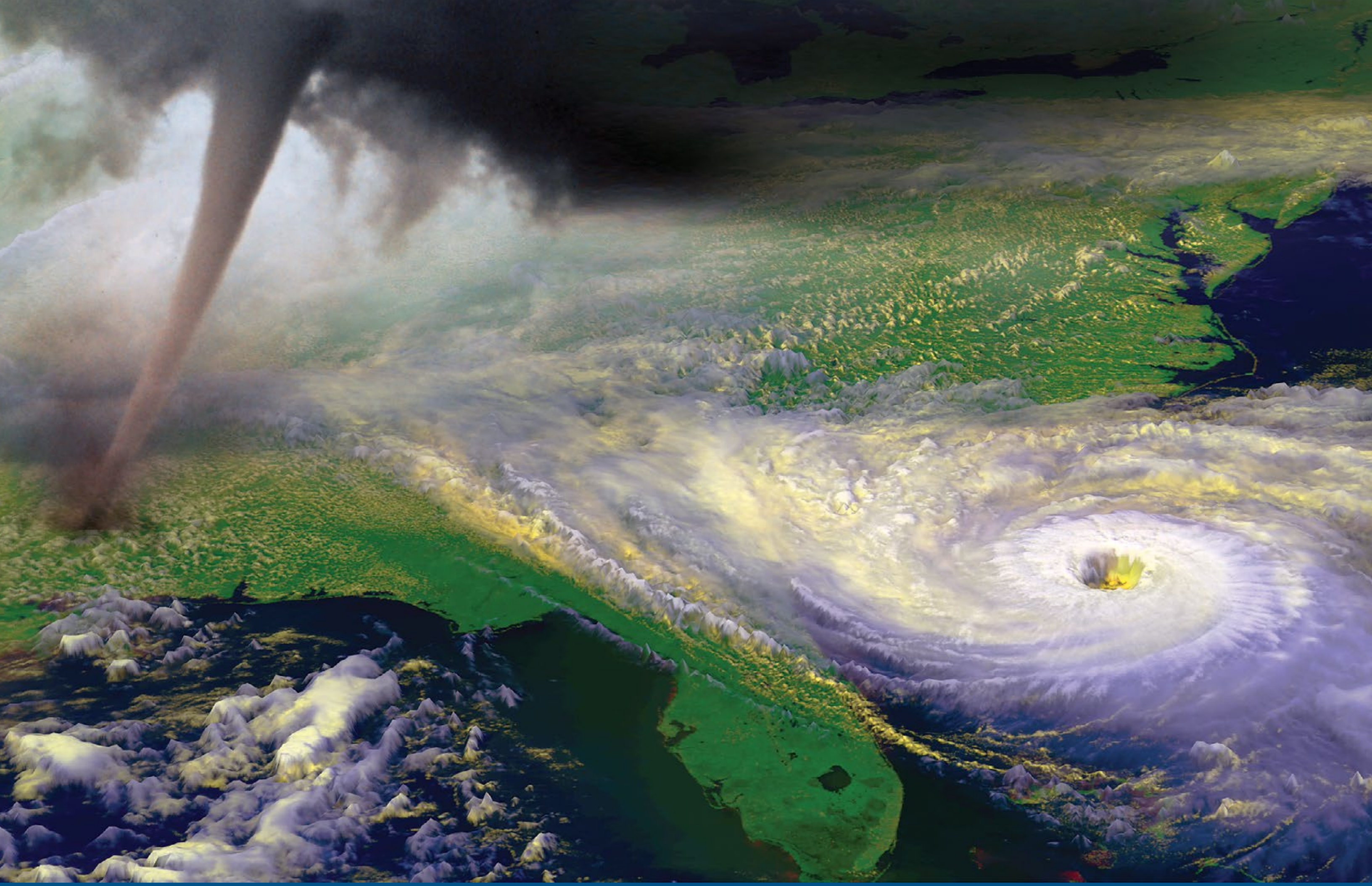

Safe Rooms for Tornadoes and Hurricanes

Guidance for Community and Residential Safe Rooms

FEMA P-361, Third Edition / March 2015

U.S. Department of Homeland Security FEMA

Safe Rooms for Tornadoes and Hurricanes

Guidance for Community and Residential Safe Rooms

FEMA P-361, Third Edition / March 2015

FEMA

Preface

Federal Emergency Management Agency (FEMA) publications presenting design and construction guidance for both residential and community safe rooms have been available since 1998. Since that time, thousands of safe rooms have been built, and a growing number of these safe rooms have already saved lives in actual events. There has not been a single reported failure of a safe room constructed to FEMA criteria.

Nevertheless, FEMA has modified its Recommended Criteria as a result of post-disaster investigations into the performance of safe rooms and storm shelters after tornadoes and hurricanes. Further, FEMA's changes also consider the 2014 update to the consensus standard from the International Code Council® (ICC®) and the National Storm Shelter Association (NSSA®), the *ICC/NSSA Standard for the Design and Construction of Storm Shelters* (ICC 500).

This third edition of FEMA P-361 presents updated and refined criteria for safe rooms compared to the second edition's 2008 criteria. The criteria presented in this publication address how to design and construct a safe room that provides near-absolute protection from wind and wind-borne debris for occupants.

FEMA continues to support the development of consensus codes and standards that establish minimum acceptable requirements for the design and construction of hazard-resistant buildings. FEMA also supported and participated in the development of the original ICC 500 and the 2014 edition. Although the ICC 500 took much of what was presented in the first edition of FEMA P-361 and updated and codified it through the consensus standard process, some differences remain between the two documents. The differences between criteria are described at the beginning of each chapter of Part B of this publication. There are also differences in scope; for example, FEMA P-361 includes emergency management considerations and risk assessment commentary that are beyond the scope of ICC 500.

When safe room designers, operators, and emergency managers implement FEMA's Recommended Criteria in their projects, they can feel confident that they are using the best available information to guide the design and construction of a safe room (public or private) that provides near-absolute protection from the deadly winds and wind-borne debris associated with extreme-wind events. Additionally, if the safe room is being constructed with FEMA grant funds, adherence to the FEMA Recommended Criteria described in Part B of this publication is required.

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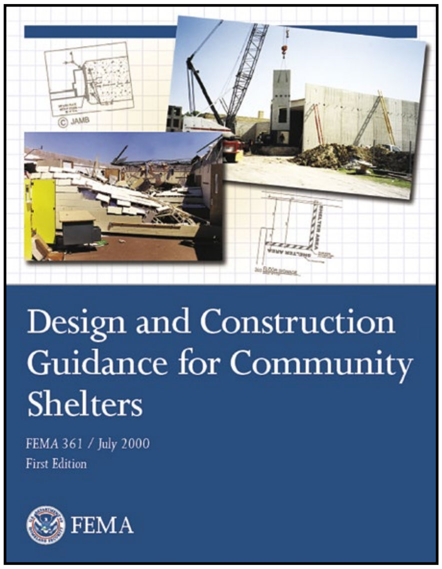
Introduction to FEMA P-361

This publication provides guidance from the Federal Emergency Management Agency (FEMA) about the planning, design, construction, and operation of safe rooms. It presents important information about the design and construction of residential and community safe rooms that will protect people during extreme-wind events such as tornadoes and hurricanes.

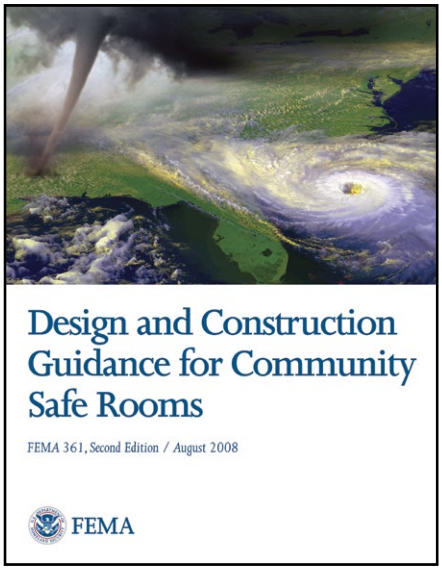
The guidance in FEMA P-361 is intended for architects, engineers, building officials, local officials and emergency managers, and prospective safe room owners and operators. FEMA P-361 was first published in 2000, and a second edition was released in 2008.

Since the second edition of FEMA P-361 was published, several significant tornado and hurricane events have occurred, considerable research has been conducted, and the ICC® has released a consensus standard to codify the design and construction requirements of extreme-wind storm shelters. This standard, the *Standard for the Design and Construction of Storm Shelters*, is known as ICC 500 and was produced by ICC in cooperation with the NSSA®. The 2000 edition of FEMA P-361 served as a legacy document for the development of ICC 500. The ICC 500 was completed in 2008 and recently updated in 2014.

This edition of FEMA P-361 is presented in two parts: Part A and Part B.



FEMA 361 (2000)



FEMA 361 (2008)

Note

FEMA P-361
SECOND EDITION VS THIRD EDITION

The most apparent difference between this edition of FEMA P-361 and the second edition is that this edition is rearranged so the chapter order and content of Part B are in sequence with the first eight chapters of ICC 500. The third edition of FEMA P-361 also features clarified guidance and revised commentary to reflect 6 more years of post-damage assessments and lessons learned, including those based on many safe rooms directly impacted by tornadoes.

Part A Content and Organization

Part A presents information that safe room designers, owners, and emergency management officials may find useful in planning, designing, and operating a safe room. Information includes FEMA's guidance and recommendations related to safe room design and construction oversight, risk assessment and analysis, costs, and benefit-cost analysis (BCA); also included are operation and maintenance (O&M) considerations for community safe rooms. Specific content consists of the following topics:

- Purpose and Background (Chapter A1)
- Extreme-Wind Risk Assessment and Analysis (Chapter A2)
- Costs and Benefit-Cost Analysis (Chapter A3)
- Operation and Maintenance Considerations for Community Safe Rooms (Chapter A4)

Part B Content and Organization

Part B consists of eight chapters that correspond to the chapters of ICC 500 (2014), the referenced standard for each topic area. Each chapter presents a comparison of the ICC 500 requirements with FEMA Recommended Criteria that should be adopted to maximize life-safety protection, and supplemental FEMA commentary.

FEMA Recommended Criteria and Supplemental Commentary

Safe rooms should be designed and constructed in accordance with the provisions of ICC 500. In addition, FEMA provides Recommended Criteria that are more conservative than code and standard minimum requirements. Based on field investigation and research, FEMA believes these Recommended Criteria are necessary to provide near-absolute protection during extreme-wind events. Part B Chapters (aside from B2, Definitions) of this publication begin by describing any FEMA Recommended Criteria that exceed the requirements found in the corresponding chapter of the 2014 version of the ICC 500.

Safe rooms constructed with FEMA grant funds are required to adhere to FEMA Recommended Criteria described at the beginning of Part B chapters as well as the corresponding ICC 500 requirements.

The supplemental commentary provides background information on provisions addressed in the corresponding chapter of ICC 500 where applicable. Additionally, the supplementary commentary explains best practice considerations that are not listed as FEMA Recommended Criteria and, in some cases, describes the justification for listed criteria.

Organization

Part B includes the following chapters, which follow the nomenclature and general content of Chapters 1 through 8 of ICC 500:

- Application and Administration (Chapter B1)
- Definitions (Chapter B2)
- Structural Design (Chapter B3)
- Siting (Chapter B4)
- Occupancy, Means of Egress, Access, and Accessibility (Chapter B5)
- Fire Safety (Chapter B6)
- Essential Features and Accessories (Chapter B7)
- Test Methods for Impact and Pressure Testing (Chapter B8)
- References and Resources (Chapter B9)

Appendices

Appendices include:

- Acronyms (Appendix A)
- Acknowledgments (Appendix B)
- Designer Checklist (Appendix C)
- Comparison Matrix of Differences between ICC 500 Requirements and FEMA Recommended Criteria (Appendix D)

Part A

CHAPTER A1
Purpose and Background

Tornadoes and hurricanes are among the most destructive forces of nature. Unfortunately, these types of wind storms continue to cause injury and death to people who are unable to safely evacuate or find shelter from these events. FEMA has long supported the development of hazard-resistant codes and standards by assessing how structures respond in a disaster. Assessment conclusions and recommendations are applied through active participation in the process of creating and developing building codes and standards, including the *Standard for the Design and Construction of Storm Shelters,* known as ICC 500.

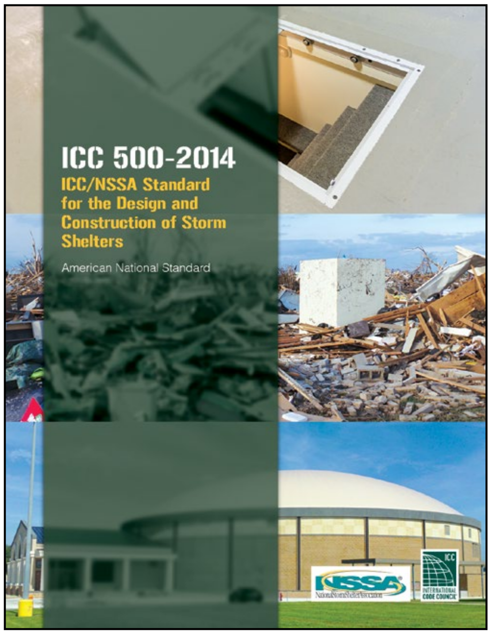


Figure A1-1. ICC 500 (2014)

This third edition of FEMA P-361 references much of the design criteria of the 2014 edition of the ICC 500 with some exceptions, all of which are identified at the beginning of Chapters B1 through B8 in Part B of this publication, and summarized in Table D-1 (Appendix D). The ICC 500 is referenced in the 2009, 2012, and 2015 International Building Code® (IBC®) and International Residential Code® (IRC®), and is therefore part of the building code (incorporated by reference) as a readily enforceable design standard. The best practices and Recommended Criteria described in FEMA P-361 are guidance; they are not code or standard enforceable in a jurisdiction unless they have been adopted as a standard for tornado or hurricane safe rooms. This publication supersedes the FEMA *National Performance Criteria for Tornado Shelters,* 1999, as well as all earlier versions of FEMA P-361.

Note

THE DEVASTATION OF TORNADOES

The National Weather Service did not start keeping organized records of tornadoes in the United States until 1950. Since then, the deadliest year for tornadoes was 2011, which claimed 553 lives. The single deadliest tornado to date was in Joplin, MO, on May 22, 2011, with 161 fatalities.

Compared with hurricanes and earthquakes, single tornado events typically affect smaller geographical areas but occur more often and cause more deaths. From 1950 through 2011, tornadoes caused about 5,600 fatalities in the United States, more than hurricanes and earthquakes combined over the same time period (NIST 2014).

This photograph taken by FEMA on February 5, 2008, in Lafayette, TN shows the vivid reality of how lives are impacted by tornadoes.
(SOURCE: JOCELYN AUGUSTINO/FEMA)

A1.1 Purpose

The primary purpose of FEMA P-361 is to provide guidance on best practices related to the design, construction, and operation of community and residential safe rooms. Specifically, this publication describes the criteria for any safe room, private or public, to be constructed so that it is capable of providing near-absolute protection for its occupants during tornadoes and hurricanes.

FEMA P-361 presents Recommended Criteria and emergency management considerations for following best practices that are consistent with and, in some cases, more conservative than the corresponding ICC 500 requirements. Safe rooms being constructed with FEMA grant funds must comply with ICC 500 requirements, the corresponding FEMA recommendations described in Part B of this publication, and the Rehabilitation Act of 1973, as amended, including Section 504, Programs, Services and Activities (29 U.S.C. § 794). Federal agencies and those receiving Federal assistance must ensure that their programs are usable and accessible to persons with disabilities (see Section B5.2.1.4).

FEMA P-361 provides guidance on the planning and engineering issues for design and construction of stand-alone safe room buildings, constructing safe rooms within a new building, and adding a safe room to an existing building. The guidance in this publication builds on knowledge gained through field investigations and research, represented in FEMA's technical reports and publications, as well as information from other national and State agencies and universities that have studied the performance of the built environment during tornadoes and hurricanes. More history related to the development of this publication is provided on the FEMA safe room website, "FEMA P-361 History and Relevant FEMA Building Science Activities," at www.fema.gov/fema-p-361-history-and-relevant-fema-building-science-activities.

Note

FEMA P-361 RECOMMENDED CRITERIA

If safe rooms are constructed with FEMA funds, the design must comply with the FEMA Recommended Criteria described in Part B of this publication. FEMA's criteria were developed to provide near-absolute protection for safe room occupants. Refer to "Recognized Design Standards" in the latest edition of Hazard Mitigation Assistance (HMA) Unified Guidance for the most current FEMA policy statement on safe room implementation.

See: www.fema.gov/hazard-mitigation-assistance.

This third edition of FEMA P-361 includes the ICC 500 requirements, but also identifies the specific technical criteria for which the FEMA guidance exceeds the minimum requirements of the ICC 500. This approach is consistent with past FEMA guidance publications. FEMA publications provide guidance on best practices that are above and beyond the minimum criteria and scope of the consensus codes and standards for design and construction of structures to resist natural and manmade hazards where knowledge or science justify those practices. FEMA guidance publications also address emergency management considerations not covered in the codes and standards.

Some aspects of the planning necessary for very-high-occupancy safe rooms that may be required in large, public venues such as stadiums or amphitheaters are beyond the scope of this publication. Although an owner or operator of such a venue should follow the applicable requirements presented in this publication, detailed guidance for operational aspects concerning very-high-occupancy safe rooms is not provided. The design of such safe rooms requires attention to human factor engineering issues that affect the life safety of a large number of people. Egress timing for thousands of people in a stadium, how to manage a large group of individuals in a safe room, and security within a safe room are examples of human behavioral issues that should be addressed when protecting a large group of people.

A1.2 Background on FEMA Safe Room Design History and ICC Code Development

The first edition of FEMA P-361, released in July 2000, set forth comprehensive design and construction criteria for tornado and hurricane shelters. These criteria were used as the basis for the design and construction of many safe rooms funded by FEMA in communities across the Nation since 2000. The second edition, published in 2008, updated and expanded the recommendations by referencing much of ICC 500. This third edition of FEMA P-361 continues to provide guidance for the design and construction of tornado and hurricane safe rooms, and includes updates to incorporate code and standard changes (IBC, IRC, ASCE 7[1], and ICC 500) and lessons learned through post-disaster investigations since 2008.

A1.2.1 Development of FEMA Safe Room Guidance

When a hurricane, tornado, earthquake, or terrorist attack results in a catastrophic natural or manmade disaster of national significance in the United States or one of its territories, FEMA may deploy a technical building sciences team to document the performance of the built environment during the event. The objectives of these teams are to observe and assess the performance of buildings, evaluate design and construction practices, and evaluate building code requirements and enforcement in light of the observed building performance. The teams then make recommendations for improving building performance in future disasters. Post-disaster studies have been conducted since the early 1970s to determine design parameters for safe rooms intended to provide protection from tornadoes and hurricanes.

In 1998, using the results of research conducted by Texas Tech University's (TTU's) National Wind Institute (NWI),[2] FEMA developed construction plans for small in-residence safe rooms and prepared the publication, *Taking Shelter from the Storm: Building a Safe Room for Your Home or Small Business* (FEMA P-320). FEMA P-320 was subsequently updated in 1999, 2008, and 2014.

1 ASCE, *Minimum Design Loads for Buildings and Other Structures*

2 Formerly called the Wind Science and Engineering Research Center (WISE) and before that, the Wind Engineering Research Center.

Note

FEMA P-361 VS FEMA P-320

FEMA P-361 provides design and construction guidance for community and residential safe rooms primarily intended for registered design professionals, whereas FEMA P-320 (2014) provides residential and small business safe room guidance specifically aimed at homeowners, builders, and contractors, though it can also be used by registered design professionals and local officials. FEMA P-320 includes prescriptive site-built safe room design drawings developed using the design criteria presented in FEMA P-361.

A copy of FEMA P-320 may be downloaded from:
www.fema.gov/safe-room-resources/fema-p-320-taking-shelter-storm-building-safe-room-your-home-or-small-business.

A1.2.2 Development of ICC 500

Using the first edition of FEMA P-361 (2000) as guidance, the ICC, in partnership with FEMA and the NSSA, formed a national committee that developed and released a consensus standard to codify the design and construction requirements of tornado and hurricane shelters. This standard, the ICC 500, was completed in the summer of 2008 and updated in 2014.

Since 2009, the IBC and IRC have incorporated ICC 500 by reference to regulate the design and construction of buildings, or portions thereof, designated as storm shelters to provide life-safety protection from tornadoes and hurricanes. Under the 2009, 2012, and 2015 IBC and IRC, whenever storm shelters are constructed, whether stand alone or part of a structure, the ICC 500 standard must be met. In addition, Sections 423.3 and 423.4 of the 2015 IBC requires ICC 500 storm shelters to be incorporated when any of the following are constructed: K-12 school buildings with an occupant load of 50 or more; 911 call stations; fire, rescue, ambulance, and police stations; and emergency operation centers. The requirement applies only in the 250 mile per hour (mph) tornado wind speed zone (see Figure B3-1 for wind speed zone details), and some exceptions are allowed.

The purpose and scope of the ICC 500 are:

> **ICC 500, Section 101.1 Purpose.** The purpose of this standard is to establish minimum requirements to safeguard the public health, safety, and general welfare relative to the design, construction, and installation of storm shelters constructed for protection from high winds associated with tornadoes and hurricanes. This standard is intended for adoption by government agencies and organizations for use in conjunction with model codes to achieve uniformity in the technical design and construction of storm shelters.
>
> **ICC 500, Section 101.2 Scope.** This standard applies to the design, construction, installation, and inspection of storm shelters constructed for protection from high winds associated with tornadoes and hurricanes. Storm shelters may be separate detached buildings or rooms and areas within buildings. Shelters designed and constructed to this standard shall be designated as either hurricane shelters, tornado shelters, or combined hurricane and tornado shelters.

A1.2.3 ICC 500 Comparison with FEMA P-361

Although similar, FEMA P-361 and ICC 500 have important differences between the requirements and criteria described in each, as well as in the terminology used.

- The purpose and scope of ICC 500 is to establish minimum requirements for the design, construction, installation, and inspection of storm shelters that provide life safety.

- The purpose and scope of FEMA P-361 is to provide guidance—including emergency management considerations – for safe rooms that provide near-absolute protection.

Note

SAFE ROOMS AND STORM SHELTERS

FEMA defines "safe rooms" as buildings or portions thereof that comply with the criteria described in this publication.

ICC 500 defines "storm shelters" as buildings or portions thereof that comply with ICC 500.

Though similar, there are important differences. All safe room criteria in FEMA P-361 meet the storm shelter requirements of the ICC 500, but FEMA P-361 includes a few design and performance criteria that are more conservative than those in the ICC 500.

Refer to Section A1.3 for definitions and terminology.

From a technical standpoint, the ICC 500 successfully standardizes and codifies much of the design guidance provided in the 2000 edition of FEMA P-361. However, some of the criteria in FEMA P-361 were modified during the consensus process that produced the ICC 500. FEMA acknowledges the rationale behind some of the changes and has accepted the new criteria with some exceptions, all of which are described in Part B of this publication and summarized in Table D-1 in Appendix D.

FEMA regularly reviews its safe room design criteria and believes some issues related to the design wind speed for residential tornado safe rooms, flood hazards, and operating a safe room warrant a more conservative approach than the one agreed upon in the ICC 500 consensus standard process. FEMA's recommendations and best practices related to these topics are described in FEMA P-361. In addition to the technical differences between ICC 500 and FEMA P-361, users should note that FEMA P-361:

- Defines a safe room differently than ICC 500 defines a storm shelter (refer to text box above and Section A1.3)
- Includes best practices, while ICC 500 is a minimum standard
- Includes operational issues and concerns not addressed by ICC 500
- Includes guidance for emerging issues and concerns from lessons learned by FEMA from assessment conducted after extreme-wind events

A1.2.4 FEMA Safe Room Grant Funding Program

FEMA is committed to the development of design and construction criteria and guidance for safe rooms and continues to advocate designing and constructing safe rooms as evidenced by its continuing support of safe room initiatives through several grant programs.

As of January 2015, FEMA grant programs have provided approximately $984 million in Federal funds towards the design and construction of nearly 25,000 residential and 2,000 community safe rooms in 25 States and Territories.

Note

HMA UNIFIED GUIDANCE

The FEMA HMA Unified Guidance is updated periodically. For information on FEMA grant programs and safe room eligibility, download the most current policy HMA Unified Guidance from: www.fema.gov/hazard-mitigation-assistance.

A1.3 Safe Room Terminology

The terms "safe room" and "storm shelter" have been used interchangeably in past publications, guidance documents, and other shelter-related materials. However, to distinguish between shelters that meet the ICC 500 standard and those that meet the more stringent FEMA criteria for life-safety protection, this publication refers to all shelters constructed to meet the FEMA criteria (whether for individuals, residences, small businesses, schools, or communities) as safe rooms. All safe room criteria in this publication meet or exceed the storm shelter requirements of ICC 500. This section describes FEMA's safe room terminology and the different types of safe rooms.

A1.3.1 Terminology

FEMA has developed specific terminology to differentiate types of tornado refuge areas from other types of "shelters." An understanding of these specific terms and the historic guidance is important because the terms FEMA uses to describe sheltering options have slightly different meanings (see text box on terminology and Table A1-1). Furthermore, the term "shelter" is used in different ways by different agencies and entities. For instance, the American Red Cross uses the term "shelter" to refer to temporary recovery areas.

FEMA safe rooms

A safe room is an interior room, a space within a building, or an entirely separate building, designed and constructed to provide near absolute life-safety protection for its occupants from tornadoes or hurricanes. Safe rooms are designed and constructed to meet the criteria in this publication or the most current edition of FEMA P-320.

Our knowledge of tornadoes and hurricanes is based on substantial meteorological records as well as extensive investigation of damage from extreme winds. However, although it has not been observed, extreme-wind events may occur or could have occurred in the past that exceed the maximum design criteria in this publication. For this reason, the protection provided by these safe rooms is called near-absolute rather than absolute.

ICC storm shelters

Storm shelters provide life-safety protection; they are designed and constructed to meet ICC 500 criteria.

Best available refuge area

Best available refuge areas are areas in an existing building that have been deemed by a registered design professional to be least vulnerable to tornado damage. The existing building may or may not have been built to meet code. It is important to note that, because these areas were not specifically designed as tornado safe rooms, their occupants may be injured or killed during a tornado. However, people in best available refuge areas are less likely to be injured or killed than people in other areas of a building. Selection of these areas is described in FEMA P-431, *Tornado Protection: Selecting Refuge Areas in Buildings*.

TERMINOLOGY

Near-absolute protection: Based on our current knowledge of tornadoes and hurricanes, the occupants of a safe room built according to this guidance will have a very high probability of being protected from injury or death.

CROSS-REFERENCE

Refer also to Section A2.1.2.1 for information on best available refuge areas.

MORE INFORMATION

A copy of FEMA P-431 may be downloaded from: www.fema.gov/media-library/assets/documents/2246.

Table A1-1. Terminology Matrix

	BEST AVAILABLE REFUGE AREA	ICC 500 STORM SHELTER	FEMA SAFE ROOM
Designed to minimum building code requirements	Maybe	Yes	Yes
Evaluated by a registered design professional and identified as least vulnerable area/room in building	Yes		
Designed specifically to provide life-safety protection per ICC 500		Yes	Yes
Designed specifically to provide near- absolute protection per FEMA P-361 criteria (including operational and emergency planning criteria)			Yes

A1.3.2 Types of Safe Rooms

This publication includes information on residential and community safe rooms, stand-alone and internal safe rooms, as well as public versus specific-occupant safe rooms.

Residential versus community safe rooms

Safe rooms may be classified into two categories: residential and community safe rooms.

- **Residential safe room.** Serves occupants of dwelling units and has an occupant load not exceeding 16 persons. Tornado and hurricane residential safe rooms, whether in-residence or external, are spaces designed and constructed to the criteria set forth in this publication.

- **Community safe room.** Any safe room not defined as a residential safe room. These safe rooms include not only public but also private safe rooms for business and other types of organizations. Tornado and hurricane community safe rooms are buildings or portions thereof that have been designed and constructed to the criteria set forth in this publication.

Stand-alone versus internal safe rooms

The two types of safe rooms covered by the guidance in this publication include:

- **Stand-alone safe room.** A separate building (i.e., not within or attached to any other building) that is designed and constructed or retrofitted to withstand extreme winds and the impact of wind-borne debris during tornadoes, hurricanes, or other extreme-wind events.

- **Internal safe room.** A specially designed and constructed room or area within or attached to a larger building. An internal safe room (room or area) should be designed and constructed or retrofitted to be structurally independent of the larger building, but provide the same wind and wind-borne debris protection as a stand-alone safe room.

These safe rooms are intended to protect occupants during a short-term extreme-wind event (i.e., an event that normally lasts no more than 24 hours) such as a tornado or hurricane. (Minimum safe room occupancy times are 2 and 24 hours for tornadoes and hurricanes, respectively.) They are **not** recovery shelters intended to provide services and housing for people whose homes have been damaged or destroyed by fires, disasters, or catastrophes.

General public versus specific-occupant safe room

Safe rooms open to the general public present unique planning and operational challenges compared to safe rooms that are open only to specific occupants. This topic is covered in detail in Sections A4.2 and A4.3 of this publication.

A1.4 Deciding Whether to Install a Safe Room

Many factors may influence the decision to construct a safe room. They include:

- The likelihood of an area being threatened by an extreme-wind event (see Chapter A2)
- The vulnerability of a structure to an extreme-wind event (see Chapter A2)
- The risk or potential losses (including deaths and injuries) associated with an extreme-wind event (see Chapter A2)
- The cost of constructing a safe room (see Chapter A3)

In addition to the above factors, the following indirect factors may influence the decision to build a safe room:

- The safe room is required by Section 423.3 or 423.4 of the 2015 IBC
- The potential for death or injury may be reason enough to build a safe room at a given site
- The benefit-cost ratio (BCR) of a safe room (see Section A3.2) may be a factor in the decision, or a minimum BCR may be required by the funding source
- Residents feel unsafe without a safe room
- A business wants to provide protection for its workers
- A safe room would allow faster business recovery after an extreme-wind event by protecting employees from injuries or fatalities
- The building is a government-owned building that is required to have a safe room
- Local ordinances require a safe room
- There may be insurance benefits associated with having a safe room

The flowchart in Figure A1-1 presents the decision-making process that should take place when considering whether to install a safe room. The main steps of this process are discussed throughout Part A.

