or other qualified source).

> In areas where Category 5 storm surges are not mapped, references in this document to "Category 5" storm surge inundation area should be taken to mean the area inundated by the highest storm surge category mapped. See Chapter 10, References, for a list of some web sites that provide state-specific storm surge inundation maps.

A residential safe room, as prescribed in FEMA 320 or designed to the criteria presented in Section 3.5.2, should not be located within the SFHA if at all possible. If it is not possible to install or place a residential safe room outside the SFHA, the residential safe room should be placed outside of the high hazard areas identified above and the top of the elevated floor of the safe room should be design and constructed to the highest of the elevations specified below based on the Flood Insurance Study (FIS) or FIRM. It is important to note, if the residential safe room plans from FEMA 320 are used, the designs are restricted by a maximum allowable height above grade as specified on the drawing sheets; for a maximum elevation above existing grade of 3 to 5 feet. The elevations that should be considered when designing the safe room are the highest of:

1. The minimum elevation of the lowest floor required by the floodplain ordinance of the community (if such ordinance exists); or

2. Two feet above the BFE, (i.e., 2 feet above the flood elevation having a 1 percent annual chance of being equaled or exceeded in any given year [100-year event]); or

3. The stillwater flood elevation associated with the 0.2 percent annual chance of being equaled or exceed in any given year (500-year event).

   **Residential Tornado Safe Room Exception:** Where a residential tornado safe room is located outside of the hurricane-prone region as identified on Figure 3-2, and the community participates in the NFIP, the safe room need only be elevated to the minimum lowest floor elevation identified by the floodplain ordinance of the community.

Note, when installing a residential safe room in an area that has not been mapped or studied as part of a NFIP flood study (or equivalent flood study), the top of the safe room floor should be elevated such that it is 2 feet above the flood elevation corresponding to the highest recorded flood elevation in the area that has not been evaluated. Should no historical flood elevation data be available for the area, the elevation of the safe room floor should be set at the elevation identified by the local authority having jurisdiction.

## 3.7 Product Testing

The design of safe rooms to resist wind forces and wind loads can be accomplished and completed by a design professional using the processes presented in ASCE 7-05 as modified in this publication or approved through laboratory testing. However, to show that the safe room provides life-safety protection against flying debris, all wall and roof assemblies, window and door assemblies, and exterior cladding (envelope) systems should successfully pass the debris impact-resistance product testing. In addition, since all openings in the safe room envelope should be protected by doors, windows, opening protective devices complying with wind pressure and debris impact-resistant criteria described in Sections 3.3, 3.4, and 3.5, these systems should also be tested and approved. Alternatively, baffles or walls to prevent windborne debris from entering the protected occupant area of the safe room complying with the design criteria of Sections 3.3, 3.4, and 3.5 should also be considered acceptable if testing shows they meet the design criteria specified in this document.

**ICC-500 CROSS-REFERENCE**

The safe room performance criteria for debris impact-resistance and product testing presented in this section of FEMA 361 are the same as the shelter design criteria presented in the ICC-500 Storm Shelter Standard Sections 305, 306, and Chapter 8, Test Method for Impact and Pressure Testing.

All safe rooms and components that protect the occupants from wind and windborne debris should be designed and tested to resist wind pressures and a breach from debris impact in accordance with the Test Method for Impact and Pressure Testing in Chapter 8 of the ICC-500. The hazard criteria specified for the impact and pressure testing of safe room components have been described in the tornado community safe room debris impact criteria of Section 3.3.2, the hurricane community safe room debris impact criteria of Section 3.4.2, and the residential safe room debris impact criteria of Section 3.5.2.

Once testing has been completed, documentation should be maintained and provided to the AHJ where the safe room is being constructed. It is important to note that DHS and FEMA are not product testing agencies and do not “certify” or lend their authority to any group to produce or provide “FEMA approved” or “FEMA certified” products. The means by which product testing and compliance with the FEMA criteria is documented and presented will be addressed later in this chapter. FEMA supports the statement in Section 306.1 of ICC-500 not to require additional testing of assemblies and products for different levels of debris impact, if the most stringent criteria of missile size and speed are met. The ICC-500 states:

> ***306.1 Shelters meeting tornado impact test requirements.*** *Shelter envelope components meeting missile impact test requirements for tornado shelters shall be considered acceptable for hurricane shelters provided they meet structural design load requirements for hurricane shelters.*

## 3.8 Permitting, Code Compliance, Professional Design Oversight, and Peer Review

This section clarifies the permitting, compliance, and involvement of the design professional in the safe room permitting design process. Where safe rooms are designated areas normally occupied for other purposes, the requirements of the applicable construction codes for the occupancy of the building should apply unless otherwise stated in this publication.