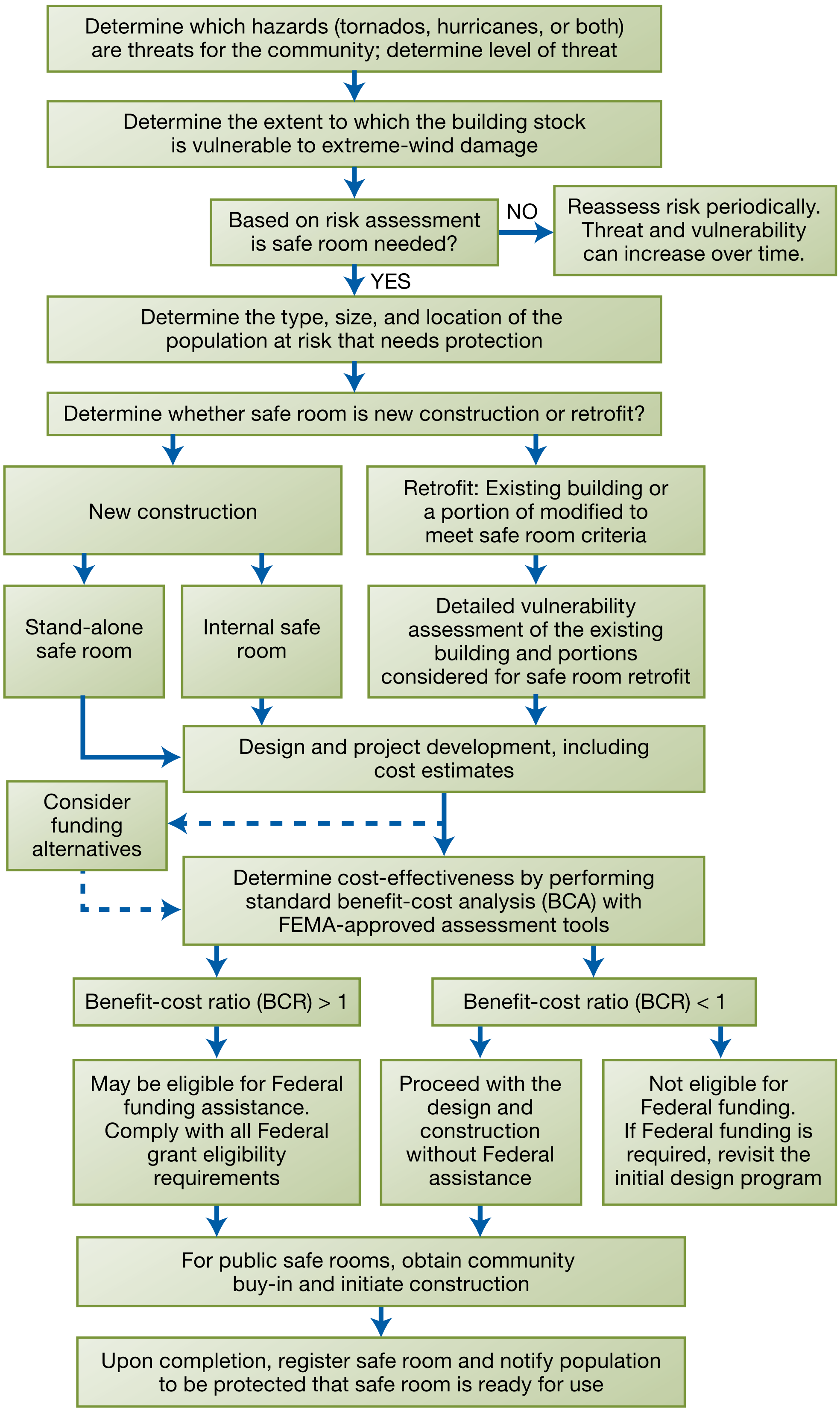


Figure A1-2. Safe room decision-making flowchart

CHAPTER A2
Extreme-Wind Risk Assessment and Analysis

Unless safe room installation is required by the building code or the authority having jurisdiction (AHJ), the safe room decision-making process should begin with risk assessment. The final decision to move forward with a safe room project may hinge on a single factor, consequence, or on an array of factors and consequences (refer also to Section A1.4). Single factors may be related to building stock vulnerability or the potential for loss of life or injury (e.g., at a hospital that cannot move patients housed in an intensive care unit or at a school that takes care of a large number of children). Nevertheless, FEMA recommends a comprehensive risk assessment process that includes the following considerations:

- Type of extreme-wind hazard (tornado, hurricane or both)
- Threat or probability and potential severity of the hazard based on historic occurrences
- Vulnerability of the building or buildings in the community intended to be served by a community safe room
- Size of the population that is vulnerable
- Community-specific consequences that may result from the hazard's occurrence

Risk assessment should be followed by risk analysis to determine protection needs and prioritize subsequent mitigation activities. If a comprehensive risk assessment and risk analysis indicates the need for protection from tornadoes and hurricanes, individuals and communities should identify the best opportunities to provide near-absolute protection for themselves and their community by installing safe rooms. When constructing a new safe room is not a feasible solution to serve an existing building, retrofitting a portion of the building with a safe room may be the best solution.

TERMINOLOGY

Hazard: Event that has the potential to cause damage or losses including injury or death.

Risk: Potential losses – both the short- and long-term effects – associated with a hazard. Risk is associated with threat and vulnerability.

- **Threat**: The probability that an event of a given recurrence interval will affect a specific location within a specified period.
- **Vulnerability**: Weaknesses in the building or site location that may result in losses or damages

MORE INFORMATION

FEMA P-320, Section 2.5, presents a simplified approach to risk assessment for homeowners and small businesses.

A2.1 Risk Assessment

The risk of death or injury from tornadoes or hurricanes is not evenly distributed throughout the United States. The safe room risk assessment process for any given location has two major elements: (1) the threat or the probability of the occurrence of an extreme-wind event, and (2) the vulnerability of the community's building(s) and population to the hazard. Potential community-specific consequences from the extreme-wind hazard may then be developed from the results of the threat and vulnerability assessments. Potential consequences may be further informed from available statistics such as annual averages of injuries and fatalities from the hazard. The following section guides the reader through the process of performing risk assessment.

A2.1.1 Assessing Threat

After determining the site-specific extreme-wind hazard (tornado, hurricane or both), assessing the level of threat is the next step in risk assessment. The level of threat is determined by the probability of a specific magnitude event occurring at the location under consideration. The probabilities of occurrence are statistical estimates drawn from historical records of previous hazard events or computer simulations that describe not only the time and location, but also the intensity, size, duration, general circumstances, and effects of the event.

Much of this information has been compiled by FEMA and other entities, such as American Society of Civil Engineers (ASCE), into risk assessment tools, such as wind speed maps and hazard event frequency maps and tables. Since the threat differs greatly in various parts of the country, tornado and/or hurricane wind speed maps can be used to gauge the site-specific level of threat for either event as related to other geographical areas. The ICC 500 wind speed maps should be used for safe room design even when the base building in which the safe room is constructed was built in accordance with the ASCE 7 wind speed map. Both tornado and hurricane ICC 500 wind speed maps and additional commentary on their development may be found in Section B3.2.4. The remaining sections on tornado and hurricane threat provide additional commentary and guidance on using wind speed maps for assessing threat.

Note

DESIGN WIND SPEED MAPS

Designers using this publication should note the difference between references to the **ASCE 7 wind speed maps and the ICC 500 wind speed maps**.

While the base building must be designed to resist the wind speeds designated in ASCE 7, a safe room must be designed to resist the higher wind speeds designated in ICC 500.

Refer also to Section B3.2.4.1 for information on design wind speeds.

A2.1.1.1 Tornado Threat

Modeling and mapping the tornado hazard is more challenging than the hurricane hazard because currently available data are relatively incomplete. The information available on tornadoes is limited by a shorter records-keeping period, minimum data archival requirements, and the inability to accurately measure tornado wind speeds. Furthermore, because the area of land directly affected by tornadoes is relatively small, tornado-related winds have a significantly lower probability of occurrence at a specific point than the high winds associated with other meteorological events (frontal systems, thunderstorms, and hurricane winds). Accordingly, the basic wind speed maps in ASCE 7-10 do not include tornado hazard data and therefore cannot be used for assessing the tornado threat.

Note

MEASURING TORNADO INTENSITY

EF Number	Wind Speed (3 second gust)
EF0	65-85 mph
EF1	86-110 mph
EF2	111-135 mph
EF3	136-165 mph
EF4	166-200 mph
EF5	>200 mph

Source: NOAA, www.spc.noaa.gov/efscale/ef-scale.html

EF = Enhanced Fujita
mph = miles per hour

The severity of a tornado is categorized by the Enhanced Fujita Scale (EF Scale) shown in Figure A2-1. Despite their rarer occurrence in comparison with weaker tornadoes, strong tornadoes are responsible for most tornado fatalities (refer to Table B3-3 to see the percentage of the occurrence of different rated tornadoes). During the period of 1950-2011, 86 percent of all tornado fatalities were caused by tornadoes rated EF3 and greater (NIST 2013). To capture tornado threat as a function of tornado severity, National Oceanic and Atmospheric Administration (NOAA) has developed maps to show areas historically subjected to the highest number of strong tornadoes. Figure A2-2 shows the areas of the United States with the highest frequency of recorded strong and violent tornadoes, those designated as EF3, EF4, or EF5.

The ICC 500 tornado wind speed map (see Figure B3-1) was developed using a deterministic analysis of NOAA tornado data to correlate the mapped frequency of strong tornadoes with four tornado wind speed zones: 250 mph, 200 mph, 160 mph, and 130 mph. The higher the tornado wind speed zone associated with any given location, the greater the threat from strong tornadoes. However, the ICC 500 tornado wind speed map does not show a high level of detail and therefore the design wind speed may not be clear when a safe room is to be sited and constructed near a tornado wind zone contour line. Designers and code officials should recognize that the mapped design wind speed contour lines were not drawn or intended to be interpreted as precise geographic coordinates. When planning or designing safe rooms, designers should remember that the intended purpose of a safe room is to protect people from death or injury. Accordingly, a prudent approach would be to assume the site lies within the higher tornado wind speed zone.

For more commentary on tornado probability related to the ICC 500 wind speed maps, please refer to Section B3.2.4.1.2.

Figure A2-1. Typical tornado damage descriptions to one- and two-family dwellings and their corresponding intensity according to the EF Scale (wind speeds are estimated 3-second-gust wind speeds)
(SOURCE: NOAA NATIONAL WEATHER SERVICE, STORM PREDICTION CENTER, WWW.SPC.NOAA.GOV/EFSCALE/EF-SCALE.HTML)

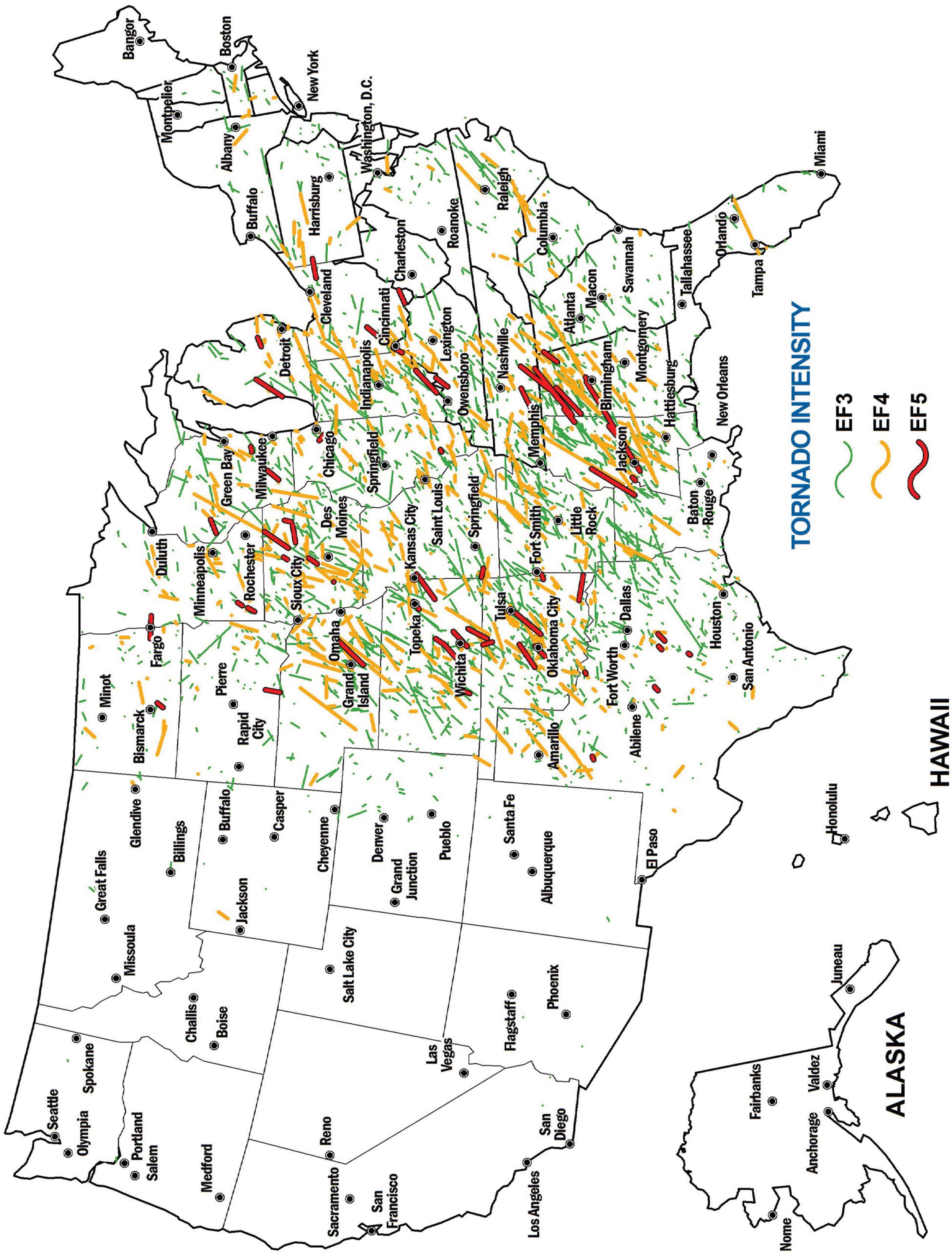


Figure A2-2. Recorded EF3, EF4, and EF5 tornadoes in the United States from 1950 to 2013
(SOURCE: NOAA NATIONAL WEATHER SERVICE, STORM PREDICTION CENTER, WWW.SPC.NOAA.GOV/GIS/SVRGIS/)

A2.1.1.2 Hurricane Threat

Hurricane frequency and intensity varies with geographic location. Wind speed maps published by ASCE incorporate hurricane hazard data and can be used to assess hurricane threat (see Figure A2-3). Regions of the country with the greatest mapped speeds have the highest level of threat from hurricane winds.

Hurricane intensity is assessed using the National Hurricane Center (NHC) Saffir-Simpson Hurricane Wind Scale comprising five categories, 1 through 5, category 5 being the most intense. Figure A2-4 shows the wind speed ranges and typical damage for each of the five hurricane categories. The wind speeds used in the Saffir-Simpson Hurricane Wind Scale have a different basis than ASCE 7-10 wind speeds, which are used in engineering design of buildings. Hurricane categories are defined in terms of sustained wind speeds over open water, while ASCE 7-10 uses peak gust wind speeds over land in flat, open terrain, as shown in Table A2-1.

Note

HURRICANE-PRONE REGION

The ASCE 7-10, Minimum Design Loads for Buildings and Other Structures, defines the hurricane-prone region as the U.S. Atlantic Ocean and Gulf of Mexico coasts where the design wind speed is greater than 115 mph for Category II Buildings (120 mph for Category III and IV Buildings as shown in Figure A2-3), as well as Hawaii, Puerto Rico, Guam, Virgin Islands, and American Samoa.

Table A2-1. Approximate Relationship between Wind Speeds in ASCE 7-10 and Saffir-Simpson Hurricane Wind Scale

SAFFIR SIMPSON HURRICANE CATEGORY	SUSTAINED WIND SPEED OVER WATER[a]	GUST WIND SPEED OVER LAND[b]
	mph	mph
1	74–95	81-105
2	96–110	106-121
3	111–129	122-142
4	130–156	143-172
5	> 157	>173

Notes:

(a) 1-minute average wind speed at 33 feet above open water

(b) 3-second gust wind speed at 33 feet above open ground in Exposure Category C. (see also Figure A2-3).

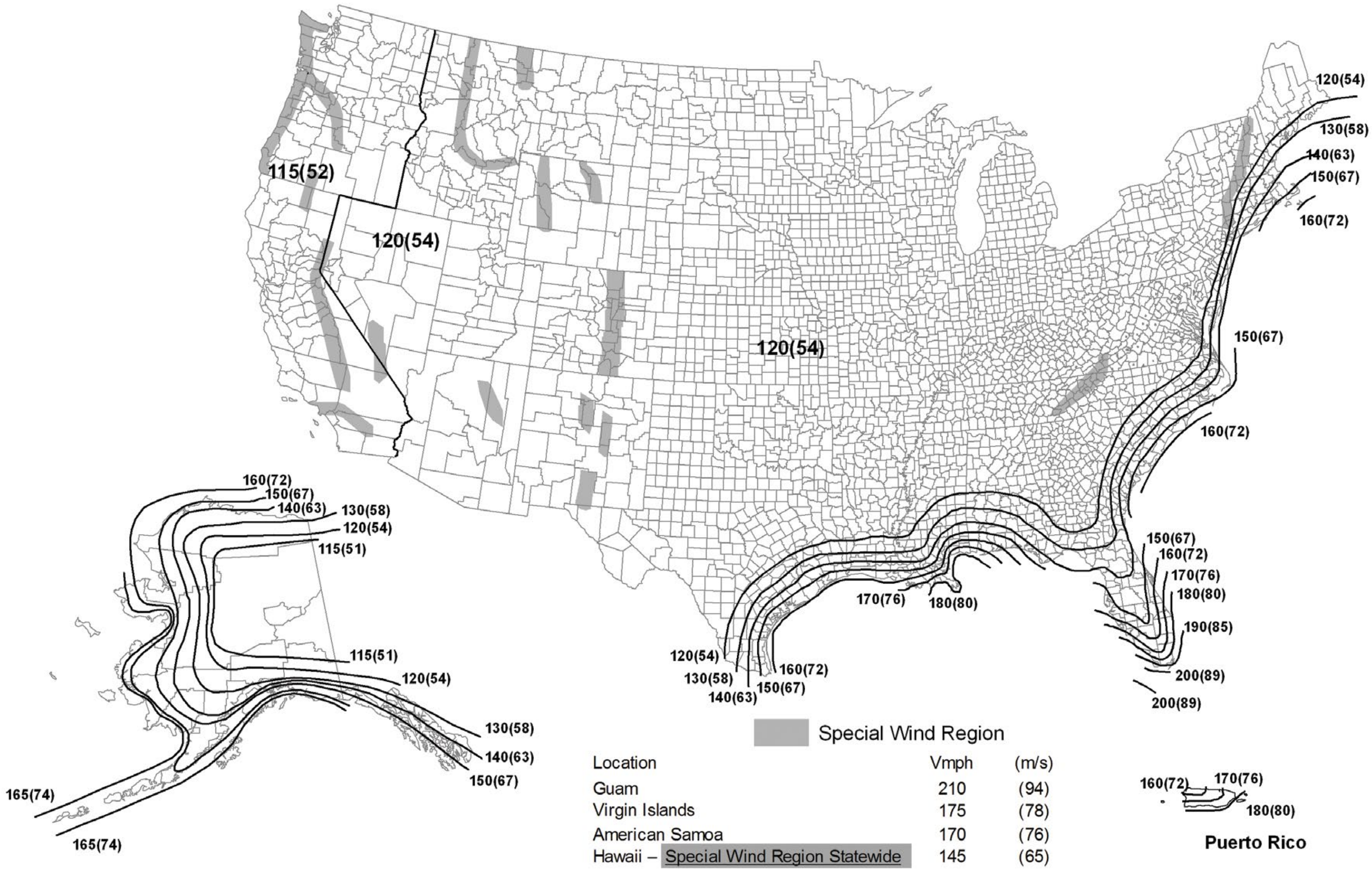
Source: Adapted from Table C26.5-1 of ASCE 7-10 Commentary.

NOAA maintains a hurricane database associated with a tool[1] that maps hurricane tracks, which allows investigation of the historical hurricane record. Records for the Atlantic Basin extend as far back as 1851. ASCE 7-10 wind speed maps are based on hurricane mean recurrence intervals (MRIs) ranging up to 1,700 years (3 percent probability of exceedance in 50 years). The ICC 500 hurricane wind speed map in this publication (see Figure B3-2) was developed using the same methodology used to model hurricane wind speeds for the ASCE 7 wind speed map, but uses instead a 10,000-year MRI (0.5 percent probability of exceedance in 50 years).

When assessing hurricane threat using wind speed maps, it may be helpful to consider information presented in both maps (ASCE 7 and ICC 500) depending on location within the hurricane-prone region. Care should be taken to reference the specific maps used for the risk assessment. Only the ICC 500 wind speed map for hurricanes should be used to design hurricane safe rooms.

For more commentary on hurricane probability related to ICC 500 wind speed maps, refer to Section B3.2.4.1.3.

1 A NOAA track mapping tool can be found here: http://coast.noaa.gov/hurricanes/.



Notes:

1. **Values are nominal design 3-second gust wind speeds in miles per hour (m/s) at 33 ft (10m) above ground for Exposure C category.**
2. **Linear interpolation between contours is permitted.**
3. **Islands and coastal areas outside the last contour shall use the last wind speed contour of the coastal area.**
4. **Mountainous terrain, gorges, ocean promontories, and special wind regions shall be examined for unusual wind conditions.**
5. **Wind speeds correspond to approximately a 3% probability of exceedance in 50 years (Annual Exceedance Probability = 0.000588, MRI = 1700 Years).**

Figure A2-3. Basic wind speeds for Occupancy Category III and IV buildings and other structures
(SOURCE: FIGURE 26.5-1B OF ASCE 7-10, USED WITH PERMISSION)

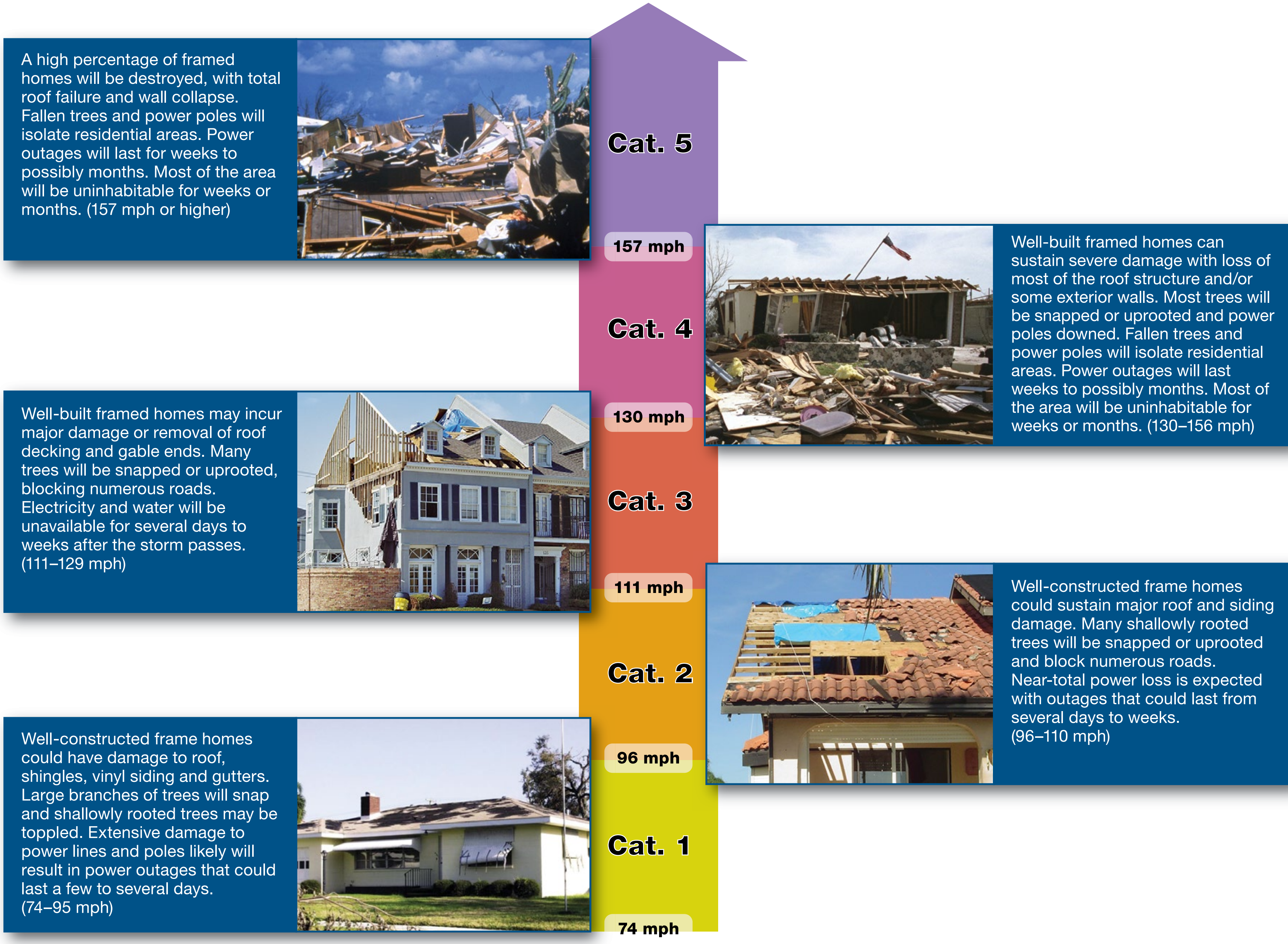


Figure A2-4. Typical hurricane damage descriptions to one- and two-family dwellings and their corresponding intensity according to the Saffir-Simpson Hurricane Wind Scale
(SOURCE: NOAA NATIONAL WEATHER SERVICE, NATIONAL HURRICANE CENTER, WWW.NHC.NOAA.GOV/ABOUTSSHWS.PHP)

A2.1.2 Assessing Vulnerability

After assessing the tornado or hurricane hazard threat for the specified location, vulnerability should be assessed. In addition to assessing the vulnerability of buildings to damage from extreme-wind events, this publication also recommends that vulnerable populations be identified. For safe room risk assessment purposes, vulnerable populations are considered to be those who are unable to be evacuated from the area likely to be impacted by the impending storm.

A2.1.2.1 Assessing Building Vulnerability

After evaluating the threat level, the second step is to assess the potential vulnerability of the community's (or building owner's) building stock to wind damage that could cause casualties. This step is especially critical for high-occupancy buildings and buildings that house vulnerable populations.

FEMA's *Best Available Refuge Area Checklist* may be useful in identifying vulnerable buildings. In addition to this checklist, the wind commentary section of ASCE 7-16 is expected to be expanded to address building vulnerabilities to tornado hazard. Both resources may be helpful in identifying building vulnerabilities. A vulnerability assessment of a building can be performed using the steps described below.

MORE INFORMATION

FEMA's *Best Available Refuge Area Checklist* and FEMA P-431, *Tornado Protection: Selecting Refuge Areas in Buildings*, can be found at: www.fema.gov/media-library/assets/documents/2246.

Identifying building vulnerabilities

Building owners should have a registered design professional conduct an inventory and ranking of the owner's building stock. This can be done in two parts:

1. The first part should comprise an assessment of the building vulnerabilities; this architectural/engineering assessment should include building-specific factors such as structural integrity, age, condition, building materials, design, and quality of construction to identify components vulnerable to the identified hazard.
2. The second part involves ranking the buildings according to the level of potential risk of serious injury or death to building occupants. This part is an especially important component of a vulnerability assessment to assist the building owner in prioritizing their safe room needs.

Identifying options for providing safe rooms

After ranking the building stock according to the level of vulnerability, the building owner should identify opportunities to build stand-alone safe rooms or to build safe room additions to existing buildings. In some instances it may be cost effective to retrofit a portion of an existing building to meet safe room criteria.

Identifying best available refuge areas within buildings

FEMA recommends that best available refuge areas be identified by a registered design professional. Best available refuge areas in each building to be used for a tornado or hurricane (refer to A2.3) can be identified during the first part of the vulnerability assessment. The best available refuge area should be regarded as an interim measure only until a safe room is made available to the building occupants.

Note

BEST AVAILABLE REFUGE AREAS

The term "best available refuge area" refers to areas in an existing building that have been deemed by a registered design professional to be the least vulnerable during a tornado. If the best available refuge area is intended to serve as a storm shelter, then the area must meet ICC 500 requirements.

See FEMA P-431 for guidance in selecting best available refuge areas.

It is important to note that, because these areas were not specifically designed as tornado safe rooms, their occupants may be injured or killed during a tornado. However, people in the best available refuge areas are less likely to be injured or killed than people in other areas of a building.

A2.1.2.2 Assessing Vulnerable Population

Safe rooms have a single purpose: to protect the lives of the population vulnerable during a tornado or hurricane. Some considerations related to determining the population vulnerability are described below. As previously noted, the emergency management measures necessary to afford protection to thousands of occupants of large, public venues such as stadiums or amphitheaters are beyond the scope of this publication.

Identifying the vulnerable population is required not only to evaluate risk (i.e., determine potential losses as a result of a disaster), but also for effective mitigation; this information is used to determine the location and optimal size/capacity of a community safe room. Because the warning times for approaching hurricanes are considerably longer than for tornadoes, the vulnerable population for hurricane safe rooms might include those who must remain in the area, such as emergency response personnel, and those who are unable to evacuate on time either because of their access and functional needs, lack of transportation, a suitable place to go, or other reasons.

The installation of any safe room in a hurricane-prone region should be coordinated with local emergency management and law enforcement personnel to ensure its use during extreme-wind events is not a violation of any local or State evacuation plan. In the case of approaching tornadoes evacuation is not possible, so the definition of vulnerable population is extended to include all people in buildings deemed vulnerable to failure from tornadoes.

The occupancy criteria in this publication (see Chapter B5) are defined using a minimum floor area per occupant approach to ensure that adequate space is provided for the safe room population, no matter who comprises that population. However, State and local agencies responsible for emergency management and developing and executing evacuation plans should be consulted when identifying a population in need of protection, particularly as it relates to the Americans with Disabilities Act (ADA). Refer also to Section B5.2.1.4.

Note

VULNERABLE POPULATION

According to (FY15) HMA Unified Guidance, the vulnerable (or susceptible) population encompasses those who must remain behind or will not have time to leave and must face an imminent threat of a tornado or hurricane or both. This includes individuals with access and functional needs as well as those who must maintain access to impacted area, such as first responders. HMA Unified Guidance is updated periodically. For information on FEMA grant programs and safe room eligibility, download the most current policy HMA Unified Guidance from: www.fema.gov/hazard-mitigation-assistance.

CROSS-REFERENCE

Information about planning for vulnerable population in the area around public safe rooms is provided in Section A4.3.

CROSS-REFERENCE

Additional information on occupancy duration is provided in Section B7.2.1.

According to FEMA's Hazard Mitigation Assistance (HMA) Unified Guidance (2015), the following are the minimum components in determining the eligible safe room population:

- Population to be protected within the area at risk of impact by tornado and/or hurricane hazards;
- Warning capabilities, logistics, and operation components that support basic safe room functions;

- Travel times and routes for the population to be protected to reach the safe room so that people are not exposed to additional hazards when moving to the protected area;
- Hazard mitigation time of protection: approximately 2 hours for tornado and 24 hours for hurricane; and
- Relationship of the population to be protected by the safe room to State or local emergency evacuation requirements.
- Effective and accessible warnings (alerts) that address the needs of individuals with access and functional needs and/or individuals who have limited English proficiency. For additional information, reference the FEMA document, *Alerting the Whole Community* (2013).

A2.2 Risk Analysis

Risk analysis brings together findings of the risk assessment to determine protection needs and prioritize mitigation activities.

A2.2.1 Analyzing Risk

Risk analysis should be performed for each proposed safe room project to make sure the safe room will serve those most vulnerable. The risk analysis compares the potential severity of damage based on the vulnerability of a building from a tornado or hurricane of a certain magnitude with the probability of occurrence of such an event at that location. Possible long- and short-term consequences of the extreme-wind event should also be considered during the risk analysis.

It is crucial to conduct a careful risk analysis, identify all design constraints, and prioritize all design parameters. Commentary presented in Section B3.2.2, *Load Combinations*, may be helpful when considering safe room design issues, especially when multiple hazards are present.

A2.2.2 Considering Multi-Hazards in Safe Room Design

Most safe rooms are built with a single purpose in mind: to protect the local population from tornadoes and/or hurricanes. This singular objective, however, should not divert the designers' and local decision-makers' attention from the all-too-real presence of other hazards, both natural and manmade. For this reason, designers and local officials alike should adopt a multi-hazard approach from the very beginning of their safe room deliberations. Considering multi-hazards in building design has gained prominence and the support of FEMA, other government agencies, and professional associations. This is not only because a multi-hazard approach ensures a comprehensive risk analysis and appropriate mitigation responses, but because it will produce more cost-effective design solutions over the life cycle of a building.

The potential adverse effects of other hazards on the functionality of safe rooms should be identified, evaluated, and documented. The final risk analysis should include these multi-hazard considerations to produce as comprehensive a list of design requirements as possible.

Multi-hazard design can be both an advantage and a disadvantage for the designer; on the one hand, two or more hazards may pose design requirements that reinforce each other, thus reducing costs and improving protection. On the other hand, design requirements for some hazards may be conflicting, thereby making them difficult to reconcile. For example, wind-resistant structures benefit from more rigid design, while earthquake resistance is enhanced through greater structural flexibility. Massive reinforced concrete roof sections, typically specified to resist extreme wind pressures and debris impact, are detrimental for earthquake-resistant design. Another example of multi-hazard conflict is when a safe room is needed in an area where a flood hazard is present. Guidance for addressing safe room siting challenges related to the flood hazard are presented in Chapter B4, *Siting*.

As noted in Section A1.4, the above described risk analysis process – including consideration of site-specific consequences and multi-hazards – should inform the decision of whether to pursue the installation of one or multiple safe rooms.

CHAPTER A3
Costs and Benefit-Cost Analysis

This chapter addresses cost and BCA considerations for safe rooms. Cost guidance is primarily directed toward community safe rooms, but may also be useful background information for residential safe room projects. Cost guidance specific to residential safe rooms can be found in Section 3.10 of FEMA P-320 (2014).

A3.1 Safe Room Costs

The cost of designing, constructing, and maintaining a safe room can be affected by factors such as location, design, new construction versus retrofit, and design wind speed. This section presents information on safe room cost and the effect of design and construction choices on cost. Cost estimates should be prepared by a registered design professional for each proposed safe room alternative.

Note

COST ESTIMATES

To be helpful with decision-making, cost estimates developed for design purposes and grant applications should be as detailed as possible to minimize delays in the grant implementation process.

A3.1.1 Design Parameters That Affect Safe Room Costs

The design parameters that have the most effect on the cost of a community safe room are:

- **Single-use versus multi-use.** Whether a safe room is single- or multi-use (i.e., used for more purposes than just as a safe room) can affect the cost of building components, finishes, furnishings, and other occupancy-driven design parameters. A simple design for a single-use, tornado community safe room will probably cost less per square foot than a large, multi-use hurricane community safe room with higher walls and a long-span roof assembly.
- **Design complexity.** The simpler the safe room (e.g., short walls, short roof spans, minimal interior partitions and finishes), the lower the cost. Safe rooms with long-span roof assemblies and/or high roof heights (such as a gymnasium) cost more.
- **Safe room design wind speed.** The safe room design wind speed affects the strength criteria. The higher the design wind speed, the greater the cost. The cost to construct a multi-purpose safe room in any given location is a function of the model building code requirements for the building's non-safe room use; the cost to construct the building will be higher in areas with higher basic wind speeds regardless of whether it includes a safe room. Examples for community safe room costs are shown in Table A3-1.

- **Safe room debris impact-resistance design criteria.** Debris impact-resistance design criteria can increase costs more than the other design parameters. Common building materials are readily available for hardening wall and roof systems to make them debris impact-resistant, but protection systems for openings and devices for doors, windows, vents, and other elements are not as readily available. As a result, safe room cost increases as the number of openings increases.
- **Foundation.** The foundation of a safe room may be simple and relatively low cost. A new in-ground safe room may cost more because of the required excavation, designing for lateral earth pressures, and ADA compliance, but the surrounding soils provide wind-borne debris protection. In comparison, an above-ground safe room located in a flood-prone area may require an elevated foundation, which is more expensive than other foundation types.
- **Resistance to large wind-borne debris loads.** Designing a safe room to resist large wind-borne debris loads (as discussed in Section B3.2.5.5) can increase costs.
- **Resistance to seismic loads.** Designing safe rooms to resist seismic loads may increase the cost of the safe room, and seismic detailing may be required in areas with high seismicity.

Table A3-1. Community Safe Room Costs: Location-Dependent Design Parameter Examples

WIND HAZARD	ASCE 7-10 RISK CATEGORY	ASCE 7 10 REQUIREMENTS FOR BASE BUILDING DESIGN WIND SPEED/ DEBRIS IMPACT PROTECTION	ICC 500 DESIGN WIND SPEED	COMPARISON OF DESIGN WIND SPEEDS (ASCE 7 10 FOR BASE BUILDING VS FEMA SAFE ROOM DESIGN)
Tornado	II	115 mph (e.g., Oklahoma City); Not required to meet wind-borne debris criteria	250 mph	Significant difference
Tornado	III/IV	200 mph (e.g., South Florida); Protected glazing required; cost differential between protected glazing and safe room glazing not large	200 mph	No difference, though FEMA design parameters are higher than ASCE 7 requirements
Hurricane	III/IV	120 mph (e.g., New York City); Not required to meet wind-borne debris criteria	160 mph	Moderate difference
Hurricane	III/ IV	200 mph (e.g., Florida); Protected glazing required; cost differential between protected glazing and safe room glazing not large	225 mph	Moderate difference

Additionally, based on recent data compiled by FEMA, many other factors can affect safe room costs. These other factors include the number and size of interior walls; size requirements for heating, ventilation, and air conditioning (HVAC) and/or sprinkler systems; land acquisition costs; and moisture protection requirements based on roof type. Other factors that can affect cost, depending on funding sources and building owner requirements, include:

- Safe room construction verification requirements per HMA Unified Guidance
- Safe room engineering design review requirements per ICC 500 and Chapter B1 of this publication
- Eligibility requirements, such as pre-award costs
- ADA compliance needs
- Outreach needs
- The need to perform an Environmental Protection Agency (EPA) Finding of No Significant Impact study, if required

A3.1.2 Cost and Size Data from Constructed and Proposed Safe Room Projects

Community wind hazard shelters were designed and constructed long before the first edition of FEMA P-361 was released in July 2000. Since then, thousands of community safe rooms have been designed and constructed throughout the United States with FEMA funding assistance. Safe rooms constructed with FEMA grant assistance must meet FEMA P-361 design criteria as presented in Part B of this publication.

Table A3-2 shows relative cost and size data from community safe room projects based on recent data. In particular, Table A3-2 shows the percent range of cost increase to construct a new safe room compared with the cost of constructing a building of the same size that complies with the minimum building code.

Table A3-2. Increase in Cost of Community Safe Room over Minimum Code Compliance

DESCRIPTION	PERCENT COST INCREASE (PER SQUARE FOOT)	EXPLANATION OF COST INCREASE
Design and construct a portion of a new building to resist 250 mph winds from a 140 mph basic wind speed (ASCE 7-05)	5% – 7%	Associated primarily with additional cost of structural elements and envelope opening protection
Design and construct a portion of a new building to resist 250 mph winds from a 90 mph basic wind speed (ASCE 7-05)	15% – 20%	Associated primarily with additional cost of structural elements and envelope opening protection
Design and construct a portion of a new building to resist debris impact from a 15-pound 2x4 board missile traveling horizontally at 100 mph and impacting vertical surfaces, and the same missile traveling vertically at 67 mph and impacting horizontal surfaces	5% – 27%	Associated with additional cost of safe room exterior walls, roof structure, and openings (debris impact resistance only; wind pressure resistance was considered in the rows above). The cost increase is highly dependent on a number of factors including but not limited to size of the safe room, materials, strength of wall and roof systems, percentage of the building exterior allocated for openings, and number of egress points to be protected. The safe room projects that were considered had minimal exterior doors and glazing, ranging from 0% to 10% of the total building exterior.
Design and construct a portion of a new building to resist 250 mph winds from a 90 mph basic wind speed (ASCE 7-05) and provide safe room debris impact protection	20% – 32%	Associated primarily with cost of structural elements and envelope opening protection.

A3.1.3 New Construction versus Retrofit

The most cost-effective way to design and construct a safe room is to include it in a new building. The cost of retrofitting an existing building (or portion thereof) is higher due to the additional design and construction constraints. In FEMA-funded safe room projects in Midwestern and Southeastern States, the construction cost of a retrofitted safe room was approximately 10 to 15 percent higher than the construction cost of a safe room in a new building.

In large, new building projects, the increase in cost for adding a safe room is relatively small. Many safe rooms constructed as part of a new school, each protecting 200 to 300 occupants, have added only 1 to 2 percent to the total project cost when the safe room was included in the design process from the beginning of the project.

A3.1.4 Cost of Hurricane Community Safe Room versus Combined Tornado and Hurricane Community Safe Room

The difference in cost of a FEMA P-361-compliant hurricane community safe room and a FEMA P-361-compliant combined tornado and hurricane community safe room has not been determined, but is estimated to be less than 5 percent. The estimate is based on the project data in Table A3-2. As the table shows, cost per square foot increases as little as 5 to 7 percent to improve building wind resistance from the level of a Risk Category III or IV facility constructed to the building code in a hurricane-prone region with 140 mph design wind speed (ASCE 7-05) versus the 200 mph safe room design wind speed criteria. It follows that there would not be a dramatic change in cost if the design parameters for a typical hurricane safe room were increased to meet the minimum criteria for a typical tornado safe room with a slightly higher wind speed (e.g., 200 to 250 mph) and the heavier debris impact test missile (15 pounds instead of 9 pounds).

A3.2 Benefit-Cost Analysis

A BCA is used to estimate the cost-effectiveness of proposed projects.

The result of a BCA is the BCR. Mitigation projects funded under FEMA's HMA programs are required to have a BCR of 1.0 or greater (i.e., the benefits, defined as losses that are avoided, must exceed the project costs).

A3.2.1 Benefit-Cost Analysis Software

Consistent with the intent of FEMA P-361 safe rooms, the reduction of injuries and deaths (life-safety benefits) are the basis for the FEMA BCA software analysis. The Tornado Safe Room BCA module and the Hurricane Safe Room BCA module are included in the current version of the BCA Tool.

> Note
>
> **BCA TOOL**
>
> The current BCA Tool can be found at the FEMA BCA website: www.fema.gov/benefit-cost-analysis.

The design of the early version of the BCA software was based on the presumed need to fund community safe rooms that were either retrofits of existing buildings or included in a new building. Project cost inputs were based on the costs of building construction and any additional maintenance costs incurred by the project, while project benefits (avoided losses) were based on the reduction of casualties (injuries and deaths) resulting from the construction of the safe room.

The current version of the Tornado Safe Room BCA module was designed with grant programs such as the Pre-Disaster Mitigation program in mind, and asks a number of questions to help identify features of the proposed safe room. Users can now choose among the following safe room projects:

- New versus retrofit
- Stand-alone versus internal
- Community versus residential

A3.2.2 Determining Project Benefits

Benefits (avoided losses) are calculated as the difference between injuries that would occur without the safe room and the reduced potential for injuries after the safe room is fully operational. The injuries before mitigation (safe room construction) are determined on the basis of potential damage to different types of buildings where potential occupants would be taking refuge during the storm.

In many cases, a community safe room that is open to the public serves an off-site population. The potential safe room occupants would need to travel to the safe room from the surrounding area within the minimum allowed time period. The methodology incorporates warning response times and travel times to the safe room in the calculation of project benefits.

The current FEMA BCA software for tornado and hurricane safe rooms remains focused exclusively on the reduction of injuries and deaths (life-safety benefits) as the basis for project benefits. The three factors used to calculate the benefits in the current software are the same as in earlier versions:

- Values associated with injury and death calculated by the Federal Aviation Administration (FAA)
- Safe room occupancy and probability of injury and death due to tornado or hurricane winds
- Probability of tornado or hurricane wind events

However, the way each factor is calculated has changed in the Tornado Safe Room module, as follows:

- **Values associated with injury and death.** In 2007, FEMA convened an outside panel of building performance experts (with significant knowledge in tornado and hurricane damage assessments) and life-safety experts from consulting firms, research organizations, and academia. The expert panel evaluated the existing methods for calculating benefits and recommended updated methods. As a result, the values associated with casualties are now divided into three injury levels (self-treat, treat and release, hospitalized) and death, based on updated tables from the FAA, in 2007 dollars.

- **Safe room occupancy and probability of injury and death due to tornadoes.** The occupancy load in the new software has been simplified to account for three intervals during a 24-hour period: day, evening, and night. Since most of the potential occupants of the community safe room will come from the surrounding areas, the new methodology allows the user to select up to two before-mitigation structure types to represent the level of risk to which the potential occupants would be exposed in conditions without a safe room. The two types can be selected from eight pre-defined structure types provided in the model, which are based on the categories used in the development of the EF Scale. The casualty rates for each damage state were defined on the basis of damage indicators (DI) and degree of damage (DOD) published in the report titled, *A Recommendation for an Enhanced Fujita Scale (EF-Scale)* (TTU 2006).

- **Probability of tornado events.** In the current software, the probability of a tornado striking a safe room is based on NOAA's historical tornado records. NOAA keeps tornado records with recorded paths or start and end points covering the period from 1950 to 2008. This information was used as part of a geospatial analysis, based on tornado probability research, to produce tornado occurrence maps for each Enhanced Fujita class. In the current software, tornado probability is calculated using published average national tornado length and width values. When the user selects the county where the safe room will be located, the pre-calculated tornado probabilities are accessed from the software database.

- **Probability of hurricane winds.** The current version of the Hurricane Safe Room module incorporates the wind speed maps developed for ASCE 7-10 to determine the potential risk of hurricanes at the safe room location. Wind speed maps are included for the recurrence intervals for the 10-, 25-, 50-, 100-, 300-, 700-, and 1700-year events. The recurrence interval and associated wind speed are determined using the wind speed maps, and then the software associates these wind speeds with the FAA injury and death values for the pre-safe room buildings used for shelter and compares them with the reduced probability for injuries and deaths resulting from the construction of a safe room.

Project costs (initial project costs and maintenance) in the BCA Tool can be developed using cost estimation tools that are included in the module. The Tornado Safe Room and Hurricane Safe Room BCA modules were developed to provide a defensible and user-friendly way to calculate life-safety benefits for community and large residential tornado and hurricane safe rooms.

CHAPTER A4
Operation and Maintenance Considerations for Community Safe Rooms

This chapter describes the operations and maintenance (O&M) considerations for community safe rooms. O&M for residential safe rooms is not discussed in this chapter, though owners of a safe room may find some of the information pertinent. For information on operating and maintaining residential safe rooms, please refer to Section 4.4 of FEMA P-320 (2014).

Disaster preparedness is crucial for quick and effective responses during emergency situations. Accordingly, every community safe room should have an O&M plan that is reviewed and updated on a regular basis. This chapter discusses some factors that should be considered when developing an effective O&M plan.

When determining how to optimize emergency management performance for a community safe room before, during, and after a hurricane or tornado event, communities should have reasonable flexibility to implement management practices that are appropriate for their local area. The purpose of this chapter is to help communities identify issues requiring careful consideration and planning so they can find appropriate solutions tailored to their specific needs. It would not be appropriate to provide a one-size-fits-all set of criteria for operating and maintaining safe rooms everywhere in the United States. For example, urban, suburban, and rural areas typically have different modes of transportation, communication, and local resources, all of which should be considered specifically when preparing an effective O&M plan. FEMA provides sample O&M plans on its safe room website; these sample plans can be used as a starting point for creating tailored community plans for new safe rooms.

Note

FEMA SAFE ROOM GRANT REQUIREMENTS

Safe rooms constructed with FEMA grant funds must meet the minimum requirements for O&M plans as described in the most current edition of FEMA's HMA Unified Guidance. The FEMA HMA Unified Guidance is updated periodically. To review or download the most current HMA Unified Guidance, refer to: www.fema.gov/hazard-mitigation-assistance.

Safe room issues covered in the HMA Unified Guidance include eligibility parameters, and implementation guidance covering issues such as eligible and ineligible costs, recognized design standards, and other important guidance items.

A4.1 Safe Room O&M Plan Objectives and Parameters

The O&M plan should identify how the safe room will be operated and maintained in a way that achieves the objective of providing life-safety protection from a tornado or hurricane given the expected warning time and duration for the event. If the community safe room is a combined safe room (i.e., designed to provide life-safety protection from both hurricanes and tornadoes), the O&M plan should cover both events whenever different measures apply.

Owners and operators of tornado and hurricane safe rooms should be ready and able to open the safe room for immediate and efficient use in response to an impending tornado or hurricane. The best way to accomplish this is twofold: (1) create an effective plan adapted to the needs of the intended occupants of the facility, and (2) provide redundancy for critical responsibilities.

The O&M plan should provide details on staffing and personnel roles and responsibilities (Section A4.2), notification procedures for potential occupants (Section A4.3), emergency provisions (Section A4.4), access and entry (Section A4.5), operation procedures during an event (Section A4.6), post-event operations (Section A4.7), and maintenance (Section A4.8).

Before developing the safe room O&M plan, the following safe room parameters should be clearly defined by the safe room owner and operator and other stakeholders.

MORE INFORMATION

Sample O&M plans can be found at: www.fema.gov/example-operations-and-maintenance-plans-for-community-safe-rooms.

Note

ANNUAL REVIEW

O&M plans should be considered to be working documents. As such, they should be reviewed and updated regularly, at least every year and after every use.

A4.1.1 Safe Room Design

The siting, size, configuration, access points, support areas, and many other aspects of the design will greatly influence the O&M of the safe room. Therefore, it is important for all stakeholders (e.g., owner/operator, planners, designers, community) to understand the issues raised in this chapter and consider how the O&M plan can best address them, along with any other location-specific issues.

A4.1.2 Multi-Use versus Single-Use

O&M plans should include steps to ensure safe room readiness. The approach outlined will vary as a function of whether the safe room is single- or multi-use. Single-use safe rooms are intended to be occupied only during an extreme-wind event, whereas multi-use safe rooms are designed to serve as functional space for other uses such as offices, classrooms or a gymnasium (as shown in Figure A4-1) when not needed as a safe room. Multi-use safe room O&M plans need to demonstrate that normal daily usage of the space will not interfere with timely safe room operations. O&M plans for single-use safe rooms should demonstrate that readiness will be maintained through measures designed to prevent the safe room from being misused or neglected. For example, using the safe room for storage decreases usable floor space and occupant capacity.

EXAMPLE

On April 27, 2011, occupants spent most of the day at a community safe room in Brookwood, AL. The town was in the warning areas for the tornadoes that day, but was not directly struck. Because the safe room was in the town park, most residents who used the safe room drove there on the day of the event. Town officials stated that the safe room was filled to "standing room only" for a good portion of the day (FEMA 2012).

Figure A4-1. Example of a multi-purpose safe room also used as a gymnasium

A4.1.3 Duration of Occupancy

The anticipated duration of safe room occupancy also drives O&M considerations. Safe rooms are different from other types of shelters in that they are designed to safeguard people only during windstorm events. FEMA considers this to be approximately 2 hours for tornadoes and approximately 24 hours for hurricanes. However, as documented in FEMA P-908, *Mitigation Assessment Team (MAT) Report Spring 2011 Tornadoes: April 25-28 and May 22* (FEMA 2012), it is not unusual for tornado safe rooms to be occupied longer on active storm days when warning periods overlap.

The longer duration of occupancy for hurricane safe rooms and combined safe rooms demands additional consideration related to occupant needs. As a result, O&M plans for community hurricane safe rooms usually need additional roles, responsibilities, supplies and services. Where relevant, the discussion in this chapter addresses the differences between tornado and hurricane considerations.

Note

HURRICANE COMMUNITY SAFE ROOM

When developing plans for hurricane community safe rooms, designers should consider other hazard-specific constraints that may be governed by local emergency management or law enforcement requirements, mandatory evacuations, and other related emergency plans that affect the movement of at-risk populations.

For some communities, when there is sufficient warning time, a large proportion of the population may be expected to leave the area of anticipated immediate impact and seek shelter outside the at-risk area. However, people such as first responders and those who are physically unable to leave the area would remain in harm's way. Therefore, for hurricane hazards, FEMA only considers providing grant funding for extreme-wind mitigation projects that are designed for populations that cannot remove themselves from harm's way during a hurricane.

To obtain the current FEMA guidance on safe rooms, contact your FEMA regional office, or review and download the latest HMA Unified Guidance from here: www.fema.gov/hazard-mitigation-assistance.

A4.1.4 Intended Occupants

The characteristics of the intended safe room occupants (known or unknown) will significantly affect planning, design, and O&M considerations. For example, a school safe room that is intended for students and staff will require different design and O&M considerations than a safe room that is intended for first responders, pump station operators, hospital patients, retirement home residents, or the general public. Every safe room design and O&M plan must therefore be tailored to the anticipated needs of the intended occupants to maximize its effectiveness.

The remainder of this chapter discusses safe rooms from the following two different occupancy considerations:

- **Safe rooms open to the general public.** All safe rooms, including those open to the general public, are designed to accommodate a maximum number of occupants and are sited to protect a designated population. O&M plans for safe rooms open to the general public should anticipate health, security, and other possible situations that may arise when occupants unknown to each other and to safe room operators congregate in limited safe room spaces. Since occupants are not already on-site – as is typical with safe rooms for specific occupants – parking should be addressed to ensure sufficient parking is available for the intended number of occupants expected to arrive by automobile.
- **Safe rooms for specific occupants.** Safe rooms intended for specific occupants must be designed and sited in accordance with the needs of the intended occupants; all occupants need to be able to travel to and access the safe room within a reasonable amount of time. Similarly, O&M plans for safe rooms intended to protect only a specific set of occupants should be tailored for the needs of the intended population; the O&M plan should be able to accurately address the needs (medical, accessibility, security, parking, etc.) of the defined set of occupants.

Note

SCHOOL SAFE ROOMS

Some school community safe rooms are made open to the general public only when school is out of session or during evening and overnight hours.

This breakdown – general public versus specific occupants – represents a starting point for considering emergency management practices for safe rooms, but does not encompass all potential factors to be considered. For example, a school safe room may be intended only for the students and staff of the school (making it a safe room for specific occupants), or it may also be intended to serve nearby residents and therefore falls into both categories (general public and specific occupants). The O&M plan for every safe room should address the anticipated occupancy conditions.

The determination of who is allowed to use a safe room is made by the building owner and a discussion of this topic is outside the scope of this publication. However, many communities have recognized the value of safe rooms for saving lives and have sought to achieve optimal occupancy to target populations by increasing accessibility 24 hours a day, year-round.

EXAMPLE

In Joplin, MO, all new school safe rooms are being designed to accommodate not only the students, faculty, and staff of each school, but also the residents who live within a 5-minute walk and a 1/2-mile drive of them. Each will have an average capacity of 1,000 to 1,500 people.

"The safe rooms are designed for that general radius around each school," according to Jason Cravens, Executive Director of Secondary Education. "We wouldn't turn people away, obviously, but there was [an assumed] capacity in designing them" (Youker 2014).

A4.2 Staffing and Personnel Considerations

Once safe room objectives and parameters have been defined and the considerations described in this chapter have been reviewed, safe room roles and responsibilities can be identified in the O&M plan. Contact lists allow the identified staff to stay connected with each other, and quickly find both emergency and non-emergency phone numbers. Ensuring that staff and personnel will be equipped with the resources and knowledge for each task they need to complete during an event is essential for the effective operation of a safe room. These roles need to be clearly defined and those assigned to the roles need to be properly trained. Further, if the safe room is to be occupied for a long time, work shift procedures may need to be developed prior to an event. The following subsections describe these staffing and personnel considerations.

A4.2.1 Roles and Responsibilities

Identifying and describing specific roles and responsibilities are a primary component of the O&M plan. The roles required for adequate functionality and orderly use of the safe room will vary depending on the hazard type, safe room occupancy, access and functional needs, multi-use space usage, and other factors. Given this variability, no list of roles is provided in this guidance. However, sample O&M plans can be found at FEMA's website www.fema.gov/example-operations-and-maintenance-plans-community-safe-rooms.

It is critically important to have personnel assigned to the full range of O&M tasks and responsibilities before any safe room ever opens. Each role should include specific responsibilities to be performed before, during, and after the event. Backup personnel should also be identified in case the assigned person is absent or unable to complete his or her duties. The list of tasks to be completed and the list of people who perform each task will vary between safe rooms as a function of the safe room's unique characteristics. Roles should be identified by role or title instead of by name in the plan because assignments will likely change over time as individuals leave the organization or community

A4.2.2 Contact Lists

Once primary and backup personnel are identified and assigned, the O&M plan should contain or reference a list of all current contact phone numbers and email addresses for each, and a copy should be kept in the safe room at all times. When referenced externally by the O&M plan, the contact list may be updated and re-circulated more efficiently than through revision of the entire O&M plan. Full contact information (i.e., home, work, and cell phone numbers and work and personal email addresses) for each person assigned a role and his or her designated backups should be provided for all safe room personnel as well.

The O&M plan should include a current list of all emergency contact numbers. A copy of the list should be kept in the safe room. The following is a suggested list of what agencies/numbers should be included:

- Emergency management contacts for the building
- Local fire department (both emergency and non-emergency numbers)

Note

REGISTERING THE SAFE ROOM

Once the safe room is constructed or installed, it should be registered with local first responders (e.g., police, fire, rescue organizations).Registration information should facilitate search and rescue operations following an event, which is especially important if safe room occupants become trapped by debris blocking the safe room door. For this reason, coordinates to safe room door should be provided.

Some cities and counties provide websites for owners and operators to register their safe rooms. It is best for safe room owners to contact local authorities for information on the best way to register in their area.

- Local police department (both emergency and non-emergency numbers)
- Local emergency medical services (EMS)
- Local emergency operations center (EOC)
- Appropriate security and medical personnel that can support the safe and effective functioning of a larger community safe room (refer also to Section A4.6); O&M plans may designate contacts on the local s police force and EMS agencies to support this function
- Local utilities (e.g., gas, electric, water, telephone)
- Emergency contractors (e.g., electrical, mechanical, plumbing, fire alarm and sprinkler service, window replacement, temporary emergency windows, general building repairs)
- Any services pertinent to continuation of operations for the organization(s) or company(ies) occupying the building (e.g., catastrophe preparedness unit, company cars, communications, mail center, maintenance, records management, purchasing/supply, data processing)

A4.2.3 Staff Training

Personnel training and drills should be conducted to ensure the operations of the safe room will run smoothly during an emergency. Personnel need to know all warning signals used, including the difference between a watch and a warning, what they mean, and what responses they trigger. This information should be emphasized in the O&M plan and reiterated through training so that it is retained and easily accessible for reference. Multiple levels of redundancy can ensure that each task will be covered if the primary person is unable to perform their duties at the time of the event. Personnel assigned to safe rooms in schools need to know what to do differently during school hours versus after school hours. If it is a combined safe room for hurricanes and tornadoes, then training needs to be provided for both types of hazards. After training, all personnel should be thoroughly familiar with the O&M plan.

Tornado or hurricane watch responses. When a watch is issued, the safe room staff should be placed on alert. The plan should specify the types of activities to be performed for each contingency depending on the type of safe room, the impending emergency, the timing of the watch announcement, and the availability of personnel responsible for safe room operations. Staff responsible for actions that should be completed before occupants arrive should be activated in advance of the warning. For example, a stand-alone tornado community safe room in a residential neighborhood should be opened and prepared for a possible emergency at this early stage.

Tornado or hurricane warning responses. When a warning is issued, the safe room staff should be activated and should begin performing the tasks specified in the O&M plan.

Periodically, the staffing and personnel list of duties should be evaluated and adjusted as needed for future events.

Def

TERMINOLOGY

Watch: A tornado watch is issued when conditions are favorable for a tornado to form.

Similarly, a hurricane watch is issued by the National Weather Service when a hurricane is possible in a given area. A hurricane watch is issued 48 hours in advance of the anticipated onset of tropical storm force winds.

Warning: A tornado warning is issued when a tornado is either occurring or is imminent based on weather radar.

A hurricane warning means that hurricane conditions are expected in the specified area. The warning is issued 36 hours in advance of the anticipated onset of tropical-storm-force winds.

A4.2.4 Work Shifts

For hurricane safe rooms or anticipated long duration events, it may be necessary to assign certain roles to several individuals so that people can be relieved of responsibilities at the end of a designated time period or shift. Additional safe room management responsibilities may include coordinating role transitions when a new work shift begins or as otherwise needed because of fatigue or health-related issues.

A4.3 Community Outreach and Notification

Community safe room owners and operators should alert potential occupants of the presence and location of the safe room, procedures to access the safe room (via mass mailings, meetings, flyer distribution, and drill exercises), any new or changing policies, and general information such as the safe room pet policy. The recommended pre-event notification considerations described in this subsection are not intended to be exhaustive.

A4.3.1 Identifying Potential Safe Room Occupant Population and Providing Information

Whether open to the general public or occupant-specific, all safe rooms are designed with maximum capacities and therefore protect a specified "at-risk" population. All potential occupants of a safe room should be notified of the safe room location and policies related to its use. Confusion about who may use a safe room can result in overcrowding, or worse, people being unable to access it due to overcapacity or the safe room doors having been locked to meet operational requirements.

Potential users in a community should be informed of the community's emergency plans well in advance of an event and should be prepared to seek refuge in their pre-assigned safe room. Neighborhoods that operate community safe rooms are encouraged to conduct regular exercises to test their operational preparedness and acquaint potential occupants with the safe room.

CROSS-REFERENCE

Refer to Section B4.2.1.6, *Siting Proximity to Occupants for Community Safe Rooms*, for information on HMA Unified Guidance related to tornado safe travel time restrictions. Section A2.1.2.2, *Assessing Vulnerable Population*, also includes guidance on tornado and hurricane safe room population limits for FEMA grants eligibility.