However, where a facility is designed to be occupied solely as a safe room, the designated occupancy should be Assembly 3 (A-3) as defined by the IBC for purposes of determination of applicable requirements that are not included in this publication or the ICC-500. Where the construction of a safe room is to take place in jurisdictions where no applicable codes exist, the provisions of the International Code Council *2006 International Building Code* should apply.

**ICC-500 CROSS-REFERENCE**

The safe room recommendations for permitting, code compliance, and design oversight presented in this section of FEMA 361 are the same as the requirements for permitting, code compliance, and design oversight presented in the ICC-500 Storm Shelter Standard.

### 3.8.1 Permitting and Code Compliance

Before construction begins, all necessary state and local building and other permits should be obtained. The design professional should meet with the local code official to discuss any concerns the building official may have regarding the design of the safe room. This meeting will help ensure that the safe room is properly designed and constructed to local ordinances or codes. As of 2008, no model building codes address the design of a tornado or hurricane safe room. The only way the design and construction of safe rooms or shelters is addressed is if the AHJ has adopted FEMA 361 or the ICC-500 as a design standard for shelters. This will change if jurisdictions adopt the 2009 Editions of the IBC and IRC that will incorporate the ICC-500 standard by reference, unless the AHJ explicitly removes the referencing text from the code language during the code adoption process.

Complete detailed plans and specifications should be provided to the building official for each safe room design. The design parameters used in the structural design of the safe room, as well as all life-safety, Americans with Disabilities Act (ADA), mechanical, electrical, and plumbing recommendations that were addressed, should be presented on the project plans and in the project specifications (see Section 3.8 for additional information on documentation of safe room information on project plans).

> The reader should be aware of descriptors and modifiers in the text of both this publication and the ICC-500 that state the code and standard requirements are applicable to the design of community safe rooms meeting FEMA's design criteria. The omission of the residential safe room is not an oversight but rather an exception to these requirements such that these items are not required for the residential safe room or the construction documents associated with the residential safe room.

Egress recommendations should be based on the maximum occupancy of the safe room as defined by Sections 3.3.1, 3.4.1, and 3.5.1, depending upon the hazard and use of the safe room. This will likely occur when the designer calculates the occupancy load based on the 5 square feet or 10 square feet per person recommended in Sections 3.3.1 and 3.4.1 for tornado and hurricane safe rooms, respectively. For multi-use safe rooms, reaching the maximum occupancy may be a rare event. For life-safety considerations, egress points for the safe room area should be designed to the maximum possible occupancy until the criteria in this publication or in the ICC-500 governing the design of safe rooms or shelters have been adopted to govern safe room design in that particular jurisdiction. As a result, the design professional will likely have difficulty providing doors and egress points with hardware (specifically latching mechanisms) that comply with code and resist the design missile impact criteria presented earlier in this chapter. Design professionals who are limited to door hardware that is acceptable to the building official but that does not meet the impact-resistance criteria should refer to Table 7-2 and also Section 7.4 for guidance on the use of missile-resistant barriers to protect doors from debris impact.

Regarding code requirements not related to life-safety or structural requirements (typically those for mechanical, electrical, and plumbing systems), the designer should design for the normal use of a multi-use safe room unless otherwise directed by the AHJ. It would not be reasonable to consider the additional cost of and need for providing additional mechanical, electrical, and plumbing equipment and facilities for the high-occupancy load that would occur only when the safe room is providing protection from a tornado or hurricane. Safe rooms designed to the criteria in this manual are for short-duration use, and the probability of their use at maximum occupancy is low.

### 3.8.2 Professional Design Oversight

The building owner should employ a registered design professional during the construction of a community safe room. The task for the design professional, is to conduct visual observations of the construction of the structural system for general conformance to the approved construction documents at significant construction stages and at completion of the construction of the structural system. Structural observation should not obviate the need for other inspections or testing as specified by this publication, the ICC-500, or the applicable building code.

Deficiencies should be reported in writing to the owner and to the authority having jurisdiction. At the conclusion of the work, the registered design professional who made the structural observations should submit to the AHJ a written statement that the site visits have been made and identify any reported deficiencies that, to the best of the structural observer's knowledge, have not been resolved.