For tornado safe rooms only intended for the portion of the public that falls within a given tornado protection (or intended occupant) zone (see Figure A4-2), safe room operators may consider coordinating with local officials to develop community-wide strategies for tornado protection awareness. This approach may prevent confusion and overcrowding. Although Figure A4-2 indicates a ½-mile radius for occupants walking to the safe room, a ½-mile radius typically applies to occupants driving to the site. For most adults, a 5-minute walking distance is about ¼ mile. Whether walking or driving to tornado safe room, anticipated travel time is the limiting factor, and while a safe room may be intended to serve occupants within a specific radius, travel time to the safe room depends upon the path prospective occupants take to reach the facility. Therefore, it may also be advisable to inform the residents of the best travel routes to the safe room location and provide corresponding signage.

Hurricane safe rooms are usually designed and built to provide life-safety protection for first responders and critical and essential services personnel and facility occupants. Community outreach for hurricane safe rooms should inform the community that the safe room is intended for specified "at-risk" groups. Also, communities that intend potential occupants to bring sufficient food to last the anticipated duration of the hurricane should provide this information to the community well in advance of the hurricane.

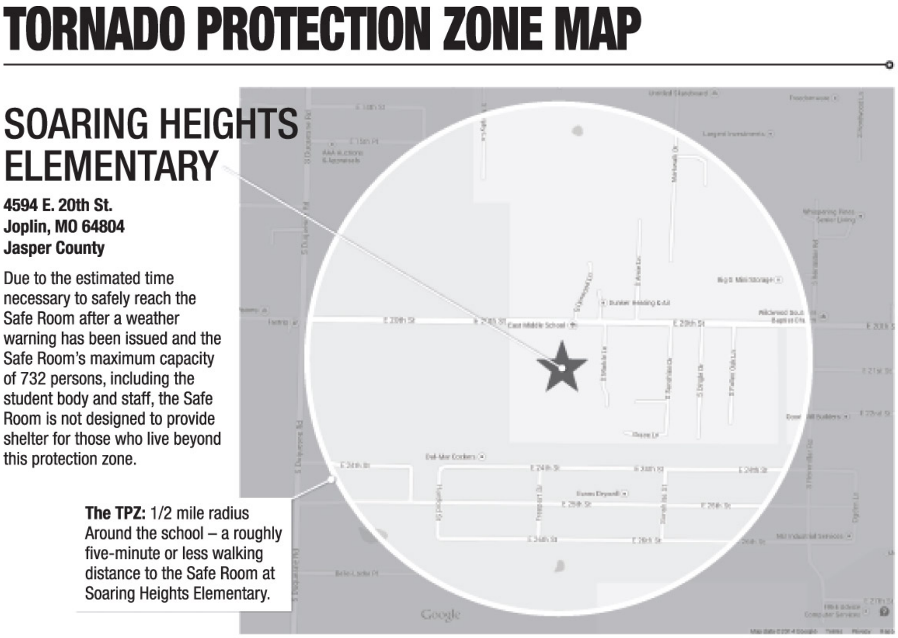


Figure A4-2. Example of a tornado protection zone map for a safe room intended to serve a specific protection (or intended occupant) zone

(SOURCE: JOPLIN SCHOOL WEBSITE, WWW.JOPLINSCHOOLS.ORG/DOMAIN/635)

A4.3.2 Signage

Placing information signs in clearly visible locations is important to alert communities to the presence of a safe room, the intended occupants and maximum occupancy of the safe room, the travel routes to the safe room, the location of the safe room entrance door, and other pertinent details. Depending on the population served, it may be necessary to include signs in languages other than English.

Safe rooms open to the general public. Signage is critical for occupants to be able to readily find and enter the safe room, especially when a safe room is inside a larger building (see Figure A4-3 for an example of a sign). In addition to directing potential occupants to the safe room, signs can also identify the area of the community the safe room is intended to serve, as shown in Figure A4-2, and can be posted to show the best travel routes to the safe room location. Signs can also inform the residents of the neighborhood served by a safe room about the occupancy limitations during any given event. Refer also to Section B5.2.4 of this publication for additional information on signage.

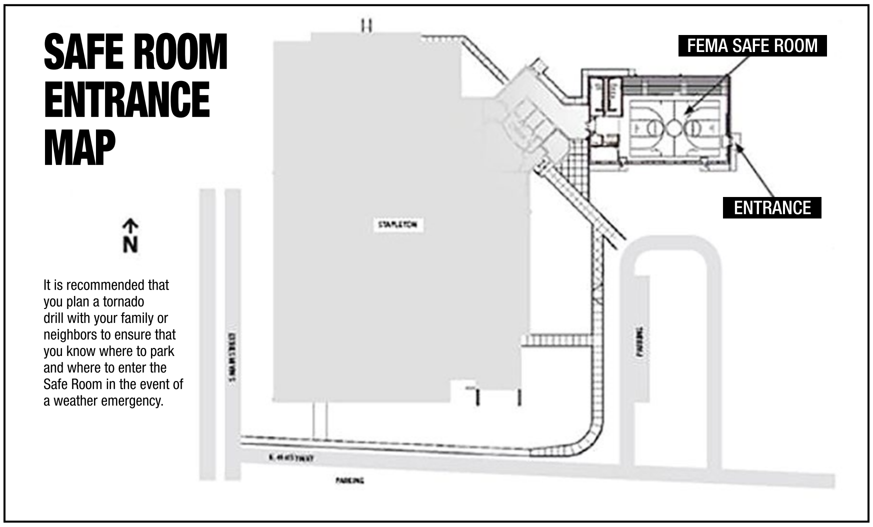


Figure A4-3. Example of a sign showing location for safe room entrance

(SOURCE: JOPLIN SCHOOL WEBSITE, WWW.JOPLINSCHOOLS.ORG/DOMAIN/635)

Safe rooms for specific occupants. The presence of safe room signage on the outside of a building can easily cause surrounding residents to assume they may use the safe room during a tornado, even when the safe rooms is designated for use solely by the occupants of the building, such as at a school, hospital, or private business. This unintentional miscommunication may be mitigated through community outreach and carefully placed and specifically worded safe room signage.

A4.3.3 Expectation of Safe Room Use during Off-Hours

Safe rooms for specific occupants. It is important for safe room owners and operators to clearly indicate to potential safe room occupants when the facility will be open. For example, will the safe room at a school be accessible after the regular school hours? At places of business, will the safe room be accessible after normal work hours? At hospitals, can employees bring their families into the hospital safe room? These types of questions should be answered by the owner/operator, specified in the O&M plan, and clearly communicated to potential occupants.

Note

OFF-HOUR USE

Safe room owners and operators should notify intended occupants of a safe room as to when the safe room is or is not available for use. For example, a school may decide their safe room is only for students and faculty use during school hours, but will be available to the surrounding community after school hours. Whatever policy is adopted, it should be clearly communicated to the community.

A4.3.4 Information on the Access and Functional Needs of Potential Safe Room Occupants

Some community safe room operators send access and functional needs request forms to those within the safe room protection zone to identify potential occupants with acute medical needs. The request forms can be used to prepare for the level of health care that may needed from the designated first aid or health services staff. Request forms can also be used to capture the potential number of service animals the safe room may need to accommodate.

If such request forms are circulated, then the responders' information should be maintained as part of the O&M plan and updated on a regular basis. All information gathered through access and functional needs request forms should be compiled and made available to appropriate safe room personnel for use during a high-wind event. Safe room staff registering arriving occupants can then use this information to notify personnel responsible for first aid and health services, as needed.

A4.3.5 Alert Signals and Drills

Potential safe room occupants should be informed of the community's emergency plans well in advance of an event and should be prepared to seek refuge in their pre-assigned safe room. It is extremely important that prospective safe room occupants recognize and understand the distinct warning signal that calls for them to proceed to the safe room. As noted in Section A2.1.2.2, warnings signals should be developed to reach individuals with access and functional needs and/or individuals who have limited English proficiency.

Neighborhoods that operate community safe rooms are encouraged to conduct regular exercises to test their operational preparedness and acquaint potential occupants with the safe room. In schools, work places, hospitals, and similar areas with regular occupants, storm refuge drills should be conducted (at least annually) to test the effectiveness of the O&M plan. Such drills will also test the signage, accuracy of contact information, knowledge of procedures by those enlisted with roles to perform, and the ability of the intended occupants to get to the safe room within the time limits. Any deficiencies found from these drills should be addressed in the O&M plan to improve the response. These tactical issues of drilling and training should be the responsibility of the safe room owners and operators or governing organization.

Clearly defined routes should be identified for safe room occupants as shown in Figure A4-4. Identified routes should be easily navigated and free of hazards (refer also to Section B4.2.1.6).

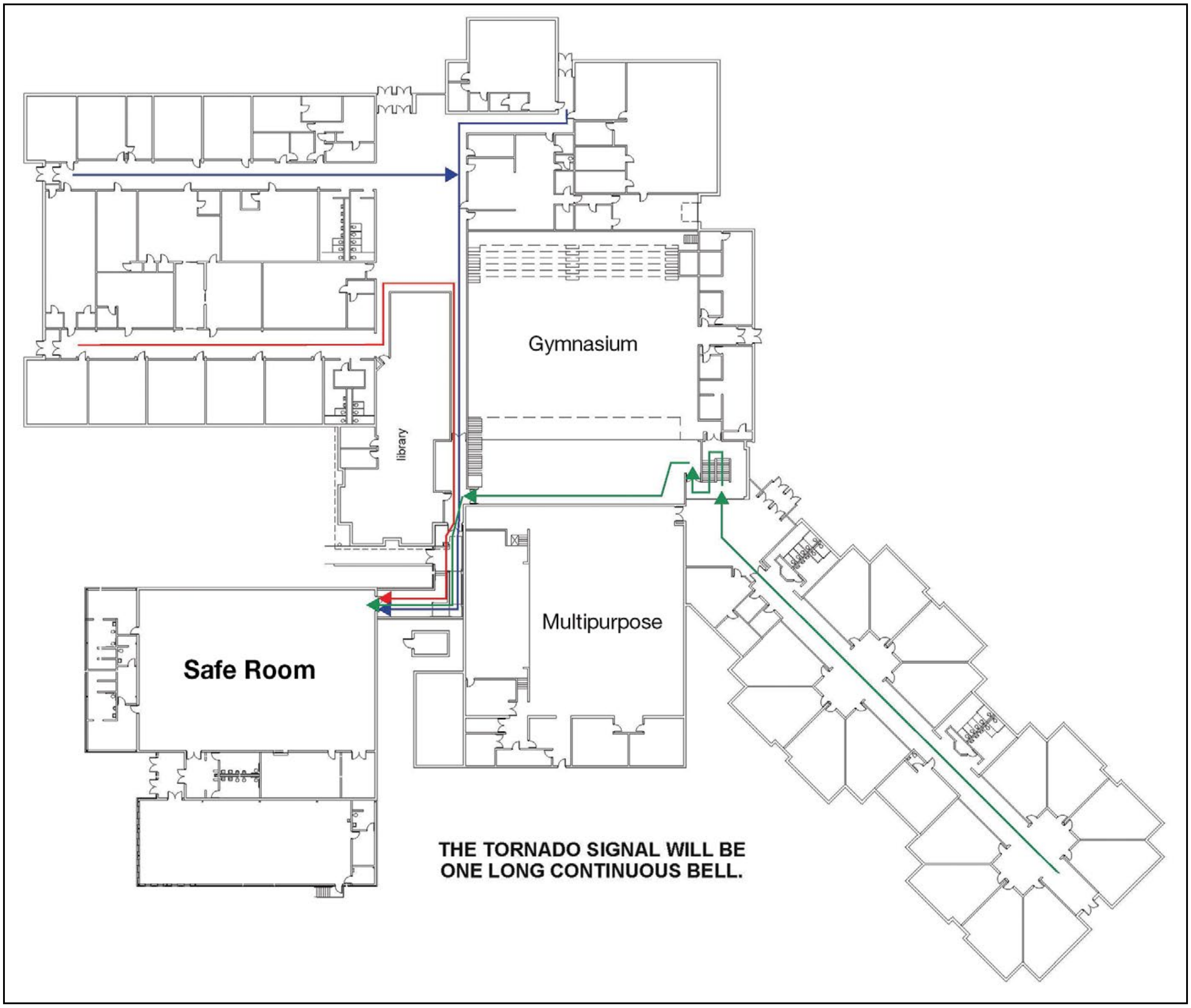


Figure A4-4. Example of a site plan clearly identifying safe room access routes
(SOURCE: HOLLISTER R-V SCHOOL DISTRICT 2013)

A4.3.6 Pets

Many people do not want to leave their pets during a storm. However, tornado and hurricane safe rooms are typically not prepared to accommodate pets. The policy regarding pets in a community safe room should be clearly stated in the O&M plan and be communicated to prospective occupants through public outreach to avoid misunderstandings and hostility when individuals arrive at the safe room. While some safe rooms allow pets confined in owner-provided, airline-approved carriers, many safe rooms allow only service animals. As described in Section A4.3.4, safe room operators may wish to identify the potential number of service animals the safe room may need to accommodate by distributing access and functional needs request forms to those within the safe room protection zone.

If a safe room owner or operator chooses to provide protected space for pets, operational plans should be developed and coordinated with designers so any requirements for the specific types of animals expected at the safe room can be met. Special accommodations for the animals might include separation distances, readily cleanable areas with drainage, a quarantine area for sick animals, more space depending on the sizes of the animals, etc.

A4.4 Emergency Provisions

Emergency provisions needed vary for different wind events. In general, emergency provisions will include food and water, communications equipment, and emergency supplies. Safe rooms serve a different function from long-term recovery shelters; however, safe room managers may elect to provide supplies that increase the comfort level of safe room occupants. For additional information, refer to Chapter B7, especially Sections B7.2.3 and B7.2.6. The following discussion is relevant to all safe rooms, regardless of its intended use.

A4.4.1 Food and Water

For tornado safe rooms, because of the short duration of occupancy, stored food is usually not a primary concern, but provision of water should be addressed in the O&M plan.

For hurricane safe rooms, since they can be occupied for 24 hours or more during a hurricane, food and water will be needed. Some O&M plans charge occupants with the responsibility of bringing enough food to last for the anticipated duration of the hurricane. Regardless, provision of food and water should be addressed in the O&M plan.

MORE INFORMATION

FEMA and American Red Cross publications concerning food and water storage in safe rooms may be found at www.fema.gov and www.redcross.org.

A4.4.2 Communications Equipment

FEMA recommends having a means of communication other than a landline telephone or cellular telephone in all safe rooms. Both tornadoes and hurricanes are likely to cause a disruption in either type of telephone service. At least one means of backup communication should be stored in or brought to the safe room such as a handheld amateur radio, citizens' band radio, or emergency radios capable of reaching police, fire, or other emergency services. If cellular telephones are relied upon for communications, the owners/operators of the safe room should install a signal amplifier to send and receive cellular signals from within the safe room. Occupants should remember that cellular systems may be completely saturated in the hours immediately after an event because of the amount of cell phone traffic, or cellular service could be unavailable because of damaged cell phone towers.

FEMA also recommends that every safe room contain either a battery-powered radio transmitter or a signal-emitting device that can signal the location of the safe room to local emergency personnel if occupants in the safe room become trapped by debris blocking the exit. The safe room owner/operator is also encouraged to register the safe room with police, fire, and rescue organizations after installation or construction. Providing geographic coordinates to the safe room entrance can facilitate post-event search and rescue operations.

A4.4.3 Emergency Supplies (ICC 500 Sec 702.4 and 703.7)

Community safe rooms should contain emergency supplies for the safety and well-being of the occupants. At a minimum, community safe rooms should contain the following safety equipment:

- Flashlights with continuously charging batteries

- Fire extinguishers (number based on occupancy type) appropriate for use in a closed environment with human occupancy, either surface-mounted on the safe room wall or in a recessed cabinet in a partition wall (required per ICC 500 Section 602)
- First aid kits rated for the safe room occupancy (required per ICC 500 Section 703.7)
- NOAA weather radio with continuously charging batteries
- Radios with continuously charging batteries for receiving commercial radio broadcasts
- A supply of extra batteries to operate radios and flashlights
- A sounding device that continuously charges or operates without a power source (e.g., canned air horn) to signal rescue workers if safe room egress is blocked
- Tools to open inoperable or debris-blocked doors. A crowbar and sledgehammer should be kept in the safe room in case debris falls against the door and prevents exiting the safe room after an event

A4.5 Access and Entry

Gaining access to the safe room can become a source of frustration for occupants seeking life-safety protection from an impending tornado or hurricane. The O&M plan should provide details on procedures for parking, entering the safe room, registering incoming occupants, and locking down the safe room before the tornado or hurricane strikes. As described in Section A4.3, the community needs to be informed well before an event occurs to avoid confusion and panic.

A4.5.1 Parking

Safe rooms open to the general public. Parking problems can adversely affect safe room access, potentially preventing occupants from entering the safe room before a tornado or hurricane strikes. Reasonable assumptions should be made about parking for safe room occupants based on its intended operations, and planned for accordingly. If the planning assumptions are not reasonable, there might not be enough parking spaces during an actual event, which can prevent people from quickly accessing the safe room. For instance, parking capacity at community safe rooms can be a problem if neighborhood residents, who are expected to walk, drive to the safe room instead. Parking should be tested during a drill, per Section A4.3.5, to see if the planning assumptions are reasonable and the O&M plan is effective. If not, the planning assumptions and O&M plan should be modified accordingly.

A4.5.2 Entering the Safe Room

Safe rooms open to the general public. Confusion has occurred during past tornado events when residents evacuated their homes to go to a community shelter, but could not get in. For example, during the Midwest tornadoes of May 3, 1999, residents in a Wichita neighborhood went to their assigned tornado shelter only to find it locked. Eventually, the shelter was opened prior to the event, but had there been less warning time for the residents, people could have been injured or killed.

The O&M plan should clearly state who is to open the safe room and identify backup personnel to respond during every possible emergency. Some community safe rooms have been installed with locks that can be operated remotely. When triggered by community alert signals, remote unlocking systems can improve safe room access efficiency. These can be set to open automatically whenever there is a watch issued for the area, sirens are activated, or at the discretion of the owner or operator of the safe room. They can also be set to turn on lights so that the occupants do not have to search for light switches. Remote unlocking can be beneficial during evening and nighttime hours when people are not likely to already be present and able to open the facility immediately. If the remote unlocking is not automatically triggered and requires human intervention, it is wise to provide a 24-hour facility, such as a sheriff's office, with access to unlock the safe room.

Safe rooms for specific occupants. When a safe room is open to only a select group of occupants, the safe room owner and operator should make sure the policy on who can enter the safe room is clearly communicated (refer also to Section A4.3). Contingencies should be in place for visitors that may be present on site during an event. As with safe rooms open to the general public, redundancy for opening the safe room should be provided by identifying backup personnel to arrive and unlock the safe room for entry. Some small community safe rooms and other safe rooms for specific occupants have given keys or access codes to all identified potential occupants.

EXAMPLE

The *Joplin Schools Community Safe Room Shelter Operations Plan* lists separate safe room operations and personnel for school hours versus non-school hours.

According to the plan, when a tornado watch or warning is issued during non-school hours, the "school district's automation system will unlock [the safe room doors] and turn on the safe room lights."

Source: www.joplinschools.org/saferooms (Refer to Shelter Operations Plan).

A4.5.3 Registering Occupants

Registering and tracking all incoming occupants of a safe room is an important process. This will enable safe room operators to identify which occupants may need special medical attention or have other specialized needs (refer also to Section A4.3.4). Suggested information to collect would be the number of occupants, genders, ages, and relative location they came from and approximate travel time. The data collected can be used for post-event analysis of occupancy numbers, estimated travel distances, assumptions that may require modification, parking adequacy, and other related issues that may need to be updated in the O&M plan to improve future safe room use.

In cases of extreme urgency, the registration process should not impede the occupants' admission into the safe room, and may be conducted after the safe room has been secured. The registration process should not slow the movement of occupants into the safe room, but may be conducted near the entrance of the safe room, with signs posted to clearly direct people to the registration area. The list of occupants can be used to account for all occupants after the event.

A4.5.4 Locking Down the Safe Room

Locking down a safe room refers to the final preparations of the safe room that are vital to provide near-absolute occupant protection from the hurricane or tornado. Locking down the safe room includes tasks such as closing and latching all operable shutters (see Figure A4-5) and doors.

All safe rooms. The process of locking down the safe room needs to be done before tornado or hurricane conditions pose a threat to the occupants. A final check should be made before locking down the safe room to ensure no more citizens are approaching, but a judgment call may be necessary when a tornado strike is imminent. Warning times for hurricanes are typically much longer, so people have more time to prepare and get to a safe room than is the case with tornado warnings. As a result, locking down a hurricane safe room is generally less urgent.

Figure A4-5. Interior operated safe room shutters in multi-purpose classroom/safe room. Image on left is normal usage; image on right shows shutters in 'lock down' position where they are closed and latched

Safe rooms for specific occupants. O&M plans for schools may wish to include a step to ensure all students are accounted for prior to lockdown.

A4.6 Operations during an Event

Safe room operations during an event include maintaining security and safety, providing first aid, and establishing and maintaining communication to applicable entities outside the safe room. While not exhaustive, the operations described in the following section should be addressed in the safe room O&M plan.

A4.6.1 Security

Safe rooms open to the general public. Safe room security and safety must be maintained by controlling the movement of people and preventing unauthorized entry into hazardous or secured areas, or unauthorized exit before the event has passed. Some O&M plans may assign security responsibilities to members of the community police force to facilitate crowd control and enhance enforcement of safe room rules. Security operations and related responsibilities should increase with the safe room's anticipated population.

Safe rooms for specific occupants. If the safe room is at a residential care facility such as a nursing home or hospital, additional areas within the facility may need to be protected. Such areas may include medical and pharmaceutical supply storage areas and intensive/critical care areas that house non-ambulatory patients. A safe room should meet the needs of all of its occupants.

A4.6.2 First Aid and Health Services

All safe rooms. Safe room staff with the necessary training and certification should be designated in the O&M plan to administer first aid as needed (see A4.2.2). Tornado safe rooms should be prepared for occupants to arrive injured as people are often injured in their haste to access the safe room. Hurricane safe rooms may need to appoint personnel to administer first aid and address other health issues that may arise during the extended stay.

Note

FIRST AID SUPPLIES

The first aid supplies shown in Table B7-1 are required in all FEMA-funded safe rooms.

Information collected on the access and functional needs of potential occupants (refer to Section A4.3.4) should be made available at the user registration desk to identify arriving occupants with possible impending health service needs.

A4.6.3 Communication

All safe rooms. Communication between the safe room, local EOCs, and other components of the disaster relief operation are critical during an extreme-wind event. Depending on the event, the staff responsible for establishing initial (pre-event) contact and a working relationship with the local EOC may also need to monitor weather conditions remotely to provide occupants with updated information. Section A4.4.2 includes a discussion on alternate means of communication that may be needed when telephones are out of order or anticipated to be out of order.

Upon receiving confirmation that danger has passed, the designated decision-maker will need to alert occupants that it is safe to exit the safe room.

A4.7 Post-Event Operations

Immediately after an event, all occupants should be accounted for, especially those that have medical needs to ensure they receive the care they need. Any equipment brought to the safe room for either medical or other reasons should be returned. Equipment used during the event, such as generators and backup utility sources, should be turned off as they are no longer needed.

Safe room operators need to coordinate closing down the safe room and preparing it for a future event. The safe room should be cleaned after an event and all the supplies should be inventoried and items replaced as needed, including food, water, and supplies.

Safe room owners and operators should review the O&M plan after an event and incorporate any lessons learned so that improvements to the plan are tracked and implemented. The O&M plan should be reviewed, and preventable problems that occurred should be fixed for future events. In some cases, developing an action report outlining the successes and failures of safe room operation components may be helpful in improving the O&M plan through revision.

A4.8 Maintenance

An effective maintenance plan will help ensure that the safe room equipment and supplies are fully functional during and after events. Each community safe room should include maintenance information in its O&M plan, including the following:

- **Update schedule.** A schedule for updating the O&M plan. Regardless of whether an event occurred, the safe room O&M plan should be reviewed and updated at least annually to ensure the most current information is included in the plan.
- **Inventory checklist.** An inventory checklist of the emergency provisions described in Section A4.4. Inventory checklists for a variety of safe room examples are available on the FEMA safe room website O&M plan section available at www.fema.gov/example-operations-and-maintenance-plans-community-safe-rooms.
- **Redundant power.** Information about the designated redundant power source(s) (e.g., batteries and/ or emergency generators) needed to satisfy the safe room stand-by power requirements for lighting and ventilation (refer to Sections B7.2.4 and B7.2.5).

- **Maintenance schedule.** A schedule showing regular safe room maintenance to be performed by a designated party. Regular maintenance and periodic testing should be performed for the following:
  - Designated stand-by power source. All batteries and fuel for emergency generators, flashlights, and emergency exit signs should be replaced, cycled out, or recharged according to schedule.
  - Door assembly. Testing the door assembly is especially important since specialized safe room door hardware can easily fall out of adjustment, rust or stick due to lack of lubrication resulting in and failure to quickly engage during an event. If door hardware needs to be replaced, it is important to make sure the replacement meets the performance criteria.
  - Ventilation, sanitation, and lighting systems.
- **Perishable schedule.** A schedule for checking perishable safe room items such as bottled water and food for their "use by" dates or scheduled cycling out.
- **Inventory schedule.** A schedule for inventorying and testing emergency equipment and tools to ensure they are in working condition.

Part B

CHAPTER B1
Application and Administration

This chapter uses Chapter 1 of ICC 500 as the referenced standard and includes a list of Recommended Criteria FEMA has identified as more conservative than the provisions in Chapter 1 of ICC 500. This chapter also includes FEMA supplemental commentary on the application and administration of safe rooms based on many years of field observations and investigations related to safe room performance.

FEMA SAFE ROOM GRANT REQUIREMENTS

Whenever a safe room is constructed with FEMA grant funds, the Recommended Criteria in Section B1.1 become requirements in addition to the requirements of ICC 500 Chapter 1.

B1.1 Criteria

The application and administration of safe rooms should be conducted in accordance with the provisions of Chapter 1 in ICC 500 with the exception of FEMA's Recommended Criteria as shown in Table B1-1.

Table B1-1. Comparison of ICC 500 Requirements to FEMA Recommended Criteria

ICC 500 REFERENCE	ICC 500 REQUIREMENTS FOR STORM SHELTERS	FEMA RECOMMENDED CRITERIA FOR SAFE ROOMS[(a)]
Section 107.1 General	Where required by the authority having jurisdiction, construction documents shall be prepared. Such documents shall contain information as required by the applicable building code and this section.	**For all safe rooms** construction documents shall be prepared **and maintained.** Such documents shall contain information as required by the applicable building code and this section.
Section 107.2.1 Design Information	For the areas of a building designed for occupancy as a storm shelter, the following information shall be provided within the construction documents: 2. A statement that the wind design conforms to the provisions of the ICC/NSSA *Standard for the Design and Construction of Storm Shelters*, with the edition year specified.	2. A statement that the wind design conforms to the provisions of the ICC/NSSA Standard for the Design and Construction of Storm Shelters, with the edition year specified **and to the provisions of FEMA P-361, with the edition year specified.**

Bolded text denotes differences between the ICC 500 Requirement and the FEMA Recommended Criteria.

Table note:
(a) Table only lists differences between FEMA P-361 and ICC 500 Chapter 1. All ICC 500 Chapter 1 requirements not listed in the table should also be met in their entirety.

B1.2 FEMA Supplemental Commentary

FEMA offers the following commentary and background information as supplemental guidance to the registered design professional for the criteria referenced in ICC 500 Chapter 1.

B1.2.1 Single-Use and Multi-Use Safe Rooms (Reference: ICC 500 Sec 104)

Safe rooms are used solely for sheltering (single-use) or have multiple purposes, uses, or occupancies (multi-use). Safe room uses (either single-use or multi-use[1]) may affect the type of safe room selected and its location. An internal or external safe room may be used for sheltering only, or it can have multiple uses. For example, a multi-use safe room at a school may also function as a classroom, a lunchroom, a laboratory, or an assembly room (Figure B1-1). Similarly, a multi-use safe room intended to serve a manufactured housing community or single-family-home subdivision may also function as a community center.

The decision to design and construct a single-use or a multi-use safe room will likely be made by the owner or operator of the safe room. To help the designer respond to non-engineering and non-architectural needs of property owners, this section discusses how safe room use may affect the type of safe room selected.

Figure B1-1. The addition to this school was designed to serve as a multi-use safe room; it is also used as a cafeteria, gym, and for large group gatherings (Wichita, KS)

B1.2.1.1 Multi-Use Safe Rooms (Reference: ICC 500 Sec 104.1)

The ability to use a safe room for more than one purpose often makes a multi-use stand-alone or internal safe room appealing to a safe room owner or operator. Multi-use safe rooms also allow immediate return on investment since the safe room space is used for daily business when it is not being used during a tornado or hurricane.

1 FEMA's *Hazard Mitigation Assistance Unified Guidance* (July 2013) calls multi-use safe rooms "dual-use" safe rooms. "Dual-use" means the same as "multiple-use" used in this publication. Contact the closest FEMA regional office for the latest FEMA policy on safe rooms.

Examples of multi-use safe rooms

The MAT investigations of the 2011 tornado outbreak (FEMA P-908), the May 3, 1999 tornadoes (FEMA P-342), and other tornado and hurricane events have found many examples of multi-use safe rooms (Figure B1-1). They include:

- Cafeterias, classrooms, hallways, music rooms, and laboratories in schools
- Cafeterias/lunchrooms, hallways, and bathrooms in public and private buildings
- Lunchrooms, hallways, and surgical suites in hospitals

CROSS-REFERENCE

Chapter B5 discusses criteria for calculating usable square footage for safe room areas. Auditoriums, laboratories, and libraries are examples of building uses that have permanent fixtures or furniture that reduce the available safe room area and must be accounted for when determining the maximum safe room population.

Hospitals, assisted living facilities, and other healthcare centers are additional examples of buildings that may benefit from multi-use, internal safe rooms. For these facilities, constructing multi-use safe rooms in areas where there are occupants who cannot be evacuated rapidly, such as intensive care units or surgical suites, would provide immediate return on investment for the safe room space. Hospitals may also need to construct additional community safe rooms for staff, patients, and visitors who may not be allowed into specially controlled portions of the hospital. Internal multi-use safe rooms in these types of facilities allow space to be optimized while providing near-absolute protection with easy access for non-ambulatory persons.

Cost

FEMA-sponsored projects have been evaluated to identify the additional cost to design and construct a FEMA P-361-compliant safe room in a new building. The FEMA project evaluations indicate that, although the cost to construct this portion of a building to meet FEMA P-361 may be 5 to 32 percent higher than normal design and construction, this percent cost increase is often less than 5 to 10 percent of the entire building construction project. Therefore, modifying a portion of a large project to be a safe room should result in a minimal cost increase compared to adding a stand-alone safe room.

B1.2.1.2 Single-Use Safe Rooms (Reference: ICC 500 Sec 104.2)

Single-use safe rooms are, as the name implies, used only in the event of a tornado or hurricane. One advantage of single-use safe rooms is that they usually have a simplified design that may be readily accepted by a local building official or fire marshal. Single-use safe rooms typically have simplified electrical and mechanical systems because they are not required to accommodate the normal daily needs of occupants. Another advantage of single-use safe rooms is that, when managed properly, they are not cluttered with furnishings and other items taking up floor space that might be needed in an emergency, which can be an issue with multi-use safe rooms.

CODES AND STANDARDS

For single-use community safe rooms with less than 50 occupants, ICC 500 requires the designated occupancy to follow Section 303 of the IBC. For single-use community safe rooms with an occupant load of 50 or greater, the occupancy type should be A-3 (assembly). For multi-use safe rooms, the occupancy type should be that of the primary use of the protected space when not in use as a safe room.

Examples of single-use safe rooms

Many single-use safe rooms were observed during the MAT site visits after the 2011 tornado outbreak, in both residential and community applications (see FEMA P-908, 2011a). Below-grade residential safe rooms were common and were mostly single-use. Although some internal, above-ground residential safe rooms are single-use, it is more common for them to be multi-use because of the ease of using the safe room for other functions, such as a closet. Figure B1-2 shows an example of a stand-alone single-use community safe room, and Figure B1-3 shows an example of a residential single-use safe room.

Figure B1-2. Prefabricated steel single-use community safe room (Brookwood, AL)

Figure B1-3. Single-use residential safe room after an EF5 tornado (Newcastle, OK)

Maintenance

The advantage of a readily available single-use safe room in an emergency can easily turn to a disadvantage if a proper O&M plan is not followed diligently. In the absence of regular use, the safe room may soon acquire other unintended functions (e.g., for temporary storage or similar uses) that can seriously impede its primary function (Figure B1-4). This problem can be avoided by adhering to a safe room O&M plan.

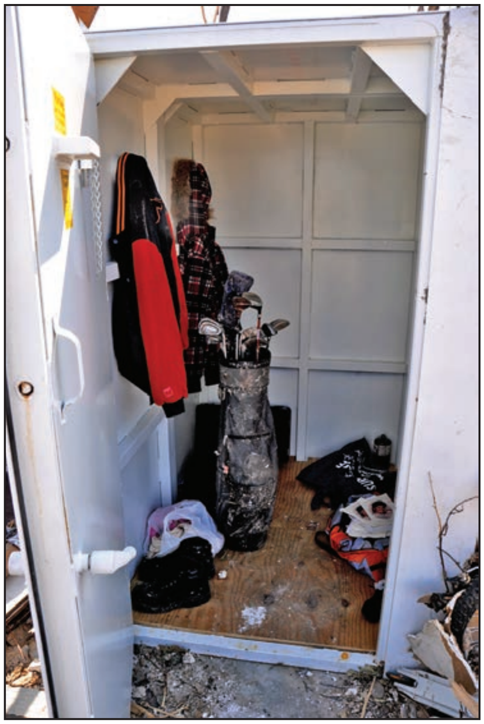


Figure B1-4. Safe room with items stored inside; such items take up space and reduce occupant capacity (Joplin, MO)

Cost

The cost of designing and constructing a single-use safe room is generally the same as for a multi-use safe room, or possibly lower because of the simplicity of the design requirements for a single function. However, the installation of single-use safe rooms can be perceived as having a much higher cost than a multi-use safe room because no other benefit is provided with the construction of the new building. This perception may also be related to the fact that the cost of operating and maintaining multi-use safe rooms can be incorporated into the cost of operating and maintaining the facilities' alternate function for a small increase in overall cost, while the cost of operating and maintaining a single-use safe room would not be incurred if the safe room itself did not exist.

B1.2.2 Permitting, Review, and Inspections (Reference: ICC 500 Sec 105 and 106)

This section clarifies the permitting, compliance, and involvement of the registered design professional in the safe room design and permitting process, specifically permitting and code compliance, peer review, special inspections and acceptance, and structural observations.

Where requirements are not provided by FEMA P-361, the applicable provisions of the codes adopted by the AHJ apply to the safe room. Safe rooms constructed in jurisdictions where no applicable codes are adopted should be designed and constructed according to FEMA P-361 and the provisions of the 2015 or most current edition of the IBC.

CODES AND STANDARDS

Section 423.3 and 423.4 of 2015 IBC requires ICC 500 storm shelters to be incorporated when any of the following are constructed:

- K-12 school buildings with occupant load of 50 or more;
- 911 call stations;
- fire, rescue, ambulance, and police stations; and
- emergency operations centers.

The requirement only applies in the 250 mph tornado wind speed zone (see Figure B3-1 for wind speed zone details) and limited exceptions are provided.

B1.2.2.1 Permitting and Code Compliance

Before construction begins, all necessary State and local building and other permits should be obtained. The registered design professional should meet with the local code official to discuss any concerns the building official may have about the safe room design. This meeting would help ensure that the safe room is properly designed and constructed to local ordinances or codes in addition to the provisions of FEMA P-361.

The requirement for the design and construction of storm shelters and safe rooms to meet or exceed the criteria in ICC 500 or FEMA P-361 is established by the AHJ. They establish this by either adopting the 2009 or later editions of the IBC and IRC that incorporate the ICC 500 standard by reference or by explicitly adopting FEMA P-361 or ICC 500 as a design standard for safe rooms or storm shelters.

CODES AND STANDARDS

This publication supersedes the FEMA *National Performance Criteria for Tornado Shelters*, 1999, as well as any earlier versions of FEMA P-361.

Complete detailed plans and specifications should be given 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; ADA requirements if it is a public safe room; and mechanical, electrical, and plumbing recommendations should be shown on the construction documents and specifications (see Section B1.2.3 for additional information on documenting safe room information on construction documents).

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 ICC 500 or the AHJ. The additional cost of providing mechanical, electrical, and plumbing equipment and facilities for the high-occupancy load that would occur only when people are using the safe room for tornado or hurricane protection might not be reasonable. For this reason, safe rooms designed to the criteria in this publication are for short-duration use, and the probability of their use at maximum occupancy is low. Minimum requirements for ventilation and sanitation management in safe rooms can be found in Chapter B7.

B1.2.2.2 Peer Review (Reference: ICC 500 Sec 106.1.1)

Construction documents for community safe rooms designed for more than 50 occupants, as well as for safe rooms in an elementary school, secondary school, day care facilities with an occupant load greater than 16, or any Risk Category IV building should undergo a peer review by an independent registered design professional for conformance with the design criteria described in this chapter.

Note

PEER REVIEW CRITERIA

FEMA P-361 and ICC 500 peer review criteria are now both triggered when safe rooms or storm shelters are designed for more than 50 occupants.

This peer review should include review of elements associated with structural design (including missile impact resistance), occupancy, means of egress, access, and accessibility, fire safety, and essential features (such as ventilation, sanitation, and backup power). These issues correspond to Chapters 3, 5, 6, and 7 of ICC 500 and this publication. The registered design professional performing the peer review should not be the same registered design professional who provides the design oversight recommended in Section B1.2.2.4.

CODES AND STANDARDS

Risk Category IV buildings are defined as essential facilities in the IBC; for more information, see Table 1604.5 of the 2015 IBC.

IBC-consistent Risk Category classifications for buildings can be found in Table 1.5-1 of ASCE 7-10.

A signed and sealed report should be submitted to the AHJ. This report should include detailed descriptions of the items reviewed, whether or not the items are compliant with the applicable standards and codes, whether or not the safe room design is acceptable, and if not, recommendations to make it acceptable.

B1.2.2.3 Special Inspections and Acceptance (Reference: ICC 500 Sec 106.2, 106.3)

Inspection of post-installed anchors

As more safe rooms and storm shelters are installed, many units (including prefabricated safe rooms or shelters) are being installed directly onto existing slab-on-grade foundations through post-installed anchor applications. These existing foundations are typically not adequate to resist the extreme-wind loads that a safe room or storm shelter must be designed for. Therefore, in addition to the slab being checked for compliance with the minimum slab thickness and minimum steel reinforcement requirements found in Section 308.1.1.1 of ICC 500, engineering calculations need to be provided to verify the adequacy of the existing slab (refer to Section B3.2.4.3.3). Post-installed anchors typically depend on adhesive bonding for pull-out resistance, making the performance of the connection highly dependent on the installation. Post-installed anchors must be appropriately selected by the designer and installed in accordance with the manufacturer's installation instructions as required in Chapter 17 of the American Concrete Institute (ACI) standard ACE 318-14, *Building Code Requirements for Structural Concrete* (ACI 2014 or later edition). ***As a best practice, any installer of post-installed epoxy anchors should be certified as an ACI-CRSI Adhesive Anchor Installer.***[2]

BEST PRACTICE

ICC 500 requires a special inspection to be performed when anchors are post-installed into hardened concrete or masonry for shelter (or shelter component) anchorage. The special inspection is intended to verify the anchor installation and capacity, as well as the foundation adequacy as detailed above. The special inspection requirements in Section 106.3.1 of ICC 500 can be bypassed on residential safe rooms only if the AHJ verifies that the foundation and anchoring complies with the installation requirements for the safe room or storm shelter.

FEMA strongly recommends that building officials or other AHJ parties ensure that the installation of the safe room complies with the design plans or the manufacturer's installation instructions (in the case of prefabricated safe rooms) before granting a waiver for the special inspection. This can be done by having the installer provide the AHJ with the necessary information ahead of the construction process, including the engineering calculations verifying the adequacy of the slab and any existing conditions, such as the thickness of the slab and the presence of any required steel reinforcement.

B1.2.2.4 Structural Observations (Reference: ICC 500 Sec 106.4)

The building owner should employ a registered design professional during the construction of a community safe room. The registered design professional should be licensed in the State in which the safe room will be constructed or installed. The task for the registered design professional is to visually observe the construction of the structural system for general conformance to the approved construction documents at significant construction stages and when the structural system is completed. Structural observation does not eliminate the need for other inspections or testing as specified by this publication, ICC 500, or the applicable building code (e.g., IBC Chapter 17, Special Inspections and Tests).

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

2 ACI and CRSI (Concrete Reinforcing Steel Institute) operate a program to train and certify Adhesive Anchor Installers (www.concrete.org/certification/certificationprograms.aspx).

B1.2.3 Construction Documents (Reference: ICC 500 Sec 107)

Although not all jurisdictions require detailed construction documents, compliance with the FEMA criteria presented in this publication requires that construction documents be prepared and maintained. Such documents should contain information as required by the applicable building code, the AHJ, and Section 107 of ICC 500 with the exceptions shown in Table B1-1 of this chapter.

> **TERMINOLOGY**
>
> **Construction Documents:** IBC defines construction documents as written, graphic, and pictorial documents prepared or assembled for describing the design, location, and physical characteristics of the elements of a project necessary for obtaining a building permit.

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 construction drawings. In addition, every safe room should have signage clearly identifying it as a safe room designed to provide life-safety protection to its occupants at a specified performance level as described in Section B1.2.4. The ICC 500 now requires all impact protective systems to have a label indicating that they have passed testing and comply with the standard. There is no universal format for labels at this time; manufacturers only need to say that the product has been tested for specific functions and performance characteristics.

B1.2.3.1 Quality Assurance / Quality Control (Reference: ICC 500 Sec 107.3)

Because a tornado or hurricane safe room is expected to provide near-absolute protection, quality assurance and quality control (QA/QC) for the construction of safe rooms should be more stringent than that used for normal building construction. Submittals should be thoroughly scrutinized for accuracy and compliance with contract documents. A registered design professional should prepare a 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.

Quality assurance plan (Reference: ICC 500 Sec 107.3.1)

A quality assurance plan should be provided for all items required in Section 107.3 of ICC 500. The registered design professional should supply enough information to facilitate the safe room being built in accordance with the design and performance criteria of this publication. The quality of both construction materials and methods should be ensured through the development and application of a quality control program.

Contractor's responsibility (Reference: ICC 500 Sec 107.3.3)

Each contractor responsible for the construction, fabrication, or installation of a main wind-force resisting system (MWFRS), doors, and windows, or any component listed in the quality assurance plan should submit a written statement of responsibility to the AHJ, the responsible registered design professional, and owner before beginning work on the system or component. The contractor's statement of responsibility should contain:

- Acknowledgement of awareness of the special criteria contained in the quality assurance plan
- Acknowledgement that control will be exercised to obtain conformance with the contract documents
- Procedures for exercising control within the contractor's organization, and the method and frequency of reporting and distributing reports
- Identification and qualifications of the person(s) exercising such control and their position(s) in the organization
- Information on the installation and construction of the MWFRS
- Acknowledgement of proper installation of the impact protective systems

While contractors should not be held responsible for whether components manufactured by others meet safe room criteria, they should be held responsible for purchasing and installing components that are consistent with the contract documents and instructions provided by the manufacturer so that they provide the appropriate level of protection.

B1.2.4 Design Information Signage and Labeling (Reference: ICC 500 Sec 108)

For additional information on signage criteria and recommendations for community safe rooms, see Section B5.2.4 and Section A4.3.2.

TERMINOLOGY

Signage: Refers to physical signs placed on or in a safe room to convey information about safe room properties and location.

Label: An independent certification permanently affixed to a product to identify key characteristics of the product.

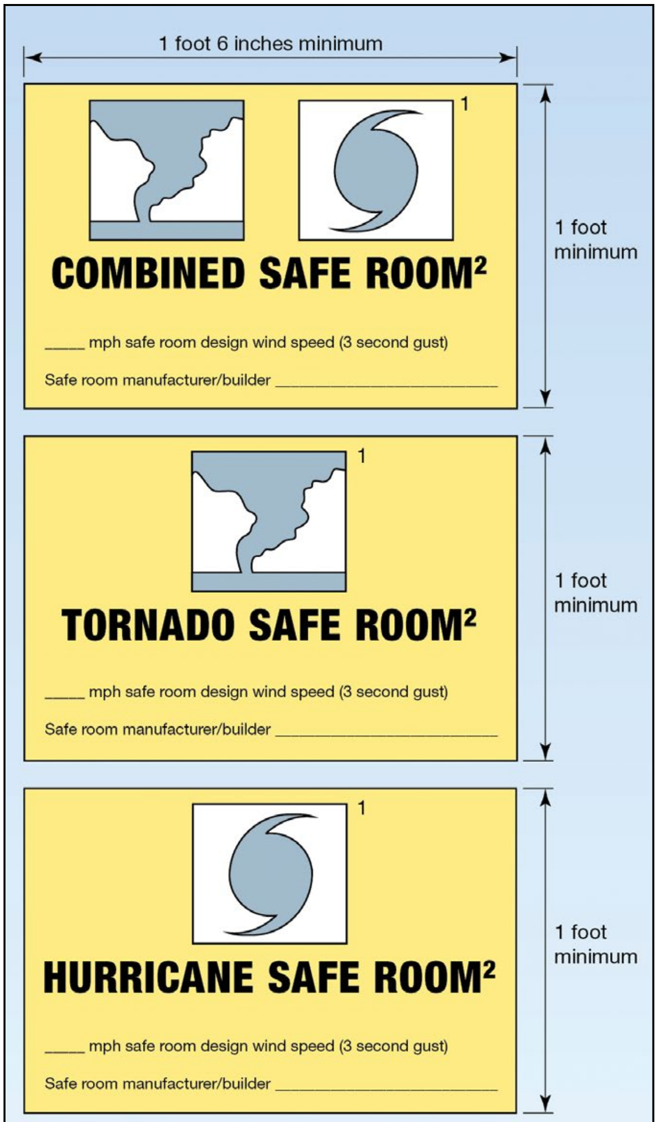
Design Information Signs

All safe rooms should have a visible and legible sign outside or inside the safe room, as illustrated in Figures B1-5 and B1-6. Signs should include the following information:

- Name of the manufacturer or builder of the safe room
- Its purpose (i.e., the storm type: tornado or hurricane)
- The design wind speed

Labeling

Any products, materials, or systems specified for occupant protection should be labeled by the agency that approved them to show the name of the manufacturer and performance characteristics, such as the test missile size and speed, and test pressure. While ICC 500 requires protective systems for openings to be labeled indicating compliance with the standard, there is no universal format for such labels. A representative example is shown in Figure B1-7.



1. The applicable picture should be shown for the hazard(s) the safe room has been designed to resist: tornado, hurricane, or combined (show both pictures).
2. The applicable hazard should be shown here. For a safe room designed to resist both hurricanes and tornadoes, use the term "combined."

Figure B1-5. Example of signage with safe room design information

Figure B1-6. Examples of design information signs; though these include Missile Impact Resistance information, such information is not required

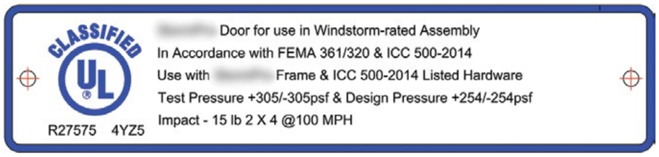


Figure B1-7. Example door label for a product that has been tested to safe room criteria

CHAPTER B2
Definitions

This chapter defines certain "terms of art" and phrases that are used in this publication to mean something specific. Any term not defined here should be understood as having a commonly accepted meaning as implied by its context. Definitions are taken from FEMA publications and guidance materials as well as from Chapter 2 of ICC 500.

Definitions reprinted from ICC 500 are referenced accordingly; the definitions are reprinted here with permission from the ICC. For ICC 500-sourced definitions, references to storm shelters also apply to safe rooms.

Applicable code (ICC 500)
The regulation for design and construction of buildings and structures adopted by the authority having jurisdiction over the construction of the specific shelter.

Areas of concentrated furnishings (ICC 500)
The areas of a storm shelter with furniture or fixtures which cannot be easily moved, including areas such as bathrooms, locker rooms, and rooms with fixed seating or fixed tables.

Areas of open plan furnishings (ICC 500)
The areas of a storm shelter which are generally free of furniture or fixtures which cannot be easily moved and of interior partitions or other features which block movement through or otherwise subdivide the space.

Areas of unconcentrated furnishings (ICC 500)
The areas of a storm shelter with furniture or fixtures which can be easily moved, including areas such as classrooms and offices.

Authority having jurisdiction (ICC 500)
The organization, political subdivision, office, or individual charged with the responsibility for administering and enforcing the provisions of building codes and code-adopted standards such as ICC 500.

Best available refuge area
Areas in an existing building that have been deemed by a registered design professional to likely offer the greatest safety for building occupants during a tornado. These areas were not specifically designed as tornado safe rooms, and as a result, occupants may be injured or killed during a tornado. However, people in best available refuge areas are less likely to be injured or killed than people in other areas of a building (text modified from FEMA P-431, *Tornado Protection: Selecting Refuge Areas in Buildings* [October 2009]).

Collapse hazards (ICC 500)
See "Hazards, collapse."

Community safe room
Any safe room not defined as a residential safe room.

Consensus standard
A standard developed by professional societies or by national and international standards-setting organizations through specific procedures and requirements that govern the consensus development process. The process is conducted to provide a consensus agreement among representatives of various interested or affected individuals, companies, organizations, and countries.

Critical support systems (ICC 500)
Structures, systems, and components required to ensure the health, safety, and well-being of occupants. Critical support systems include, but are not limited to, potable and waste water systems, electrical power systems, life safety systems, and HVAC systems.

Design wind pressure (ICC 500)
The wind pressure on a specific location of the shelter envelope, as determined in accordance with Section 304 [of ICC 500] Wind Loads, which controls the design of components and cladding (C&C) of the shelter envelope or the MWFRS for the shelter.

Design wind speed

- **ASCE 7 basic wind speed (ASCE 7-10):** The 3-second gust speed at 33 feet (10 meters) in Exposure C (see Section 26.7.3) as determined in accordance with Section 26.5.1.
- **ICC 500 design wind speed (ICC 500):** Values shall be the nominal 3-second gust wind speed in miles per hour (km/h) at 33 feet (10 meters) above ground for open terrain (Exposure C).

Fire barrier (ICC 500)
A fire-resistance-rated vertical assembly of materials designed to restrict the spread of fire in which openings are protected.

Hazards (ICC 500)

- **Collapse.** Debris from wind damage to adjacent, taller structures which could fall onto the shelter.
- **Laydown.** Nearby structures such as towers or large trees that could fall onto the shelter, if the shelter is within the laydown radius of the structure.
- **Rollover.** Vehicles and small buildings, such as temporary classroom buildings, that could roll over due to extreme winds and impact the shelter.

Host building (ICC 500)
A building which is not designed or constructed as a storm shelter that totally or partially encloses a storm shelter or is connected to a storm shelter.

Impact-protective system (ICC 500)
System or device such as a shutter, door, or other device mounted on the inside or outside of the exterior wall of a shelter and which has been demonstrated by testing to be capable of withstanding the impact of test missiles as detailed in [ICC 500].

Interior surface of the shelter component (ICC 500)
The inside surface of any structural component of the storm shelter envelope.

Label (ICC 500)
An identification applied on a product by the manufacturer that contains the name of the manufacturer, the function and performance characteristics of the product or material, and the name and identification of an approved agency and that indicates that the representative sample of the product or material has been tested and evaluated by an approved agency.

Labeled (ICC 500)
Equipment, materials, or products to which has been affixed a label, seal, symbol, or other identifying mark of a nationally recognized testing laboratory, approved agency, or other organization concerned with product evaluation that maintains periodic inspection of the production of the above-labeled items, and whose labeling indicates either that the equipment, material, or product meets identified standards or has been tested and found suitable for a specified purpose.

See also "Label."

Laydown hazards
See "Hazards, laydown."

Local emergency planning committee (ICC 500)
A group of citizens defined by the community as having responsibility for local emergency planning. The committee shall be recognized by the governing body as having this responsibility.

Natural ventilation (ICC 500)
Passive ventilation, not requiring a power source, resulting from convection of heated air, movement of inside air, and movement of outside air over and around the storm shelter, resulting in air exchange through vent openings.

Near-absolute protection
Level of protection afforded to the occupants of a safe room built according to the guidance in the most current edition of FEMA P-361. Our current knowledge of tornadoes and hurricanes indicates that safe room occupants will have a very high probability of being protected from injury or death.

Occupant support areas (ICC 500)
The areas required to ensure the health, safety, and well-being of occupants. Occupant support areas include, but are not limited to, shelter management, food preparation, water and food storage, electrical and mechanical rooms, toilet and other sanitation rooms, and first-aid stations.

Occupied shelter areas (ICC 500)
The designated storm shelter area.

On-site (ICC 500)
Either inside, immediately adjacent to, or on the same site as the designated storm shelter facility, and under the control of the owner or lawful tenant.

Peer review (ICC 500)
A review of the storm shelter in accordance with Section 106.1.1 of the ICC 500 by a registered design professional(s) independent from the registered design professional(s) in responsible charge of the storm shelter design. The peer review includes checking the construction documents, calculations, and quality assurance plan for the storm shelter design.

Penetration
When a building component is impacted by debris and the debris enters the component but not to the extent that it enters the protected space. Penetration of a safe room component may be considered a failure when it results in excessive spalling, permanent deformation, dislodgement, or disengagement of that component.

Perforation
Failure of a safe room component from wind-borne debris that occurs when a missile impacts a safe room component and passes through it and into the protected space of the safe room by any amount.

Prefabricated safe room
A safe room that has been assembled off-site and transported to the site where it will be installed.

Protected occupant area (ICC 500)
The portions of the shelter area that are protected from intrusion of storm debris by alcove or baffled entry systems in accordance with Section 804.9.7 of ICC 500.

Rebound impact (ICC 500)
The rebound impact by a test missile, or fragments thereof, on a portion of the shelter protective envelope after the test missile has impacted another surface of the shelter protective envelope.

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

Rollover hazards
See “Hazards, rollover.”

Safe room
A storm shelter specifically designed to meet FEMA safe room Recommended Criteria and provide near-absolute protection in extreme-wind events, including tornadoes and hurricanes.

See also “near-absolute protection.”

Shelter entry system, alcove (ICC 500)
An entry system that uses walls and passageways to allow access and egress to the shelter interior while providing shielding from wind-borne debris in accordance with Section 306.5 of ICC 500.

Shelter entry system, baffled
See “Shelter entry system, Alcove.”

Shelter envelope (ICC 500)
The protective walls, roofs, doors, and other protected openings which are designed to meet the requirements of Chapter 3 of ICC 500 to provide protection to occupants during a severe windstorm.

Special inspection (ICC 500)
Inspection of construction requiring the expertise of an approved special inspector in order to ensure compliance with the ICC 500 standard and the approved construction documents.

Special inspector (ICC 500)
A qualified person employed or retained by an approved agency and approved by the building official as having the competence necessary to inspect a particular type of construction requiring special inspection.

Storm shelter (ICC 500)
A building, structure, or portion(s) thereof, constructed in accordance with [ICC 500], designated for use during a severe wind storm event such as a hurricane or tornado.

- **Community storm shelter (ICC 500).** Any storm shelter not defined as a residential storm shelter.
- **Residential storm shelter (ICC 500).** A storm shelter serving occupants of dwelling units and having an occupant load not exceeding 16 persons.

Storm shelter design wind speed (ICC 500)
The maximum wind speed for which the shelter has been designed. Values shall be the nominal 3-second gust wind speed in miles per hour (km/h) at 33 feet (10 m) above ground for open terrain (Exposure C).

Storm shelter occupant load (ICC 500)
The occupant load intended for a room or space when that space is in use as a storm shelter.

CHAPTER B3
Structural Design

This chapter uses Chapter 3 of ICC 500 as the referenced standard and includes a list of Recommended Criteria FEMA has identified as more conservative than the provisions in Chapter 3 of ICC 500. This chapter also includes FEMA supplemental commentary on structural design of safe rooms based on many years of field observations and investigations related to safe room performance.

FEMA SAFE ROOM GRANT REQUIREMENTS

Whenever a safe room is constructed using FEMA grant funds, the Recommended Criteria shown in Section B3.1 become requirements in addition to the requirements of ICC 500 Chapter 3.

B3.1 Criteria

The structural design of safe rooms should be in accordance with the provisions of Chapter 3 in ICC 500 with the exception of FEMA's Recommended Criteria as shown in Table B3-1.

Table B3-1. Comparison of ICC 500 Requirements to FEMA Recommended Criteria

ICC 500 REFERENCE	ICC 500 REQUIREMENT FOR STORM SHELTERS	FEMA RECOMMENDED CRITERIA FOR SAFE ROOMS[a]
Section 304.2 Design Wind Speed	For tornado shelters, the design wind speed shall be in accordance with Figure 304.2(1). For hurricane shelters, the design wind speed shall be in accordance with Figure 304.2(2).[b]	**For all residential safe rooms, the design wind speed shall be 250 mph, regardless of location.**

Bolded text denotes differences between the ICC 500 Requirement and the FEMA Recommended Criteria.

Table notes:

(a) Table only lists differences between FEMA P-361 and ICC 500 Chapter 3. All ICC 500 Chapter 3 requirements not listed in the table should also be met in their entirety.

(b) ICC 500 tornado wind speeds for all storm shelters range from 130 mph to 250 mph. ICC 500 hurricane wind speeds for all storm shelters range from 160 mph to 235 mph.

B3.2 FEMA Supplemental Commentary

Chapter B3 supports the design and performance criteria for the structural systems and envelope systems (including openings and opening protection assemblies) for tornado and hurricane safe rooms. The intent of this chapter is to present the "how and why" of the structural design criteria, including, where appropriate, the discussion of how the criteria presented in this publication differ from the ICC 500 requirements. The performance criteria include some discussion on debris impact-resistance, which is augmented by the commentary in Chapter B8 of this publication.

FEMA offers the following commentary and background information as supplemental guidance to the registered design professional for the criteria referenced in ICC 500 Chapter 3.

B3.2.1 General Approach to the Structural Design of Safe Rooms (Reference: ICC Sec 301)

The design criteria presented in this chapter are based on the best information available at the time this publication was published. The wind loads a safe room is designed to resist are primarily based on the load determination criteria in ASCE 7, with modifications as required by ICC 500 and in some cases, additional changes as described in Section B3.1. Please note that ICC 500 modifies some of the other loads, e.g., rain loads and roof live loads, beyond the requirements of ASCE 7 and the IBC. Wind loads should be combined with the appropriate gravity loads and other prescribed loads acting on the safe room as required by the load combinations presented in Chapter 3 of ICC 500 and described in Section B3.2.2.

The commentary discussions in this chapter are based on codes and standards available for adoption by any jurisdiction. Specifically, the criteria are based on the ICC 500-2014, ASCE 7-10, ASCE 24-14, the 2015 IBC, and the 2015 IRC unless otherwise noted. For design and construction criteria not provided in this publication or in the ICC 500, the IBC and IRC (as appropriate) should be used to determine the requirements for completing the safe room. Should a designer, builder, or manager have any questions regarding design criteria presented in this publication, the following approach should be taken:

1. When questions arise pertaining to the difference between FEMA P-361 criteria and another code or standard (such as the ICC 500), the criteria in FEMA P-361 should govern. If not, the safe room cannot be considered to be a FEMA-compliant safe room.

2. When questions arise pertaining to design and construction criteria not presented in FEMA P-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 protection from both tornadoes and hurricanes, the entire safe room should be designed and constructed using the more conservative of the two sets of criteria.

4. When questions arise pertaining to criteria or requirements not addressed by this publication or the ICC 500, the 2015 IBC (with references to ASCE 7-10 and ASCE 24-14) and 2015 IRC should be used to determine the design and construction criteria. When these codes or standards have conflicting criteria, the most conservative criteria should apply.

B3.2.1.1 Design Considerations and Safe Room Types

This publication offers design guidance on two types of safe rooms:

- Stand-alone safe rooms
- Internal safe rooms: shelter areas that are located inside of or connected to a larger building, which is called a host building.

The guidance in this publication is intended for the design and construction of new safe rooms, as well as for the addition of

> Note
>
> **RETROFITS**
>
> The registered design professional performing retrofit work on existing buildings should apply the new design guidance presented in this publication to the retrofit design.

safe rooms to existing buildings by hardening an existing room or area (i.e., retrofitting). When considering retrofitting an existing building, the retrofit safe room must be designed to the same requirements and provide an equal level of protection as a new safe room. The wide variety of structural systems and large number of different configurations of existing buildings preclude a comprehensive review of all retrofit options, so limited guidance is provided on modifying buildings to create a safe room where none previously existed. However, a registered design professional engaged in a safe room retrofitting project should be able to use the guidance in this publication to identify the appropriate hazards at the site, determine the risk, and calculate the loads acting on the building that is the subject of the safe room retrofit.

B3.2.1.1.1 Stand-Alone Safe Rooms

The results of the risk assessment discussed in Chapter A2 may show that the best solution for protecting large numbers of people is to build a new, separate (i.e., stand-alone) building specifically designed and constructed to serve as a tornado or hurricane safe room.