**ICC-500 CROSS-REFERENCE**

The safe room criteria for Peer Review of Safe Room Designs in this section of FEMA 361 are more stringent than the Peer Review criteria presented in the ICC-500 Storm Shelter Standard Sections 305, 306, and Chapter 8, Test Method for Impact and Pressure Testing.

### 3.8.3 Peer Review

Construction documents for community safe rooms designed for more than 50 occupants should undergo a peer review by an independent registered design professional for conformance with the design criteria of this chapter. This peer review should focus on the structural and non-structural design of elements that provide life-safety protection for the occupants of the safe room. The design professional performing the peer review may be the same design professional who provides design oversight as recommended in Section 3.8.2.

## 3.9 Construction Documents, Signage Criteria, and Labeling

This section provides the criteria that should be adhered to when documenting the design criteria on project plans or within the safe room itself. The location of the safe room, the design criteria for the safe room, the product testing information, and similar information should be clearly identified on the project plans or construction documents. In addition, all safe rooms should have a label clearly identifying it as a safe room designed to provide life-safety protection to its occupants at a specified performance level; this is referred to as signage.

**ICC-500 CROSS-REFERENCE**

The safe room recommendations for construction documents, signage, and labeling presented in this section of FEMA 361 are the same as the construction documents, signage, and labeling presented in the ICC-500 Storm Shelter Standard.

### 3.9.1 Construction Documents

Although not all jurisdictions require detailed construction documents, compliance with the FEMA criteria presented in this publication requires that construction documents should be prepared and maintained. Such documents should contain information as required by the applicable building code, the authority having jurisdiction, and this section.

The following information applicable to construction and operation of the safe room should be supplied on the construction documents:

a) **Safe Room Design Information.** The area being designated for use as a safe room should be clearly identified on the construction documents. In addition, the following information should be provided for these areas, as part of the construction documentation:

1. A floor plan drawing or image representing the entire facility indicating the location of the safe room on a site or within a building or facility.
2. A statement that the wind design conforms to the provisions of the FEMA 361, *Design and Construction Guidance for Community Safe Rooms*, with the edition year specified.
3. The safe room design wind speed, mph.
4. The importance factor, I.
5. The wind exposure *category (indicate all if more than one is used)*.
6. The internal pressure coefficient, $GC_{pi}$.
7. The topographic factor $K_{zt}$.
8. The directionality factor $K_d$.
9. A statement that the safe room has/has not been constructed within an area susceptible to flooding in accordance with Chapter 3 of this publication.
10. Documentation showing that components of the safe room envelope will meet the missile impact and pressure test recommendations identified in Chapter 3 of this publication and Chapter 8 of the ICC-500 Storm Shelter Standard.
11. The occupancy load of the safe room.
12. The usable safe room floor area.
13. Venting area (sq. in.) provided locations in the safe room.
14. If applicable, the designer should document the flood hazard at the site and the design elevation used for the safe room (per Section 3.6).
15. The lowest floor elevation (and corresponding datum) of the structure containing the safe room, the lowest floor elevation of the safe room floor, and the lowest floor or a room or space that houses any mechanical, electrical, or support equipment that is needed for the operation of the safe room.

b) **Enclosure.** When a safe room is to be constructed as a portion of a host building, the walls and floors enclosing the safe room should be clearly indicated on the drawings.

c) **Signage.** The type and location of signs recommendations by this publication should be indicated on the floor plans.

d) **Inspections.** Where any special details are utilized in the design of the structure, or where any special investigations are recommended that are in addition to those required by the applicable building code, the construction documents should contain a schedule of the inspections recommended and the criteria for the special installation.

e) **Special Details.** The construction documents should provide any special manufacturer's details or installation instructions for systems or equipment designed for the safe room.

f) **Special Instructions.** The construction documents should contain details of special instructions recommended for the specified functional operation of the safe room, such as:

1. Type and location of equipment and amenities provided within the safe room, including water supply, sanitary facilities, fire extinguishers, batteries, flashlights, special emergency lighting equipment, or any other equipment recommended to be installed in the safe room.

2. Specifications for any alarm system to be installed.

3. Instructions for the installation or deployment of any special protection equipment, such as shutters, screens, special latching of doors or windows, any equipment or switching for mechanical, electrical and plumbing equipment.