Potential advantages of a stand-alone safe room include the following:

- The safe room can be constructed away from potential laydown or collapse hazards
- The safe room will be structurally separate from any building and therefore not vulnerable to being weakened by way of connection or debris loading if part of an adjacent structure collapses
- The safe room does not need to be integrated into an existing building design

CROSS-REFERENCE

The information in Chapter A2, *Extreme-Wind Risk Assessment and Analysis*, may be useful in determining what type of safe room should be constructed.

B3.2.1.1.2 Internal Safe Rooms

The results of the risk assessment discussed in Chapter A2 may show that a safe room area specifically designed and constructed within or connected to a building is a more attractive alternative than a stand-alone safe room, especially when the safe room is to be used mainly by the occupants of the building. Potential advantages of an internal safe room include the following:

- A safe room that is partially shielded by the surrounding building may not experience the full force of the tornado or hurricane wind. (Note, however, that any protection provided by the surrounding building cannot be considered in the determination of wind loads and debris impact for safe room design.)
- A safe room designed to be within a new building can be constructed in an area of the building that the building occupants can reach quickly, easily, and without having to go outside during the storm.
- Incorporating the safe room into a planned renovation or building project may reduce the safe room cost.

One potential disadvantage of an internal safe room is the risk of surrounding building debris collapsing on it. However, when this risk is properly considered by the registered design professional, a safe room constructed within a building is an acceptable application of the safe room concept. See next "Codes and Standards" text box for more information on how ICC 500 addresses considerations related to loading from the host structure; access considerations resulting from host structure debris around or atop the safe room – both ingress and egress – are described in Section B5.2.1.2.

CODES AND STANDARDS

The ICC 500 provisions make some distinctions between stand-alone (separate detached buildings) and internal (rooms or areas within buildings) shelters. It should be noted that Sections 304.8 and 304.9 of the ICC 500, *Shielding of storm shelters by host and adjacent buildings* and *Storm shelters connected to host buildings*, respectively, provide specific design criteria for shelters that are connected to existing structures or new structures surrounding the shelter to specify the interaction between the two structures (the shelter and the non- shelter). Even though the host building may fail, the requirements of Section 304.9 of the ICC 500 are intended to prevent damage to the host building from compromising the safe room.

B3.2.1.2 Structural and Building Envelope Characteristics of Safe Rooms

The primary difference in a building's structural system when designed for use as a safe room, as compared to conventional use, is the magnitude of the wind forces and wind-borne debris it is designed to withstand. Safe rooms are designed for greater wind speeds (and corresponding greater wind pressures) and larger and more energetic wind-borne missiles than conventional (normal) buildings.

The design of door and glazing assemblies of safe rooms are typically governed by wind-borne debris requirements (wind-borne debris causes many of the injuries and much of the damage from tornadoes and hurricanes). Exterior glazing in conventional buildings is not required to resist wind-borne debris, except when the buildings are located in the wind-borne debris regions within hurricane-prone regions (see Section 26.10.3.1 in ASCE 7-10). Per the IBC, glazing in buildings in wind-borne debris regions must be impact-resistant glazing systems or protected with an impact-protective system. These systems include laminated glass, polycarbonate, or "hurricane shutters." The ASCE 7 wind-borne debris criteria were developed to minimize property damage and improve building performance by reducing the risk of internal pressurization. They do not require unglazed doors, walls, and roofs to be debris impact-resistant. To provide a life-safety level of protection, the safe room design criteria include substantially greater resistance to penetration from wind-borne debris.

To provide adequate life-safety protection, in addition to the glazing, the roof, wall, and door assemblies of a safe room must resist the specified wind-borne debris impacts. Sections B3.2.5.1, B3.2.5.2, and B3.2.5.3 present the debris impact-resistance performance criteria for the tornado, hurricane, and residential safe rooms, respectively.

B3.2.2 Load Combinations (Reference: ICC 500 Sec 302)

For Strength Design or Load and Resistance Factor Design (LRFD), ICC 500 states that load combinations should be used in accordance with Section 2.3 of ASCE 7, with the wind load (W) determined in accordance with Section 304. ICC 500 specifies that Exception 1 to ASCE 7 Section 2.3.2 (reduction of load factor for live loads) shall not apply. For Allowable Stress Design (ASD), the load combinations should be in accordance with ASCE 7 Section 2.4. ICC 500 provides specific requirements for storm shelter loads other than wind loads, including roof live loads and rainfall loads. Although not explicitly stated in ICC 500 Section 302, these other loads modified by ICC 500 should be used in the ASCE 7 load combinations.

B3.2.3 Non-Wind Load Considerations (Reference: ICC 500 Sec 303)

Section 303 of ICC 500 includes modifications to several types of non-wind related loads, including rain loads, roof live loads, and flood loads.

B3.2.3.1 Rain Loads

ICC 500 requires rain loads for structural design to be determined in accordance with ASCE 7, but additionally specifies that the rainfall rate for hurricane shelters be determined by adding a rate of 6 inches per hour to the rainfall rate established in Figure 303.2 of ICC 500. The rainfall rate maps in Figure 303.2 are from the International Plumbing Code® and correspond to the 100-year, 1-hour rainfall rate. The additional 6 inches per hour accounts for more intense rainfall rates possible in hurricanes

B3.2.3.2 Roof Live Loads

ICC 500 requires roof live loads applied to the shelter to be as specified in ASCE 7, but not less than 100 pounds per square foot for tornado shelters and not less than 50 pounds per square foot for hurricane shelters. In the event of a collapsing host building or other surrounding structures onto the safe room, roof live load conditions may well exceed the required minimum. Furthermore, impact loading from collapse or laydown hazards may need to be taken under specific consideration. As with all code- and standard-required minimum loads, it is important for designers to consider actual site conditions and increase minimum loads as appropriate.

B3.2.3.3 Flood Loads

Flood hazard design criteria for safe rooms are discussed in Section B4.2.2. Note that these criteria define where a safe room may be sited. FEMA recommends that safe rooms be sited outside of any area subject to flooding. For safe rooms that follow this recommendation, it is possible there would be no flood loads to consider. However, if the safe room meets all applicable siting criteria per Section B4.1, and has building elements (such as its foundation) below the design flood elevation, those elements should be designed in accordance with the flood loading provisions of ASCE 7 and any applicable provisions of ASCE 24. The lowest floor used for safe room space and/or safe room support areas should be elevated to the higher of the minimum floor elevations described in Section B4.1, which should be used as the design flood elevation for flood load calculations. There are minor differences between the ICC 500 requirements and FEMA P-361 Recommended Criteria related to determining the minimum floor elevation (refer to Section B4.1 for additional information).

CROSS-REFERENCE

Refer to Section B4.1 for safe room minimum floor elevations.

B3.2.3.4 Seismic Loads and Seismic Detailing

In some locations around the United States, the risk of seismic events may be substantial enough that the building code requires seismic design and detailing. In some cases, the building code may require seismic detailing even when the structural design of the safe room is found to be controlled by the wind loads. Any seismic design and detailing requirements of the prevailing code or AHJ must be met, and should be reviewed for compatibility with other design parameters and prioritized according to the design program.

Wind and seismic loads differ in the mechanics of loading (i.e., the way the load is applied). In a wind event, the load is applied to the exterior of the envelope of the structure, and internal building elements that are not part of the MWFRS of the building will not typically receive loads unless there is a breach of the building envelope. Earthquakes, however, induce loads based on force acceleration relationships. These relationships require that all objects of mass develop loads. Therefore, all structural elements and non-structural components within and attached to the structure will be loaded. As a result, seismic loading requires both exterior building elements and internal building elements (including non-load-bearing elements and fixtures) to be designed for the seismically induced forces.

B3.2.4 Wind Loads and Design (ICC 500 Sec 304)

To resist wind loads, the design of a safe room relies on the basic wind load determination approach taken in ASCE 7, with modifications as described in this section and Section 304 of ICC 500. 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.

B3.2.4.1 Design Wind Speeds for Safe Rooms

The prevailing wind hazard along the Gulf of Mexico and Atlantic coasts, in the Caribbean, and for some Pacific islands is a hurricane (some regions of the Pacific refer to hurricanes as "cyclones" or "typhoons"). Tornadoes are the greatest wind hazard in interior areas of the United States.

The maps in Figures B3-1 and B3-2 present tornado and hurricane safe room design wind speeds, respectively. The four zones on Figure B3-1 have corresponding tornado safe room design wind speeds of 130 mph, 160 mph, 200 mph, and 250 mph. Similarly, Figure B3-2 shows the hurricane safe room design wind speed contours, which range from 160 to 220 mph for the U.S. mainland. Hurricane speeds range from 165 to 235 mph for Hawaii and the U.S. Territories.

B3.2.4.1.1 Background on Safe Room Design Wind Speed Maps

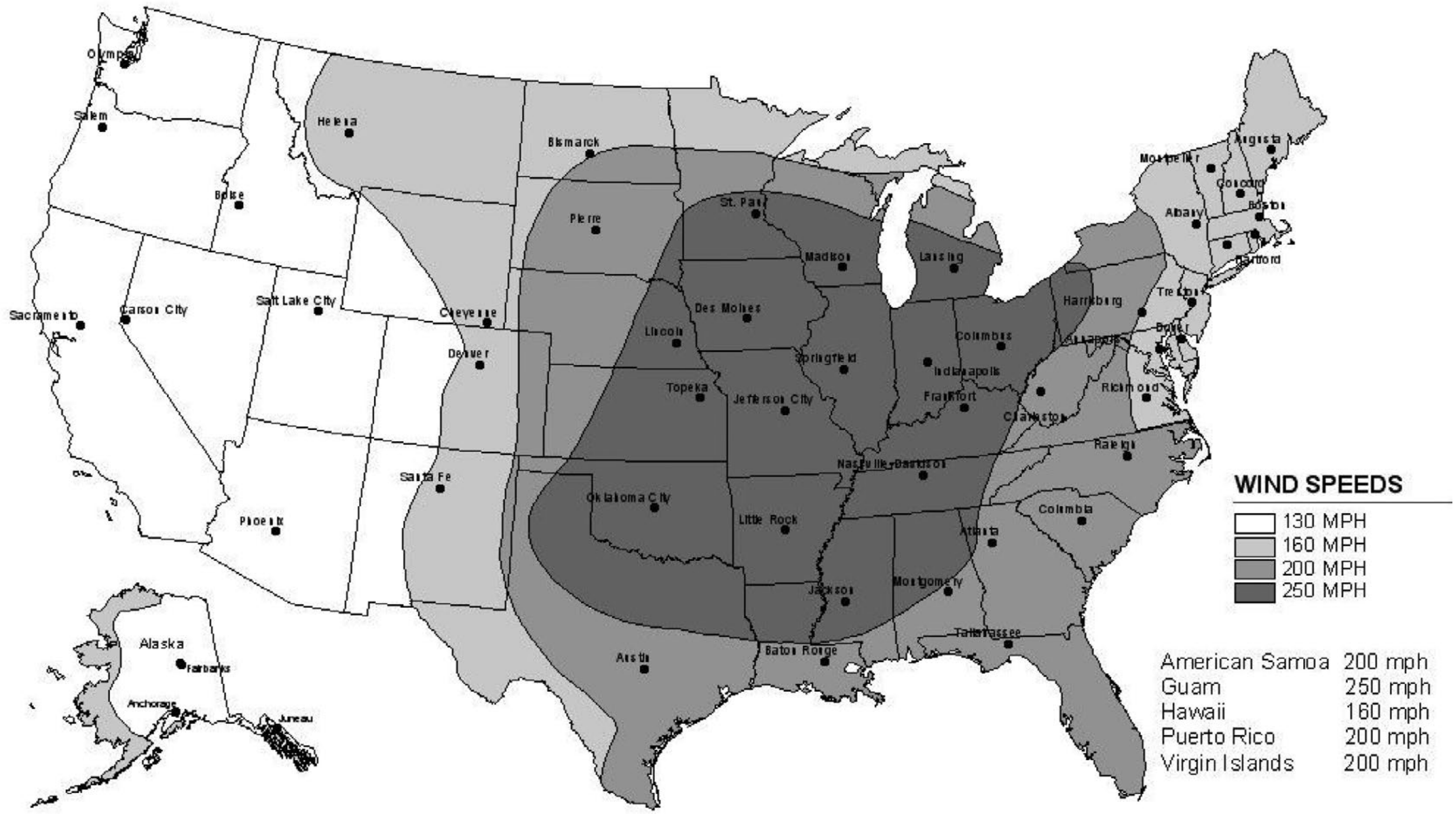
Safe room design wind speeds are 3-second gust speeds at 33 feet above grade in Exposure C (which is consistent with the definition of basic wind speeds used in ASCE 7). Consequently, the safe room design wind speeds can be used in the wind pressure calculation formulas from ASCE 7 to determine wind loads, as required in ICC 500 Section 304. The hurricane safe room design wind speeds shown in Figure B3-2 are valid for most regions of the country. However, the Special Wind Regions (e.g., mountainous terrain, river gorges, ocean promontories) shown on the ASCE 7 basic wind speed maps are susceptible to local effects that may cause substantially higher wind speeds at safe room sites.

Note

SAFE ROOM DESIGN WIND SPEED MAPS

Tornado: The ICC 500-2014 tornado wind speed map (Figure B3-1) is similar to the map that first appeared in FEMA P-361 (2000), which was slightly modified, subsequently adopted by ICC 500, and also included in the second edition of FEMA P-361 (2008).

Hurricane: The ICC 500-2014 hurricane wind speed map (Figure B3-2) was revised by ICC 500 from the original version in ICC 500-2008. FEMA P-361 (2008) adopted the original map as this edition has adopted the revised one.



Notes:

1. Values are nominal three-second gust wind speeds in miles per hour at 33 feet above ground for Exposure Category C.
2. Multiply miles per hour by 0.447 to obtain meters per second.

Figure B3-1. Safe room design wind speeds for tornadoes
(SOURCE: ICC 500 FIGURE 304.2(1); USED WITH PERMISSION)

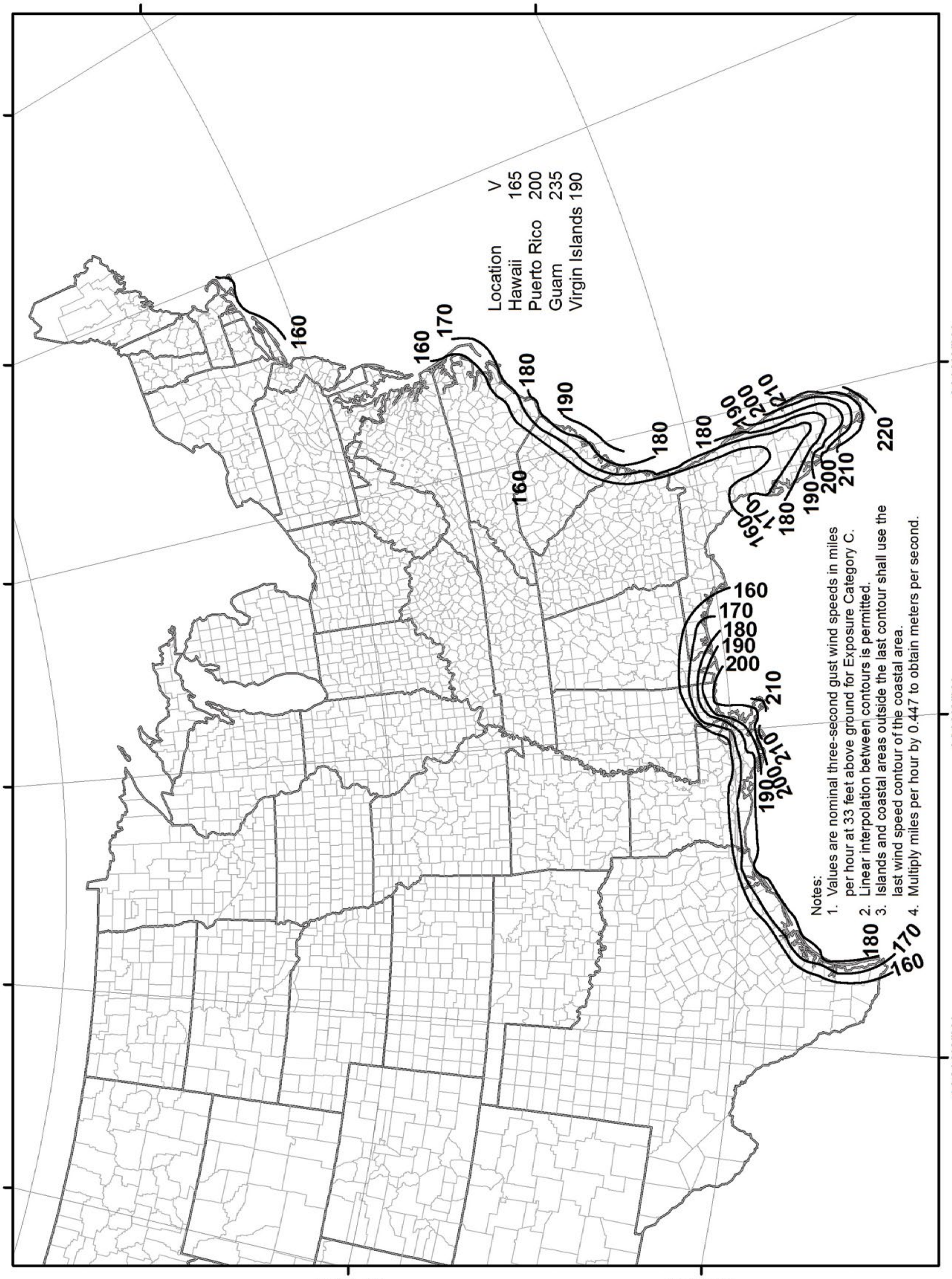


Figure B3-2. Safe room design wind speeds for hurricanes
(SOURCE: ICC 500 [2014] FIGURE 304.2(2); USED WITH PERMISSION)

B3.2.4.1.2 Tornado Design Wind Speed Map (Reference: ICC 500 Sec 304.2)

The safe room design wind speed map for tornadoes is shown in Figure B3-1, which is identical to the ICC 500 tornado shelter design wind speed map. As described in this section, the map was developed from an analysis of historic tornadoes and represents a deterministic map of maximum tornadic wind speeds likely to occur in different regions of the country.

CROSS-REFERENCE

Information on tornadoes, tornado hazards, and the Fujita and Enhanced Fujita Scales is presented in Section A2.1.1, *Assessing Threat*.

Development of the Safe Room Design Wind Speeds for Tornadoes

The NOAA Storm Prediction Center data used to develop the Figure B3-1 wind speed zones covered the years 1950 through 2006. The current map is nearly identical to the first edition FEMA P-361 safe room wind speed map which was developed in conjunction with TTU using data collected from 1950 through 1998. Tornado occurrence statistics prior to 1950 are available, but they are lower quality. From 1950 through 2006, a total of 50,096 tornadoes were recorded in the contiguous United States. Each of these tornadoes was assigned an F Scale level. Table B3-2 shows the number of recorded tornadoes and percentages for each F Scale level, as well as the cumulative percentages. As noted in Table B3-2, less than 2 percent of the tornadoes were in the F4 category and less than 1 percent were in the F5 category.

Table B3-2. Tornado Frequencies in the United States (1950-2006)

Fujita Scale Percentage	Number of Tornadoes	Percentage	Cumulative
F0	20,728	43.68	43.68
F1	16,145	34.03	77.71
F2	7,944	16.74	94.45
F3	2,091	4.41	98.86
F4	491	1.03	99.89
F5	50	0.11	100
Totals	47,449	100	

Source: Data is from NOAA Storm Prediction Center

To develop wind speed zones, NOAA tallied the occurrences of tornadoes between 1950 and 2006 and plotted them on a grid map of the United States composed of 80 km x 80 km squares (2,470 square miles). Tornadoes rated using the F Scale were reclassified as EF Scale events (same corresponding scale number) and the number of combined EF3, EF4, and EF5 tornado occurrences within each 2,470-square mile square was tabulated for the whole country. These frequencies of occurrence data were used to develop the location of the contours shown in Figure B3-1.

Note

HISTORICAL OCCURRENCES

There were 56,221 recorded tornadoes between 1950 and 2011. Of these, the NWS rated 95 percent as EF0-EF2, 4 percent as EF3, and 1 percent as EF4-EF5.

250 mph wind speed zone: The 250 mph wind speed zone includes all 2,470-square mile grid squares with two or more EF5 tornadoes recorded between 1950 and 2006. The 250 mph zone also includes areas with 10 or more EF4 and EF5 tornado occurrences combined during this same period. In Figure B3-1, the darkest zone covers the middle part of the United States, where the most intense tornado damage has occurred.

200 mph wind speed area: The 200 mph wind speed area was developed using the statistics of EF3 tornado occurrences. Most areas with 20 to 30 EF3 tornadoes in a 2,470-square mile grid square also had enough EF4 and EF5 tornadoes to be included in the 250 mph wind speed zone. To be conservative, the 200 mph wind speed zone was extended to cover areas where more than five EF3 tornadoes were identified within a single square. This zone extends along the Gulf and lower Atlantic coastal areas to include hurricane winds. There are a couple of grid squares in New York and Massachusetts that fall outside of this zone even though they have more than five EF3 tornado occurrences. They are considered outliers and have had less than 10 EF3 occurrences.

160 mph wind speed area: The 160 mph wind speed area was developed for the remaining areas east of the Rocky Mountains. The western border for this zone approximately follows the Continental Divide. The 160 mph area covers all tornadoes of EF2 or lower intensity.

130 mph wind speed areas: In the area west of the Rocky Mountains, there are relatively few tornado occurrences, and none have been rated EF5. From 1950 to 2006, only two tornadoes were rated EF4, and only 10 were rated EF3. For the 2008 edition of FEMA P-361, it was determined that a wind speed of 130 mph is sufficient for this zone.

B3.2.4.1.3 Hurricane Design Wind Speed Map (Reference: ICC 500 Sec 304.2)

FEMA P-361 uses the shelter design wind speeds identified in Figure 304.2(2) of the ICC 500 as hurricane safe room design wind speeds (Figure B3-2). The ICC 500 map was developed using the same probabilistic methodology used to model hurricane wind speeds for the ASCE 7 wind speed maps, but for a 10,000-year MRI (0.5 percent probability of exceedance in 50 years). Hurricane safe room design wind speeds range from 160 to 235 mph.

> **CROSS-REFERENCE**
>
> Information on hurricanes and hurricane hazards is presented in Section A2.1.1, *Assessing Threat*.

Development of hurricane wind speeds

The hurricane shelter design wind speed map used in the 2008 version of ICC 500 was a 10,000-year MRI map generated using the hurricane simulation models described in Vickery et al. (2000) and Vickery et al. (2006), which were also used to create the hurricane contours in the ASCE 7-05 wind speed maps. When developing the first edition of the ICC 500 standard in 2008, the ICC 500 Storm Shelter Standard Committee considered wind speed maps with MRIs ranging from 1,700 to 10,000 years (1,700 years is the MRI associated with the ASCE 7-05 Occupancy Category IV buildings, which includes hurricane shelters). Hurricane wind speeds were found to rapidly increase for lower MRI values and flatten out for higher MRIs (longer return periods). The committee decided that the 10,000-year MRI map was the most appropriate for hurricane shelters, given life safety considerations and uncertainties in the estimation of wind speeds.

After a thorough review of the information used to prepare the initial ICC 500 hurricane shelter design wind speed map and coordination with the ICC 500 Standards Committee, FEMA adopted the ICC 500 hurricane storm shelter map for the second edition of FEMA P-361 (2008). (The first edition FEMA P-361 (2000) used a single wind speed map for tornadoes and hurricane safe room).

The hurricane shelter design wind speed map used in the 2014 edition of ICC 500 and this publication (as shown in Figure B3-2) is slightly different. The current wind speed map is based on the updated hurricane modeling methods used in the ASCE 7-10 standard. Improvements in the modeling process for ASCE 7-10 included improved representation of the hurricane wind field and new models for hurricane weakening after landfall, described in Vickery et al. 2010 and in Section C26.5.1 of ASCE 7-10. The net effect of the modeling improvements was a slight decrease in hurricane shelter design wind speeds in most locations, typically on the order of 5-10 mph.

B3.2.4.1.4 Wind Speeds for Alaska

The State of Alaska does not get hurricanes and is not prone to tornadoes, but it does experience extratropical cyclone winds and thunderstorms. The safe room design wind speeds are based on contours shown on the ASCE

7-10 maps. The 160 mph safe room wind speed zone is designated for coastal areas that experience basic wind speeds of 130 mph or higher as shown on the ASCE 7-10 Occupancy Category II basic wind speed map. For interior, inland areas, where the ASCE 7-10 basic wind speeds are less than 130 mph, the safe room design wind speed is 130 mph. Safe room design wind speeds are shown in Figure B3-1.

B3.2.4.1.5 Potential for Exceeding Design Wind Speed

The design wind speeds chosen by FEMA for safe room guidance were determined with the intent of specifying near-absolute protection with an emphasis on life safety. Historically, most tornado deaths have occurred during tornadoes classified as F3/EF3, F4/EF4, or F5/EF5. While the number of fatalities per single tornado increases steadily with EF number, the total number of tornado fatalities for EF3 tornadoes is about the same as the total for EF4 and EF5 events, on the order of 1000-2000 for each of F3/EF3, F4/EF4, and F5/EF5 during the period of 1950-2011. For hurricanes, the largest storms have typically been the deadliest; however, most hurricane deaths are associated with storm surge inundation, not high winds. For both hazards, such intense storms are rare. Even in those areas of the middle of the country where the risk of EF4 and EF5 tornadoes is greatest, the likelihood that a particular building will be struck by an EF4 or EF5 tornado is extremely low. Though rare, safe room design must stand up to these extremely rare events if they are to provide near-absolute protection. Furthermore, community safe rooms protect occupants from surrounding buildings and neighborhoods, so the area protected is much greater than the area of the single building.

Tornado probabilities

Tornado probability estimates have typically been based on historical records of tornado observations and classifications within large areas surrounding the site. These areas have ranged from 80 km (49.71 miles) by 80 km (49.71 miles) squares to 1 degree latitude and longitude squares. Consequently, they are subject to considerable uncertainty, particularly for the rare EF4 and EF5 storms. Although analysis of historical records provides some insight into areas of the United States where there is higher risk of tornado activity, the length of the historic record is relatively short; furthermore, tornado intensity has been determined through observed damages, so tornadoes in areas with lower populations may have gone undetected, unrated, or underrated. Registered design professionals should understand that the safe room design wind speed contours on the map shown in Figure B3-1 have been smoothed and rounded upward because of the low number of observations and large variability that occurs when using a deterministic analysis.

During development of the EF Scale, tornado wind speeds were reanalyzed to better correlate with observed damages. The reanalysis resulted in a decrease in wind speeds assigned to EF Scale-rated events in comparison with F Scale-rated events. ICC 500 uses the 250 mph 3-second gust design wind speed for the areas with greatest risk from the most intense tornadoes, which corresponds to the fastest observed tornado wind speeds occurring within close proximity to the ground. A 250 mph wind speed is near the upper end of the F4 Scale and would be considered a strong EF5 tornado (refer to Table B3-2). This approach provides a conservative design wind speed for the riskiest region and allows reductions in wind speeds for other east coast zones based on relative risks while maintaining the lowest tornado design wind speed for that region close to the bottom of the EF4 range.

Hurricane probabilities

The hurricane shelter design wind speeds in the ICC 500 standard represent an MRI of 10,000 years. This corresponds to a 0.01-percent-annual probability of exceedance, or 0.5 percent probability of exceedance in 50 years, and provides a consistent risk-based design approach for hurricane shelters and safe rooms. The lower limit of the hurricane safe room and shelter design wind speed was set by ICC at 160 mph, which is close to the upper wind speed limit of an EF3 tornado. Since nearly all observed tornadoes spawned by hurricanes have been classified as EF3 or lower, this lower limit is a reasonable and conservative design criteria for safe rooms intended for use during a hurricane.

Note

WIND LOAD CALCULATIONS

The simplified methods for determining wind loads in ASCE 7-10 Chapters 27, 28, and 30 should not be used for the design of any safe room. These simplified procedures pre-determine the controlling conditions for certain types of buildings to reduce the number of variables required, and the variables and coefficients incorporated into the simplified method are inconsistent with the modifications required in this publication and ICC 500.

B3.2.4.2 Calculating Wind Loads

The following section provides guidance and commentary on steps taken to calculate wind loads for any safe room by examining safe room design parameters, application of the ASCE 7-10 "Directional Procedure," and how to combine different wind load effects that act simultaneously on the building. It is important for designers to remember that other effects, such as debris impact, may control the design of an element rather than the direct wind pressure.

The wind load design methodology for the MWFRS described in this publication is based on the use of the ASCE 7-10 "Directional Procedure" with additional modifications of specific coefficients as specified in ICC 500 and in this publication. Designers are permitted to use the ASCE 7-10 "Envelope Procedure" (Chapter 28) and "Wind Tunnel Procedure" (Chapter 31) subject to the ASCE scope limits for each procedure. The provisions of the ASCE 7-10 "Directional Procedure" and the "Envelope Procedure" should not be combined or mixed (e.g., the designer should not use the "Directional Procedure" to calculate lateral loads and the "Envelope Procedure" to calculate uplift on the roof).

CROSS-REFERENCE

Section B3.2.4.2.2, *Using the ASCE 7 Directional Procedure*, provides additional information on this topic.

Designers should not reduce the calculated wind pressures or assume a lower potential for wind-borne debris impacts on the exterior walls and roof surfaces of an internal safe room. Although a safe room inside a larger building or otherwise shielded from the wind is less likely to experience the full wind pressures and wind-borne debris impacts, it should still be designed for the design wind pressures and potential wind-borne debris impacts that would apply to a stand-alone safe room. This is because it should be assumed that the structure surrounding the internal safe room and any adjacent structures providing shielding may sustain substantial damage or collapse in extreme-wind events, thereby offering no protection to the safe room.

B3.2.4.2.1 Parameters for Calculating Wind Pressures

Wind pressure assumptions and procedures for normal-use buildings are not always appropriate for safe rooms. As a result, when calculating the velocity pressure, MWFRS wind pressures, and C&C wind pressures for safe rooms using Formulas B3-1, B3-2, and B3-3 (see next subsection), the following parameters require adjustment: site exposure category, directionality factor, and topographic factor, as described later in this section.

For combined hazard safe rooms (i.e., safe rooms for protection from both tornadoes and hurricanes), the design should be governed by the more conservative site- and hazard-specific criteria. Note that when determining design wind pressures, the hazard with the greater wind speed may not necessarily control the design since wind speed is just one of many parameters that affect wind pressures. Wind pressures for both hazard types should be analyzed to ensure the design is capable of resisting the greatest loads applied by each. A similar comparative analysis should be conducted for all other loads, all the way through determination of load combinations, since some non-wind loads are different for the two storm types (such as roof live loads, rain loads, and flood loads). For safe room missile impact criteria (refer to Section B3.2.5), ICC 500 Section 306.1 permits storm shelter envelope components that meet tornado shelter missile impact criteria to be considered acceptable for hurricane shelters provided they meet the structural load requirements for hurricane shelters.