### 3.9.2 Signage Criteria and Labeling

All safe rooms should have a sign outside or inside the safe room with the name of the manufacturer or builder of the safe room, its purpose (i.e., the storm type), and safe room design wind speed. The sign should remain legible and visible. Further, any products, materials, or systems specified for occupant protection should be labeled by the agency that approved them when called for by the applicable publication (such as this document), standard (such as the ICC-500), or the local building code.

## 3.10 Quality Assurance/Quality Control and Special Inspections

Because a tornado or hurricane safe room should perform well during extreme conditions, quality assurance and quality control (QA/QC) for the design and construction of the safe room should be at a level above that for normal building construction. Design calculations and shop drawings should be thoroughly scrutinized for accuracy. When the design team is satisfied that the design of the safe room is acceptable, a registered design professional should prepare the quality assurance plan for the construction of the safe room. The construction documents for any tornado or hurricane community safe room should contain a quality assurance plan as defined in Sections 3.10.1 through 3.10.3.

### 3.10.1 Detailed Quality Assurance/Quality Control Recommendations

The quality assurance plan should be based on the Special Inspection Requirements listed in Sections 1704, 1705, and 1706 of the IBC; however, because of the design wind speeds involved, exceptions that waive the need for quality assurance when elements are prefabricated should not be allowed. The IBC recommends using these special inspections and quality assurance program when the design wind speeds are in excess of 110 to 120 mph (3-second gust), depending on exposure or if the building is in a high seismic hazard area. Sufficient information to ensure that the safe room is built in accordance with the design and performance criteria of this manual should be provided by the design professional. The quality of both construction materials and methods should be ensured through the development and application of a quality control program.

A quality assurance plan should be provided for the following:

a) Roof cladding and roof framing connections

b) Wall connections to roof and floor diaphragms and framing

c) Roof and floor diaphragm systems, including connectors, drag struts, and boundary elements

d) Main wind force resisting systems, including braced frames, moment frames, and shear walls

e) Main wind force resisting system connections to the foundation

f) Fabrication and installation of components and assemblies of the safe room envelope recommended to meet missile impact test recommendations of this chapter

g) Recommendations for components and cladding, including soffits

h) Corrosion resistance or protection of metal connectors exposed to the elements that provide load path continuity

i) Recommendations for critical support systems connections and debris impact-protection of the components and connections

### 3.10.2 Quality Assurance Plan Preparation

The design of each main wind force resisting system and each wind-resisting component should include a quality assurance plan prepared by a registered design professional. The quality assurance plan should identify the following:

a) The main wind force resisting systems and wind-resisting components

b) The special inspections and testing to be required in accordance with Section 106.2 of the ICC-500

c) The type and frequency of testing to be performed

d) The type and frequency of special inspections to be performed

e) The structural observations to be performed in accordance with Section 106.4 of the ICC-500

f) The distribution, type, and frequency of reports of test, inspections, and structural observations to be prepared and maintained

### 3.10.3 Contractor's Responsibility

Each contractor responsible for the construction of a MWFRS or any component listed in the quality assurance plan should submit a written statement of responsibility to the authority having jurisdiction, the responsible design professional, and owner prior to the commencement of work on the system or component. The contractor's statement of responsibility should contain:

a) Acknowledgement of awareness of the special criteria contained in the quality assurance plan

b) Acknowledgement that control will be exercised to obtain conformance with the construction documents

c) Procedures for exercising control within the contractor's organization, and the method and frequency of reporting and the distribution of reports

d) Identification and qualifications of the person(s) exercising such control and their position(s) in the organization

**Exception:** Prefabricated or panelized safe room components that have been inspected and labeled by an approved agency meeting the requirements of the applicable building code.

### 3.10.4 Special Inspections and Acceptance

The construction of safe rooms and installation of all equipment should be subject to inspections in accordance with the applicable building code. Special inspections should be provided for construction and installation of materials as required by the applicable building code, and when the proposed work comprises:

a) Construction materials and systems that are alternatives to traditional materials and systems prescribed by the applicable code

b) Unusual design and construction applications

In addition, where fabrication of structural load-bearing and debris impact-resistant components and assemblies is being performed on the premises of a fabricator, a special inspection of the fabricator's shop should be performed. However, this inspection may be waived if the prefabricated or panelized safe room components have been inspected and labeled by an approved agency that meets the requirements of the applicable building code.