B3.2.4.2.2 Using the ASCE 7 Directional Procedure

The equations for the Directional Procedure are shown here so they can be explained in more detail. The velocity pressure equation (Equation 27.3-1, ASCE 7-10) is shown in Formula B3-1. The design wind pressure equation for a particular building surface for MWFRS (Equation 27.4-1, ASCE 7-10) is shown in Formula B3-2. Lastly, the design wind pressure for C&C (Equation 30.4-1, ASCE 7-10) is shown in Formula B3-3. The following sections include guidance and commentary to assist designers in choosing values needed to generate wind pressures to be resisted by the safe room for life-safety protection.

Velocity pressure calculation: Formula B3-1

The velocity pressure, q_z, is a function of height above ground, exposure category, topographic conditions, directionality factor, and wind speed (Formula B3-1). The velocity pressure exposure coefficient (K_z) factor accounts for the boundary layer effects of wind flowing close to the surface of the earth where it interacts with the terrain, buildings, and vegetation. The following section provides guidance on selecting the appropriate site exposure category (factor of K_z), topographic factor, and the required safe room directionality factor of 1.0.

Formula B3-1. Velocity Pressure

$$q_z = 0.00256\, K_z\, K_{zt}\, K_d\, V^2$$

where:

q_z	=	velocity pressure (psf) calculated at height z above ground
K_z	=	velocity pressure exposure coefficient at height z above ground
K_{zt}	=	topographic factor
K_d	=	directionality factor = 1.0
V	=	safe room design wind speed (mph) (from Figure B3-1 or B3-2)

Exposure: Values of the velocity pressure exposure coefficient (K_z) are presented in tabular form in ASCE 7 as a function of height above ground and terrain exposure. Selection of the appropriate exposure category differs for tornadoes and hurricanes.

Tornado: For tornado safe rooms, ICC 500 requires the use of Exposure C, since the vertical velocity profile and the effects of surface roughness on tornadic wind speeds have not yet been determined.

Hurricane: For hurricane safe rooms, the use of Exposure B (urban, suburban, and wooded areas) is not permitted except in very limited circumstances, so Exposure Category C (open terrain) or Exposure Category D (near a large body of water) should be applied in most cases. Exposure Category B is permitted only in the design of the MWFRS and only if Exposure Category B exists for all wind directions and is likely to remain Exposure Category B after a hurricane of the intensity corresponding to the hurricane safe room design wind speed.

Topographic factor: The topographic factor (K_{zt}) in ASCE 7 is based on the acceleration of straight line winds over hills, ridges, or escarpments.

Tornado: Some post-disaster observations suggest that tornado damage may increase where there are topographic changes, but conclusive evidence supporting quantitative adjustment of the topographic factor is not available at the time of the publication. Therefore in accordance with ICC 500, the topographic factor for tornado safe rooms need not exceed 1.0.

Hurricane: Damage documentation in hurricane disasters suggests that buildings on escarpments are subjected to higher forces than buildings otherwise situated. Designers should carefully consider the increased loads associated with siting safe rooms in locations that are likely to experience topographic effects. If it is necessary to locate a safe room on a hill or an escarpment, requirements given in ASCE 7 for the topographic factor should be used.

Directionality factor: The directionality factor (K_d) in ICC 500 and FEMA P-361 is conservatively set at 1.0. This is because wind directions may change considerably during a tornado or higher intensity hurricane, and a building may be exposed to intense winds from its most vulnerable direction. Therefore, the use of 0.85 for K_d in ASCE 7 for normal building design is not permitted by ICC 500.

Safe room design wind speed: For community safe rooms, the ICC 500 wind speed maps reproduced in Figures B3-1 and B3-2 should be used to determine the safe room design wind speeds for tornado and hurricane safe rooms, respectively.

While ICC 500 allows all storm shelters to be designed in accordance with the hazard-specific design wind speed (ICC 500 Figures 304.2(1) and 304.2(2)), FEMA requires that all FEMA-funded residential safe rooms be designed to withstand a 250 mph design wind speed (see Table B3-1). With small residential safe rooms, the cost differential associated with designing and constructing the safe room to resist a worst case event is far less significant than for community safe rooms, which are typically larger. Using the FEMA Recommended Criteria wind speed helps to offset increased residential safe room risk that can result from potentially less stringent design, construction, and installation oversight. FEMA's requirement may also prevent small prefabricated safe rooms designed to lesser wind speeds from being relocated to areas with higher wind speeds.

BEST PRACTICE

Tornado: As noted in Chapter A2, the ICC 500 tornado wind speed map (Figure B3-1) does not show a high level of detail; therefore, when a safe room is to be sited and constructed near a tornado wind zone contour line, the design wind speed may not be clear. Designers and code officials should recognize that the mapped design wind speed contour lines are not drawn or intended to be interpreted as precise geographic coordinates. When planning or designing safe rooms, it is important to remember the intended purpose of a safe room is to protect people from death or injury. ***Accordingly, a prudent approach would assume that the site in question falls within the higher tornado wind speed zone*****.**

Hurricane: In addition to the national hurricane safe room design wind speed map shown in Figure B3-2, ICC 500 also provides regional maps showing the same hurricane wind contours at a larger scale, which allows users to more easily locate safe room sites and interpolate, as needed.

The hurricane safe room design wind speeds shown in Figure B3-2 are valid for most regions of the country. However, the Special Wind Regions (e.g., mountainous terrain, river gorges, ocean promontories) shown on the ASCE 7 basic wind speed maps are susceptible to local effects that may cause substantially higher wind speeds at safe room sites. When the desired safe room location is within a Special Wind Region, or there is reason to believe that the wind speed on the map does not reflect the local wind climate, the registered design professional should seek expert advice from a wind engineer or meteorologist. This may require designing the safe room for a higher wind speed than delineated on the map to ensure near-absolute life protection for the occupants.

Pressure on MWFRS calculation: Formula B3-2

Once velocity pressure is determined using Formula B3-1, wind pressures are determined for MWFRS and C&C elements using Formulas B3-2 and B3-3 respectively. The only major difference in calculating MWFRS and C&C pressures for safe rooms when compared with normal buildings (beyond differences in the velocity pressure described previously) is in assignment of the enclosure classification and the related internal pressure coefficients. The following section provides guidance for making this critical determination.

Formula B3-2. Pressure on MWFRS for Buildings

$$p = qGC_p - q_i\,(GC_{pi})$$

where:

p	=	pressure (psf)
q	=	q_z for windward wall calculated at height z above ground
q	=	q_n for roof surfaces and all other walls
G	=	gust effect
C_p	=	external pressure coefficients
q_i	=	q_h = velocity pressure calculated at mean roof height
GC_{pi}	=	internal pressure coefficients

Internal pressure coefficient: The internal pressure coefficient (GC_{pi}), which incorporates the gust effect factor, accounts for internal pressure due to normal leakage of air entering or exiting the building in addition to situations where there are large openings in the building envelope. This leakage creates a pressure increase or a decrease within the building.

Enclosure classification and internal pressure coefficient: ICC 500 requires that a storm shelter's enclosure classification be determined in accordance with ASCE 7, provided that the largest door or window on a wall that receives positive external pressure is considered an opening. This provision accounts for the possibility that even an appropriately designed, installed, maintained, and operated pressure and impact-rated door or window or shutter may fail if struck by a larger or more damaging missile than it was designed and tested to resist.

This provision also accounts for potential problems due to improper maintenance of operable doors, windows, and shutters; improper operation (e.g., incomplete closure or latching) prior to and during a storm; and purposeful opening during a storm. Many such cases have been documented (AAWE 2004). There are documented instances where impact protective systems (shutters) were improperly latched or unlocked because keys were unavailable. In other instances, doors were deliberately opened to admit late arriving occupants or for other reasons (e.g., to allow movement between different shelter areas or the observation of damage conditions, let in fresh air, let out people who wanted to smoke), and in some of those cases, before the doors were re-latched or locked, they were compromised by strong gusts.

Tornado safe rooms must also meet the atmospheric pressure change (APC) venting requirements of ICC 500 Section 304.7 unless designed as partially enclosed with internal pressure coefficient, GC_{pi}, set at ±0.55. The following design guidance should be considered when selecting the appropriate safe room internal pressure coefficient.

Tornado: In tornadic events, maximum wind pressures should be combined with pressures induced by APC if the building is sealed or, like most safe rooms, nearly sealed. Although most buildings have enough air leakage in their envelopes that they are not affected by APC, safe rooms are very “tight” buildings, with few doors and few or no windows. A building designed to nullify APC-induced pressures, through adoption of the venting provisions in ICC 500 Section 304.7, would require a significant number of openings in the safe room to allow pressure to equalize. Allowing wind to flow through the safe room through large openings to reduce internal pressures (venting) could create an unsatisfactory environment for the occupants, possibly leading to panic.

BEST PRACTICE

Ventilation is needed to ensure that safe room occupants have sufficient airflow to remain comfortable, but code-compliant ventilation is not sufficient to nullify APC-induced pressures. Designers who wish to eliminate the need for venting to alleviate APC-induced pressures should use higher values of GC_{pi} ***(in safe room design, GC_{pi}= ±0.55 is considered the best practice for community and residential safe rooms)***. Design pressures determined using wind-induced internal and external pressure coefficients are comparable to the pressures determined using a combination of wind-induced external pressure coefficients and APC-induced pressures. Thus, the resulting design will be able to resist APC-induced pressures, should they occur.

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Hurricane: In hurricane events, tornadic vortices are often embedded in the overall storm structure. Although these tornadoes are typically smaller and less intense than tornadoes occurring in the interior of the country, swaths of damage reminiscent of tornado damage have been noted in several hurricanes.[1] In addition to increased pressures related to possible tornadoes during hurricane events, the likelihood of component failure resulting from improper door operation increases with the duration of safe room occupation. ***To enhance structural reliability, community and residential safe rooms can be designed using a GC_{pi} value of ±0.55 as best practice.***

Gust effect factor and external pressure coefficient: The gust effect factor depends on wind turbulence and building dimensions. The gust effect factor can be calculated or, for a rigid building, a value of $G = 0.85$ can be used, per Section 26.9 of ASCE 7-10. The external pressure coefficient (C_p) for the design of the MWFRS (Formula B3-2) is based on the physical dimensions and shape of the building, and the surface of the building in relation to a given wind direction. The process for selecting the external pressure coefficient to determine MWFRS pressures is the same for safe rooms as for normal use buildings.

Pressure on C&C and attachments: Formula B3-3

One of the most common methods for calculating the loads for C&C and attachments is the use of the ASCE 7-10 Equation 30.4-1 in Chapter 30, “Part 1: Low-rise Buildings (h≤60 ft),” shown here as Formula B3-3.

Formula B3-3. Pressures on C&C and Attachments

$$p = q_h [(GC_p) - (GC_{pi})]$$

where:

p	=	pressure (psf)
q_h	=	velocity pressure calculated at mean roof height
GC_p	=	external pressure coefficients
GC_{pi}	=	internal pressure coefficients

1 It has not been confirmed whether these swaths are caused by localized gusts or unstable small-scale vortices.

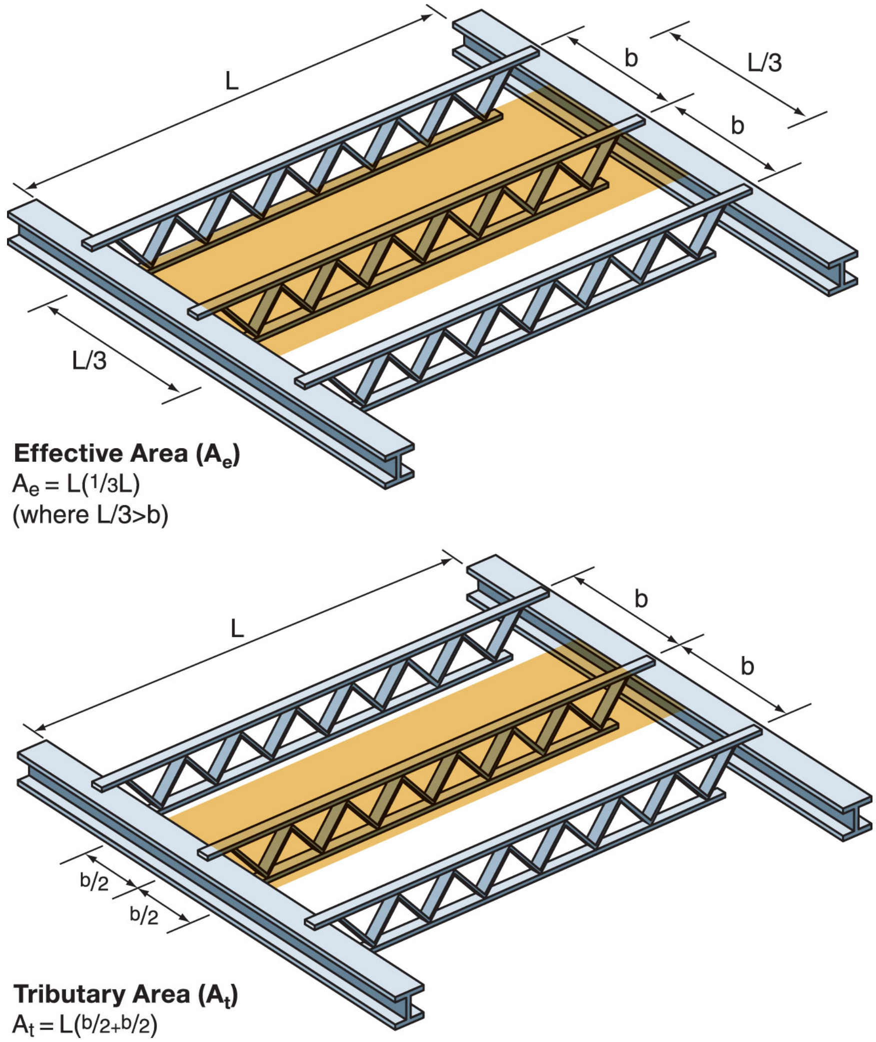
The external pressure coefficients (GC_p) are given in semi-log graphs and are a function of location on the building (wall or roof), roof slope, and effective wind area (see Section 26.2 of ASCE 7-10 for the definition of effective wind area). Like MWFRS, the process for selecting the external pressure coefficient to determine C&C pressures is the same for safe rooms as for normal use buildings.

External pressure coefficient: The value of GC_p for C&C elements is related to the location on the building surface (wall or roof), roof slope, and the effective wind area of the element. Effective wind area is essentially the area tributary to a particular element. However, the width of the tributary area need not be less than 1/3 the length (or span) of the area. Using this effective width provides a better approximation of the actual load distribution for elements with long and narrow tributary areas. It is not uncommon for the effective wind area of a C&C element to be different from the tributary area for the same element (see Figure B3-3). The effective wind area is used to select the external pressure coefficient for calculating the design wind pressure. The tributary area is still the area over which the calculated wind pressure is applied for that specific C&C-designed element. For cladding fasteners, ASCE 7 requires that the effective wind area shall not be greater than the area that is tributary to an individual fastener.

The external pressure coefficient is constant and maximum for effective wind areas less than 10 square feet and constant and minimum for effective wind areas greater than 100 square feet or 500 square feet, depending on the building surface and the height of the building. If the tributary area of a component element exceeds 700 square feet, the design wind pressure acting on that component may be based on the MWFRS provisions.

Once the appropriate MWFRS and C&C wind pressures are calculated for the safe room, they should be applied to the exterior wall and roof surfaces of the safe room to determine design wind loads for the MWFRS and component and cladding elements of the safe room. After these wind loads are identified, the designer should determine the relevant load combinations for the safe room (refer to B3.2.4.2.2).

Figure B3-3. Comparison of tributary and effective wind areas for a roof supported by open-web steel joists



B3.2.4.2.3 Combination of Wind Loads: MWFRS and C&C

According to ASCE 7, the MWFRS is an assemblage of structural elements assigned to provide support and stability for the overall structure and transfer wind loads acting on the entire structure to the ground. The MWFRS generally carries wind loads from more than one surface of the building. Elements of the building envelope that do not qualify as part of the MWFRS are identified as C&C. Some elements are considered part of both C&C and MWFRS, depending on the wind load and direction being considered. For example, load bearing exterior walls may transmit MWFRS wind uplift forces from the roof, and/or shear forces from a roof diaphragm/adjacent walls as axial and in plane shear forces respectively, in addition to simultaneously receiving C&C wind loads directly, which result in out of plane shear and bending in the wall.

Consider the exterior reinforced masonry wall shown in Figure B3-4. For wind direction 1, some of the lateral loads from the windward wall can be transferred through the side wall as in-plane shear (depending on design of the lateral load resisting system) and calculated using MWFRS provisions; axial loads from the roof are also calculated using MWFRS provisions. Out-of-plane loads from wind suction acting directly on the masonry side wall are calculated using C&C provisions. For wind direction 2, out-of-plane loads from wind acting directly on the masonry wall are calculated using C&C provisions and axial loads from the roof are calculated using MWFRS provisions.

B3.2.4.3 Continuous Load Path Concepts

Structural systems that provide a continuous load path are those that support all loads acting on a building, laterally and vertically (inward and outward, upward and downward). Many buildings have structural systems capable of providing a continuous load path for gravity (downward) loads, but do not provide a continuous load path for the lateral and uplift forces generated by tornadic and hurricane winds; such buildings commonly experience significant damage or collapse in extreme winds.

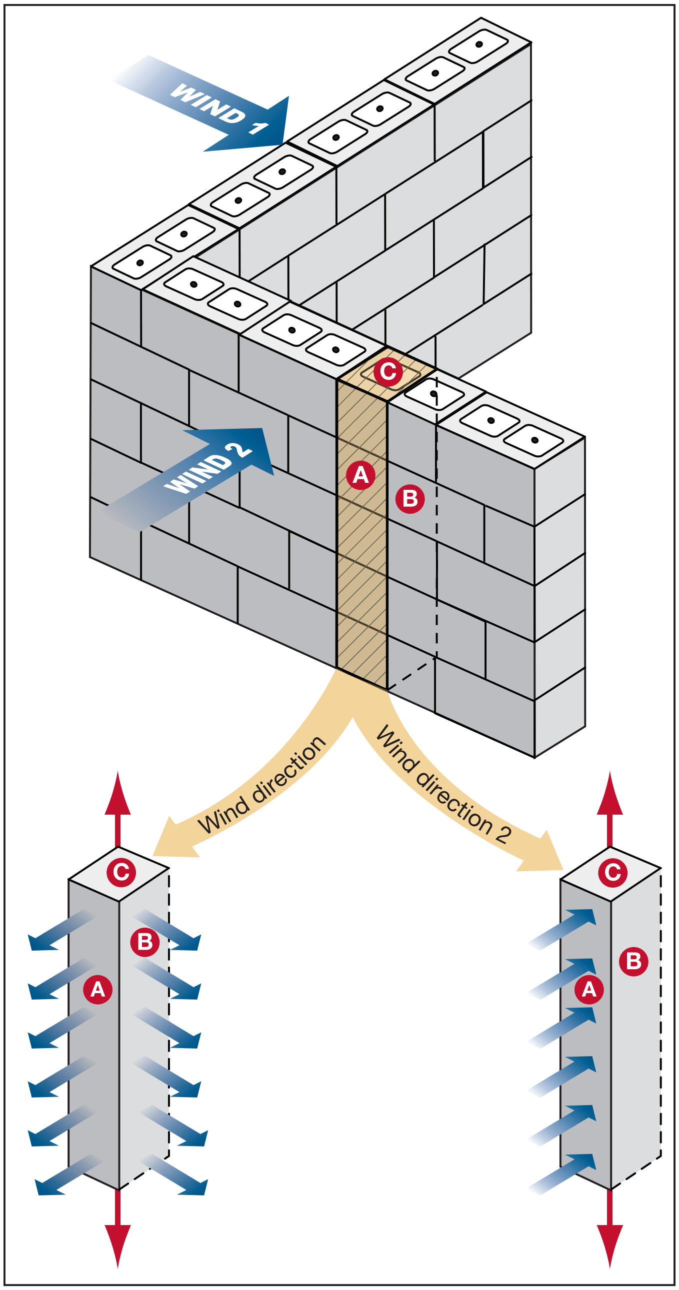


Figure B3-4. MWFRS combined loads and C&C loads acting on a safe room wall section

A continuous load path can be thought of as a "chain" running through a building. The "links" of the chain are structural members, connections between members, and any fasteners used in the connections (e.g., nails, screws, bolts, welds, or reinforcing steel). To be effective, each "link" in the continuous load path must be strong enough to transfer loads without permanently deforming or breaking. Because all applied loads (e.g., gravity, dead, live, uplift, lateral) must be transferred into the ground, the load path must continue unbroken from the uppermost building element through the foundation and into the ground.

In general, the continuous load path that carries wind forces acting on a building's exterior starts with cladding elements such as wall cladding, roof covering and decks, and windows or doors. These items are classified as C&C in ASCE 7 (the roof deck would be classified as a MWFRS when designed as a horizontal diaphragm). Roof loads transfer to the supporting roof deck or sheathing and then to the roof structure made up of rafters, joists, beams, trusses, and girders. The structural members and elements of the roof must be adequately connected to each other and to the walls or columns that support them. The walls and columns must be continuous and connected properly to the foundation, which, in turn, must be capable of transferring the loads to the ground.

Figure B3-5 illustrates connections important to continuous load paths in masonry, concrete, or metal-frame buildings. Figure B3-5 also demonstrates the lateral and uplift wind forces that act on the structural members and connections. Figure B3-6 illustrates a continuous load path in a typical commercial building. A deficiency in any of the connections depicted in these figures may lead to structural damage or collapse.

In a tornado or hurricane safe room, this continuous load path is essential for the safe room to resist wind forces. The designers of safe rooms should be careful to ensure that all connections along the load path have been checked for adequate capacity.

Figure B3-5. Critical connections important for providing a continuous load path in a typical masonry, concrete, or metal-frame building wall (for clarity, concrete roof deck is not shown)

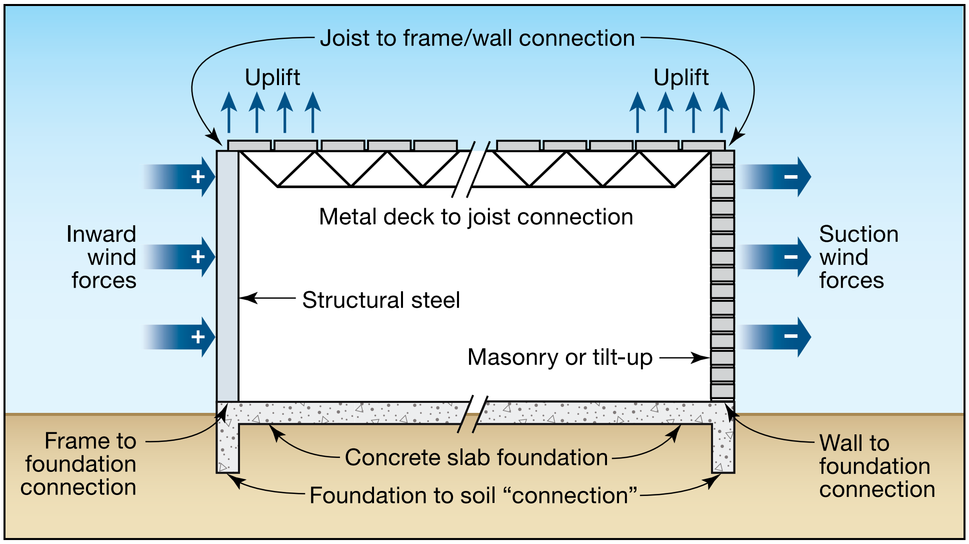
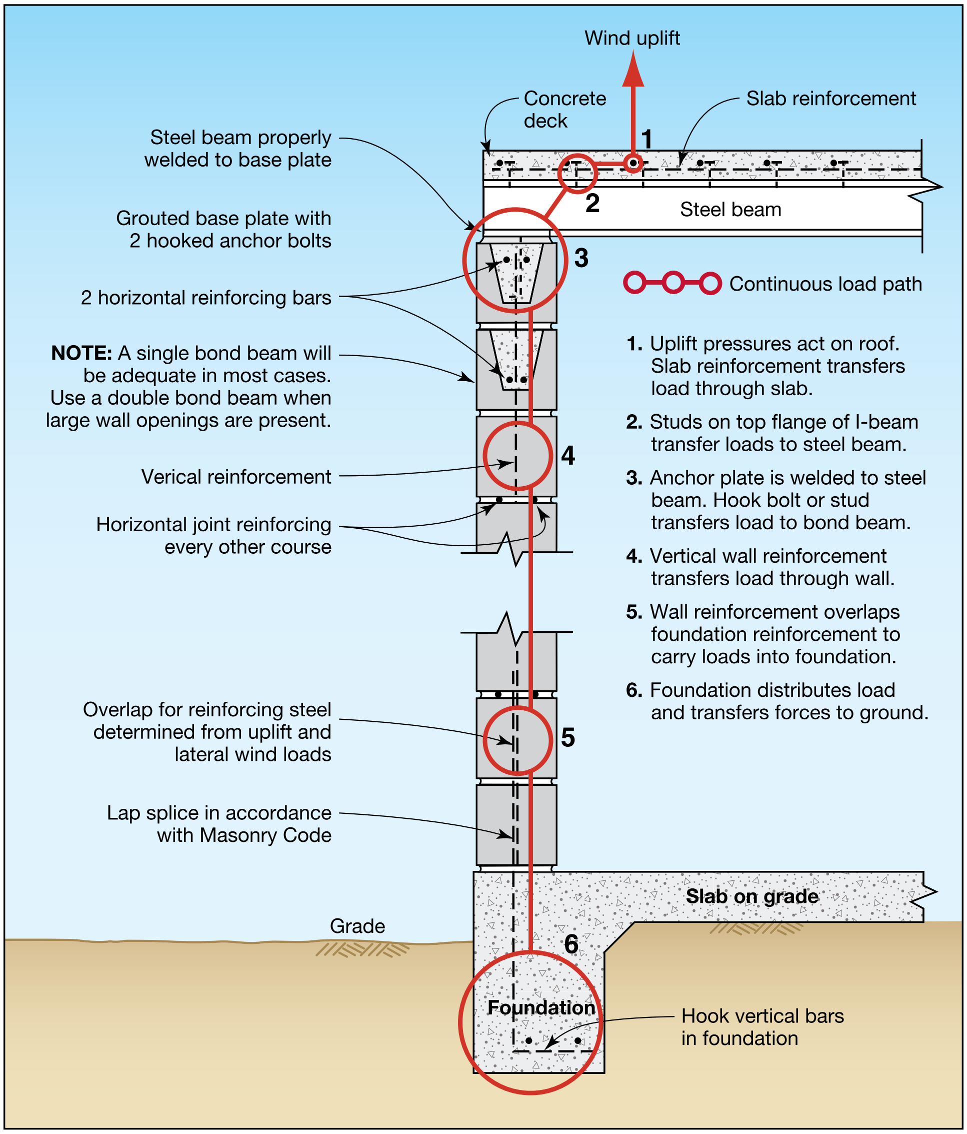


Figure B3-6. Continuous load path in a reinforced masonry building with a concrete roof deck



B3.2.4.3.1 Anchorages and Connections

A common problem during extreme-wind events is the failure of connections between building elements. This failure is often initiated by a breach in the building envelope, such as broken doors and windows or partial roof failure, which allows internal pressures within the building to increase rapidly. This phenomenon is illustrated in the schematic in Figure B3-7, which shows the forces acting on buildings when a breach occurs.

Anchorage and connection failures can lead to the failure of the entire safe room and loss of life. ***Therefore, whenever feasible, it is best practice for the design of anchorages and connections to be based on the C&C loads calculated from ASCE 7.*** All effects of shear and bending loads at the connections should be considered.

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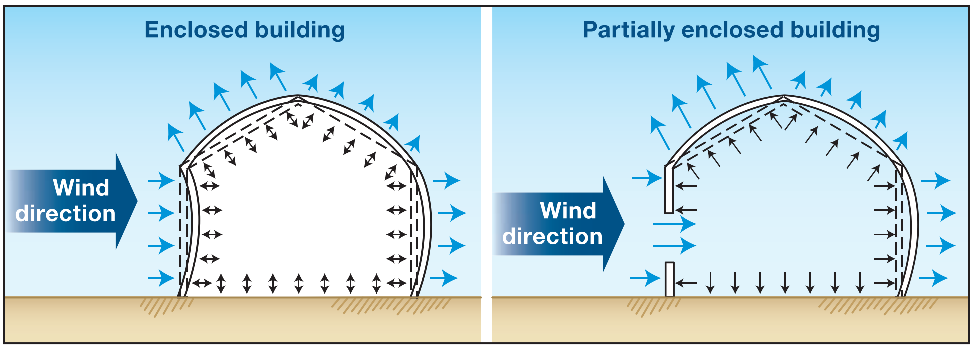


Figure B3-7. Internal pressurization and resulting building failure due to design winds entering an opening in the windward wall

B3.2.4.3.2 Roof Connections and Roof-to-Wall Connections

Adequate connections must be provided between the roof sheathing and roof structural support, steel joists, and other structural roofing members and walls or structural columns. These are the connections at the top of the continuous load path and are required to keep the roof system attached to the safe room.

Reinforcing steel, bolts, steel studs, welds, screws, and nails are usually used to connect roof decking of a safe room to supporting members. The size and number of these connections required for a safe room depend on the wind pressures that act on the roof systems. Examples of connection details for masonry, cast-in-place, and precast concrete safe rooms designed for some of these conditions may be found in case studies available on the safe room website at www.fema.gov/legacy-fema-p-361-case-studies.

Figure B3-8 shows damage to a school in Oklahoma that was struck by a tornado. The school used a combination of construction types: steel frame with masonry infill walls and load-bearing unreinforced masonry walls. Both structural systems supported open-web steel joists with a lightweight roof system composed of light steel decking, insulation, and a built-up roof covering with aggregate ballast.

Figure B3-8 highlights a connection failure between a bond beam and its supporting unreinforced masonry wall, as well as the separation of the bond beam from roof bar joists. See Figure B3-6 for an illustration of connections in a reinforced masonry wall that are likely to resist wind forces from a tornado or hurricane. Note that four connection points – between the roof decking and joists, the joist and the bond beam, the bond beam and the wall, and the wall to the foundation – are critical to a sound continuous load path.

Figure B3-8. Load path failed between the bond beam and the top of the unreinforced masonry wall when struck by an F4 tornado (Moore, OK 1999)
(SOURCE: FEMA P-342)

B3.2.4.3.3 Foundation-to-Wall Connections (Reference: ICC 500 Sec 308)

Anchor bolts, reinforcing steel, embedded plate systems properly welded together, and nailed mechanical fasteners for wood construction are typical connection methods for establishing a load path from foundation systems into wall systems. These connections are the last connections in the load path that transfer the forces acting on the building into the foundation and, ultimately, into the ground. The designer should check the ability of both the connector and the material into which the connector is anchored to withstand the design forces.

Figure B3-9 shows two columns from a building that collapsed when it was struck by the vortex of a weak tornado. Numerous failures at the connection between the columns and the foundation were observed. Anchor bolt failures were observed to be either ductile material failures or, when ductile failure did not occur, embedment failures.

The adequacy of the foundation to resist or transfer all applicable loads is of equal importance as the adequacy of the anchors that transfer the loads to it. Foundations of safe rooms, including both new and existing slabs-on-grade, are required to be designed for the applicable loads in accordance with Section 308 of ICC 500. At a minimum, new and existing slabs-on-grade must be 3.5 inches thick

CODES AND STANDARDS

Section 106.3.1 of ICC 500 requires a special inspection to be performed when safe room anchors are post-installed in hardened concrete and masonry. The special inspection is intended to verify the anchor installation and capacity, as well as the foundation adequacy. This requirement can be bypassed on residential safe rooms only if the AHJ verifies that the foundation and anchoring complies with the requirements of the safe room or storm shelter design.

and have steel reinforcement as follows: 6 x 6 – W1.4 x W1.4 welded wire or No. 4 bars, at a maximum spacing of 18 inches on center, in two perpendicular directions.

There are some exceptions for very heavy safe rooms that can be installed on existing slabs-on-grade without a foundation in one- and two-family dwellings. This is only allowed if the dead load of the safe room is heavy enough to resist sliding and global overturning from the safe room design wind pressures. In these cases the slab thickness and reinforcement should be verified as sufficient to support the weight of the safe room.

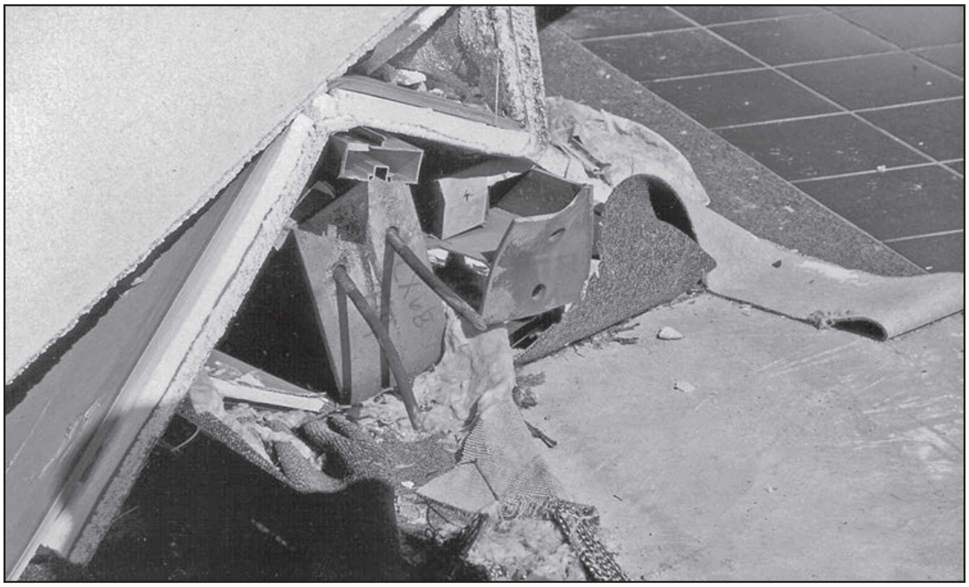


Figure B3-9. Two steel columns failed at their connection to the foundation when the anchor bolts that secured the column released from the concrete (embedment failure) while the anchor bolts that secured the column on the right experienced a ductile failure

B3.2.5 Debris Hazards (Reference: ICC 500 Sec 305)

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.

Wind-borne debris protection levels for safe rooms in ICC 500 are more stringent than the levels in the IBC, IRC, and ASCE 7. FEMA P-361 includes more restrictive guidance than ICC 500 for residential safe rooms since all residential safe rooms must be meet the 250 mph design criteria. All building elements that make up the portion of the safe room that protects the occupants should resist impacts from wind-borne debris. No portion of the envelope (roof, wall, opening, door, window, etc.) should fail due to wind pressure or be breached by the specified missile (at the appropriate debris impact wind speed). The only exceptions are roof or wall coverings that perform according to code for non-safe room design features, but are not needed to protect the safe room occupants. In addition, openings for ventilation into and out of the safe room should be hardened to resist both wind loads and missile impact test criteria.

> Note
>
> **RESIDENTIAL SAFE ROOM DOORS**
>
> For more information and guidance on finding an adequate door for residential tornado safe rooms, please see the *Tornado Safe Room Door Fact Sheet* on the safe room website or at www.fema.gov/media-library/assets/documents/99139.

If the safe room is located in an area that already requires impact-resistant glazing or protection with an impact-resistant covering protection for openings to minimize damage to buildings and contents, the code-mandated requirements for property protection must still be adhered to, and 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 B8 of this publication.

B3.2.5.1 Test Missile Criteria for Tornado Community Safe Rooms (Reference: ICC 500 Sec 305.1.1)

For tornado hazards, the safe room missile impact criteria for large missiles vary with the safe room design wind speed. Specifically, the representative missile for the missile impact test for all components of the building envelope of a safe room should be a 15-pound 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 B3-4 presents the missile impact speeds for the different wind speeds applicable for tornado safe room designs.

Table B3-3. Tornado Missile Impact Criteria

SAFE ROOM DESIGN WIND SPEED	MISSILE SPEED (OF 15 POUND 2X4 BOARD MEMBER) AND SAFE ROOM IMPACT SURFACE
250 mph	Vertical Surfaces: 100 mph Horizontal Surfaces: 67 mph
200 mph	Vertical Surfaces: 90 mph Horizontal Surfaces: 60 mph
160 mph	Vertical Surfaces: 84 mph Horizontal Surfaces: 56 mph
130 mph	Vertical Surfaces: 80 mph Horizontal Surfaces: 53 mph

Table notes: 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.

B3.2.5.2 Test Missile Criteria for Hurricane Community Safe Rooms (Reference: ICC 500 Sec 305.1.2)

For hurricane hazards, the safe room 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-pound 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 B3-5 presents the missile impact speeds for the different wind speeds applicable for hurricane safe room designs.

Table B3-4. Hurricane Missile Impact Criteria

SAFE ROOM DESIGN WIND SPEED	MISSILE SPEED (OF 9 POUND 2X4 BOARD MEMBER) AND SAFE ROOM IMPACT SURFACE
235 mph	Vertical Surfaces: 118 Horizontal Surfaces: 24 mph
230 mph	Vertical Surfaces: 115 mph Horizontal Surfaces: 23 mph
220 mph	Vertical Surfaces: 110 mph Horizontal Surfaces: 22 mph
210 mph	Vertical Surfaces: 105 mph Horizontal Surfaces: 21 mph
200 mph	Vertical Surfaces: 100 mph Horizontal Surfaces: 20 mph
190 mph	Vertical Surfaces: 95 mph Horizontal Surfaces: 19 mph
180 mph	Vertical Surfaces: 90 mph Horizontal Surfaces: 18 mph
170 mph	Vertical Surfaces: 85 mph Horizontal Surfaces: 17 mph
160 mph	Vertical Surfaces: 80 mph Horizontal Surfaces: 16 mph

Table notes: 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

B3.2.5.3 Test Missile Criteria for Residential Safe Rooms

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-pound 2x4. The speeds of the test missile impacting vertical and horizontal safe room surfaces are presented in Table B3-6. FEMA test missile impact criteria differ from ICC 500, which allows residential storm shelters and storm shelter components to meet the impact criteria required for the storm shelter design wind speed where it is to be constructed or installed. Depending on the area, this design wind speed could be lower than the worst case scenario tornado wind speed of 250 mph.

Typical residential safe rooms have fewer envelope penetrations than community safe rooms, so the cost differential associated with uniform worst case impact criteria is less significant and can help to offset increased risk resulting from potentially less stringent design, construction, and installation oversight. It may also prevent small prefabricated safe rooms that were designed to lesser wind speeds from being relocated to higher wind speed zones.

Table B3-5. Residential Safe Room Test Missile Impact Criteria

SAFE ROOM DESIGN WIND SPEED	TEST MISSILE SPEED (OF 15 POUND 2X4 BOARD MEMBER) AND SAFE ROOM IMPACT SURFACE
250 mph	Vertical Surfaces: 100 mph Horizontal Surfaces: 67 mph

Table notes: 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.

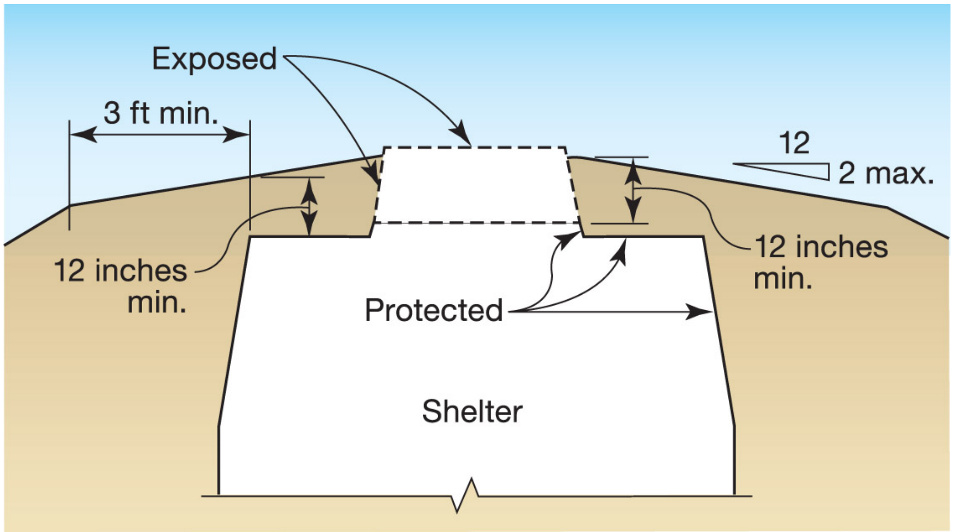
B3.2.5.4 Soil Cover as Protection from Debris Impact

Soil cover on or around safe rooms can help protect the safe room from debris impact. Debris impact resistance may not be required for portions of safe rooms that are below ground or covered by soil (Figure B3-10). 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 because the surfaces are not exposed. Soil in place around the safe room as specified above provides suitable protection from the representative tornado safe room test missile. Figure B3-11 (based on ICC 500 Figure 305.2.2) presents this information graphically.

The referenced soil cover provisions assume the soil is compactable fill. When fill is placed on top of or around a safe room, the soil should be compacted to achieve 95 percent compaction of the dry density of the soil as defined by a Modified Proctor Test. The fill cannot be the soil type used in vegetative roofs unless it can be shown to be compactable fill.

Figure B3-10. View of a community shelter that is partially below grade (Wichita, KS, 1999 tornado)
(SOURCE: FEMA P-342)

Figure B3-11. Soil cover over a safe room relieving the requirement for debris impact-resistance



B3.2.5.5 Lay Down, Rollover, Collapse, and Large Falling/ Flying Debris Hazards (Reference: ICC 500 Sec 305.3)

Following the design criteria for the wind speed selected from Figures B3-1 and B3-2 and the representative test missile impact criteria outlined in Sections B3.2.5.1, B3.2.5.2, and B3.2.5.3 will produce safe room designs with roof and wall assemblies capable of withstanding some impacts from slow-moving, large (or heavy) falling debris. Clemson University performed limited testing of large debris impact as discussed below.

Summary of Clemson University research

The purpose of the Clemson University testing was to provide guidance on the residual capacity of roof assemblies when the safe room is located where falling debris may be a hazard. In this testing, two types of safe room roof assemblies were subjected to impacts from deformable, semi-deformable, and non-deformable debris released from heights up to 100 feet and allowed to impact the roofs by free-fall.

Non-deformable debris included barrels filled with concrete weighing between 200 and 1,000 pounds. Semi-deformable debris included barrels filled with sand weighing between 200 and 600 pounds, while deformable debris included HVAC units and larger objects weighing from 50 to 2,000 pounds. Impact speeds for the falling debris were calculated from the drop height of the debris. The speed of the objects at impact ranged from approximately 17 to 60 mph. Impacts were conducted in the centers of the roof spans and close to the slab supports to observe bending, shear, and overall roof assembly reactions.

Cast-in-place and precast concrete roof sections were constructed from the design plans in case studies that are available on the safe room website at www.fema.gov/legacy-fema-p-361-case-studies. The heavily reinforced, cast-in-place concrete roof performed quite well during the impact testing. Threshold spalling, light cracking, to no visible damage was observed after impacts by the deformable missiles, including the large 2,000-pound deformable object that struck the slab at approximately 60 mph. Impacts from the 1,000-pound concrete barrel did cause spalling of concrete from the bottom surface of the roof near the center of the slab, which would pose a significant hazard to the occupants directly below the point of impact. However, significant spalling required relatively high missile drops (high impact speeds).

When the 1,000-pound concrete barrel impacted the roof at approximately 39 mph, spalling of the slab extended into the slab from the bottom surface to the middle of the slab. During this heavy spalling, the largest fragments of concrete were retained in the roof by the steel reinforcement. Metal decking (22 gauge) was successfully used as cast-in-place formwork on one of the test samples to retain concrete spalls created by the falling debris.

The 1,000-pound concrete barrel completely perforated the flange of the double-tee beam in one drop from 50 feet (impacting at 39 mph) and caused significant damage to the stem in a second drop from the same height. Little damage occurred when the deformable debris materials (HVAC units, the 300-pound sand barrels, and a 1,500-pound deformable object) were dropped on the double-tee beams. Only light cracking and threshold spalling were observed from impacts from these deformable objects.

Note

FEMA P-320 DESIGNS

When using the designs provided in FEMA P-320 for residential and small business safe rooms, the safe room user/operator should be aware that falling debris was considered during the design of those prescriptive design solutions. As such, the use of safe rooms compliant with the FEMA P 320 safe room criteria within light-framed, low-rise buildings is considered appropriate, even though portions of the building may collapse on the safe room.

Design and siting implications of Clemson University research

Based on the research conducted by Clemson University, designers should consider the following information when designing safe rooms.

Roof design: In addition to the roof live load requirements detailed in Section 3.2.3.2, it may be necessary to address additional loads identified during the risk assessment. Based on the Clemson University research, roof designs that incorporate a uniform thickness (i.e., flat slab) provide a more uniform level of protection from laydown, collapse, and large falling/flying debris, anywhere on the roof, than a waffle slab, ribbed slab, or other designs that incorporate a thin slab supported by secondary beams. If siting the safe room away from potential laydown and collapse hazards is not a viable solution, using a roof design with a flat slab may protect safe room occupants from laydown, collapse, and large falling/flying debris on safe room roof assemblies. If the concrete is cast onto metal decking, the steel beams/decking should be connected to the concrete with shear connector studs to contain spalling concrete. Future research may yield information that results in a more refined approach to designing safe rooms to resist the forces created by laydown, rollover, collapse, and large falling/flying debris.

Falling debris: Falling debris also creates structural damage, the magnitude of which is a function of the debris mass and distance the debris falls. Falling debris generally consists of building materials and equipment that have significant mass and fall short distances from taller structures nearby or overhead (Figure B3-12). When siting the safe room, the designer should consider placing the safe room away from a taller building or structure so that, if the building or structure collapses, it will not directly impact the safe room. If it is not possible to site the safe room away from all potential falling/flying debris hazards, the designer should strengthen the roof and wall assemblies for the potential dynamic load that may result from these large objects impacting the safe room.

The location of the safe room can affect the type of debris that may impact or fall on it. For residential buildings, the largest debris generally consists of wood framing, kitchen appliances (e.g., refrigerators), and vehicles. In larger buildings, other failed building components (e.g., steel joists, precast concrete, or rooftop equipment) and vehicles may fall on or impact a safe room (Figures B3-12 to B3-16). Chapter B4 discusses how to minimize the effects of falling/flying debris by choosing the most appropriate location for a safe room at any given site.

TERMINOLOGY

Lay down hazard: Nearby trees and towers and other tall structures that can potentially fall onto a safe room (Figure B3-12).

Rollover hazard: Vehicles and small buildings, such as portable classrooms or storage buildings, which can roll or tumble and impact a safe room (Figure B3-13).

Collapse hazard: Debris from an adjacent taller building or portions of a building above a safe room that falls onto a safe room (Figure B3-14).

Large falling/flying debris hazard: Large objects such as portions of buildings (e.g., the roof assembly shown in Figure B3-15 and precast concrete panels) that become airborne and impact a safe room.

Figure B3-12. Lay down hazard: failure of a large communications tower onto a building (Joplin, MO, 2011 tornado)

(SOURCE: FEMA P-908, RECOVERY ADVISORY 5)

Figure B3-13. Vehicle rollover hazard (Greensburg, KS, 2007 tornado)

Figure B3-14. Collapse hazard: the story above an Emergency Operations Center collapsed. Masonry walls (red arrow) and part of the roof structure fell onto the second story floor slab above the EOC (Tuscaloosa, AL, 2011 tornado)

(SOURCE: FEMA P-908, RECOVERY ADVISORY 6)

Figure B3-15. Flying debris hazard: an EF1 tornado blew a school gymnasium's steel truss and steel deck roof assembly approximately 230 feet (Cleveland, TN, 2011)

Figure B3-16. Collapse hazard: tall precast wall panels collapsed onto the floor slab (Midwest tornado, 2003)

B3.2.6 Component Design and Testing (Reference: ICC Sec 306)

To demonstrate that the safe room provides life-safety protection, all safe room components (e.g., wall, roof, door, glazing, and opening protection assemblies) should successfully pass the component-specific testing requirements set forth in Section 306 of ICC 500. Specifications and procedures for all safe room tests are provided in ICC 500, Chapter 8, "Test Methods for Impact and Pressure Testing."

Missile impact testing criteria for safe room components are described in Sections B3.2.5.1 (tornado community safe rooms), B3.2.5.2 (hurricane community safe rooms), and B3.2.5.3 (residential safe rooms). FEMA commentary on this topic is presented in Chapter B8.

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 is addressed in Chapter B1.

FEMA supports Section 306.1 of ICC 500, which states that no additional testing of assemblies and products for different levels of debris impact are required if the most stringent criteria of missile size and speed are met.

Information and commentary on safe rooms is presented in Chapter B8.

WEATHER PROTECTION

Because of the short duration of tornadoes, enhanced weather protection is not required for tornado safe rooms. ICC 500 Section 307 requires exposed C&C assemblies and roof coverings of hurricane storm shelters to be designed to resist rainwater penetration and wind loads associated with the safe room design event.

Providing a secondary line of protection, such as roof and wall membranes, is best practice as discussed in FEMA P-424, FEMA P-543, and FEMA P-577.

BEST PRACTICE

CODES AND STANDARDS

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

Alcove or Baffled Entry Systems

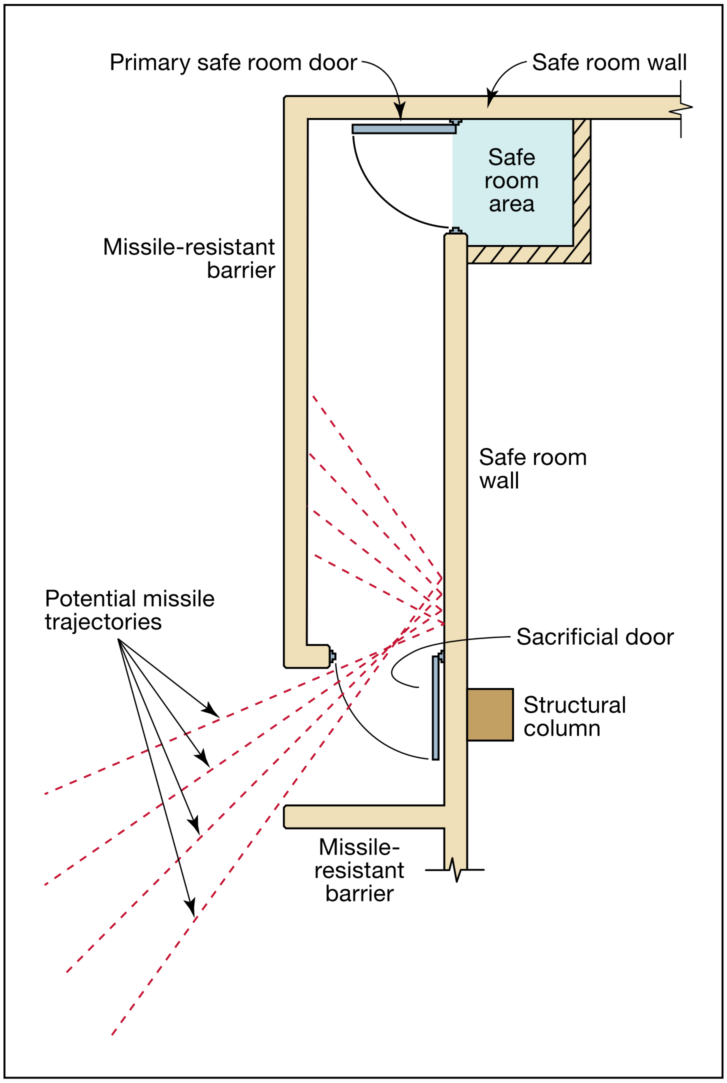
In lieu of specifying doors that meet the test missile criteria, test missile-resistant barriers can be designed to protect doors from wind-borne debris impacts and meet the criteria of this publication.

The safe room designs from the second edition of FEMA P-361 (now available as case studies on the safe room website at www.fema.gov/legacy-fema-p-361-case-studies) use alcoves to protect primary safe room doors from debris impacts. However, a door may be necessary in order to satisfy some fire rating requirements within the building code. To satisfy the missile impact criteria for the primary safe room door and code egress requirements, a protective missile-resistant barrier and roof assembly should be designed to meet the design wind load and missile impact criteria for the safe room and maintain the egress width provided by the door itself.

Although the wind pressures at the primary safe room door should be reduced by the presence of the alcove, there has not been much research to quantify the reduction. ***While not required by ICC 500 Sec 804.9.7.1, to better protect occupants from the effects of small flying debris, it is best practice to install a primary safe room door tested to resist the safe room design wind pressure.*** The sacrificial door is not required to be designed to resist the wind pressure or test missile impact criteria. See Figure B3-17.

BEST PRACTICE

Figure B3-17. The primary door of the safe room is protected by a debris-resistant barrier. Note: the safe room roof extends past the safe room wall and connects to the top of the debris-resistant barrier to prevent intrusion of debris traveling vertically.



CHAPTER B4
Siting

This chapter uses Chapter 4 of ICC 500 as the referenced standard and includes a list of Recommended Criteria FEMA has identified as more conservative than the provisions in Chapter 4 of ICC 500. This chapter also includes FEMA supplemental commentary on siting based on many years of field observations and investigations related to safe room performance.

FEMA SAFE ROOM GRANT REQUIREMENTS

Whenever a safe room is constructed using FEMA grant funds, the Recommended Criteria shown in Section B4.1 become requirements in addition to the requirements of ICC 500 Chapter 4.

B4.1 Criteria

The siting of safe rooms should be conducted in accordance with the provisions of Chapter 4 in ICC 500 with the exception of FEMA's Recommended Criteria as shown in Table B4-1.

For safe rooms being constructed with FEMA grant funds, the listed exceptions become mandatory minimum requirements in addition to the corresponding ICC 500 criteria. FEMA grant programs have specific flood hazard siting limitations as described in Section B4.2.2. Additionally, the planning and design of community safe rooms funded with FEMA grants should be conducted according to the process mandated by Title 44 of the Code of Federal Regulations (CFR) Chapter 1, Subchapter A, Part 9, *Floodplain management and protection of wetlands*. Refer to Section B4.2.2 for additional discussion on FEMA siting requirements.

Table B4-1. Comparison of ICC 500 Requirements to FEMA Recommended Criteria

ICC 500 REFERENCE	ICC 500 REQUIREMENT FOR STORM SHELTERS	FEMA RECOMMENDED CRITERIA FOR SAFE ROOMS[a]
Section 401.1.1 **Minimum floor elevation of community shelters**	The lowest floor used for the occupied shelter and occupant support areas of a community shelter shall be elevated to the higher of the elevations determined by: 1. The flood elevation, including coastal wave effects, having a 0.2 percent annual chance of being equaled or exceeded in any given year; or 2. The flood elevation corresponding to the highest recorded flood elevation if a flood hazard study has not been conducted for the area; or 3. The maximum flood elevation associated with any modeled hurricane category including coastal wave effects; or 4. The minimum elevation of the lowest floor required by the authority having jurisdiction for the location where the shelter is installed; or 5. Two feet above the flood elevation having a 1 percent annual chance of being equaled or exceeded in any given year. <u>Exception:</u> Items no. 1 and 3 shall not apply to shelters designed, constructed, designated, and used only as tornado shelters.	The lowest floor used for the occupied safe room and occupant support areas of a community safe room shall be elevated to or above the higher of the elevations determined by: 1. The flood elevation, including coastal wave effects, having a 0.2 percent annual chance of being equaled or exceeded in any given year[b]; or 2. The flood elevation corresponding to the highest recorded flood elevation if a flood hazard study has not been conducted for the area; or 3. The maximum flood elevation associated with any modeled hurricane category including coastal wave effects; or 4. The minimum elevation of the lowest floor required by the authority having jurisdiction for the location where the safe room is installed; or 5. Two feet above the flood elevation having a 1 percent annual chance of being equaled or exceeded in any given year.[b] <u>Exception:</u> **Item 3 (only)** shall not apply to safe rooms designed, constructed, designated and used only as tornado safe rooms.
Section 401.1.2 **Minimum floor elevation of residential shelters**	The lowest floor used for the occupied shelter area of a residential shelter shall be elevated to the higher of the elevations determined by: 1. The flood elevation, including coastal wave effects, having a 0.2-percent annual chance of being equaled or exceeded in any given year; or 2. The flood elevation corresponding to the highest recorded flood elevation if a flood hazard study has not been conducted for the area; or 3. The maximum flood elevation associated with any modeled hurricane category, including coastal wave effects; or 4. The minimum elevation of the lowest floor required by the authority having jurisdiction for the location where the shelter is installed. <u>Exception:</u> Items 1 and 3 shall not apply to shelters designed, constructed, designated, and used only as tornado shelters.	The lowest floor used for the occupied residential safe room shall be elevated to the higher of the elevations determined by: 1. The flood elevation, including coastal wave effects, having a 0.2 percent annual chance of being equaled or exceeded in any given year[b]; or 2. The flood elevation corresponding to the highest recorded flood elevation if a flood hazard study has not been conducted for the area; or 3. **Not Applicable**[c] 4. The minimum elevation of the lowest floor required by the authority having jurisdiction for the location where the shelter is installed. 5. **The flood elevation having a 1 percent annual chance of being equaled or exceeded in any given year.**[b] <u>Exception:</u> **Item 1 (only)** shall not apply to safe rooms designed, constructed, designated, and used only as tornado safe rooms.

Table B4-1. Comparison of ICC 500 Requirements to FEMA Recommended Criteria (continued)

ICC 500 REFERENCE	ICC 500 REQUIREMENT FOR STORM SHELTERS	FEMA RECOMMENDED CRITERIA FOR SAFE ROOMS[(a)]
Section 404.1 **Community Shelter Siting**	Community shelters shall be located outside of the following high-risk flood hazard areas: 1. Flood hazard areas subject to high-velocity wave action (V zones) 2. Floodways <u>Exception:</u> Community shelters shall be permitted in flood hazard areas subject to high-velocity wave action (V zones) where permitted by the Board of Appeals in accordance with the provisions of the International Building Code.	Community safe rooms shall be located outside of the following high-risk flood hazard areas: 1. Flood hazard areas subject to high-velocity wave action (V zones) **and Coastal A zones**[(d)] 2. Floodways <u>Exception:</u> Community safe rooms shall be permitted in flood hazard areas subject to high-velocity wave action (V zones) **and Coastal A zones**[(d)] where permitted by the Board of Appeals in accordance with the provisions of the International Building Code **and after completing the 8-step Decision Process for Executive Order (EO) 11988, as amended, and as provided by Title 44 of the Code of Federal Regulations Part 9.6, Decision-Making Process.**
Residential Shelter Siting	*[ICC 500 does not provide restrictions for siting residential shelters in flood hazard areas]*	**Residential safe rooms shall be located outside of the following high-risk flood hazard areas:** **1. Flood hazard areas subject to high-velocity wave action (V zones) and Coastal A zones**[(d)]**;** **2. Floodways;** **3. Any areas subject to storm surge inundation associated with any modeled hurricane category, including coastal wave effects.**

***Bolded text** denotes differences between the ICC 500 Requirement and the FEMA Recommended Criteria.

Table notes:

(a) Table only lists differences between FEMA P-361 and ICC 500 Chapter 4. All ICC 500 Chapter 4 requirements not listed in the table should also be met in their entirety.

(b) Where an approximate or detailed flood hazard study has been completed but the 1-percent- and/or 0.2-percent-annual-chance flood elevations have not been determined, those elevations should be obtained from the authority having jurisdiction or determined in accordance with accepted hydrologic and hydraulic engineering practices used to define Special Flood Hazard Areas.

(c) Not applicable because residential safe rooms should not be located in areas subject to storm surge inundation associated with any modeled hurricane category; refer to Residential Shelter Siting with respect to flood hazards in this table.

(d) Coastal A Zones are defined as the area landward of Zone V or landward of an open coast without mapped Zone V. The inland limit of the Coastal A Zone is the Limit of Moderate Wave Action if delineated on a Flood Insurance Rate Map or designated by the authority having jurisdiction.

B4.2 FEMA Supplemental Commentary

FEMA offers the following commentary and background information as supplemental guidance to the registered design professional for the criteria referenced in ICC 500 Chapter 4 or presented as FEMA requirements in Section B4.1.

B4.2.1 General Siting Considerations

Safe rooms by their very function are exceptionally dependent on their location for their effectiveness. Safe rooms must be located as close as possible to their potential users, specifically the population at risk from extreme-wind hazards.

CROSS-REFERENCE

Operators of community safe rooms should consider operational issues, described in Chapter A4.

In addition, the location of a safe room is determined by other considerations, such as safety, accessibility, and a variety of environmental factors. This section examines the most important factors that should be considered when siting a safe room. Refer also to Chapter A4, which describes safe room operational considerations, some of which may affect siting decisions.

B4.2.1.1 Function and Use

Community safe rooms may be designed and constructed to serve a single property or facility, such as a school, hospital campus, or a manufactured housing park, or to serve multiple properties, such as those in a neighborhood. Conversely, residential safe rooms serve only occupants in dwelling units and may be sited anywhere on a property (e.g., inside of a home, in a backyard, garage, etc.) as long as the door is located within a 150-foot travel path from an exterior door of the dwelling unit (if located outside).

The site selection criteria that pertain to the functionality of a safe room are closely associated with the risk and vulnerability assessment criteria described in Chapter A2. Risk and vulnerability considerations that must be considered include:

- The size and geographic distribution of the at-risk population
- The vulnerability of the at-risk population with respect to the buildings they normally occupy
- The vulnerability of the at-risk population with respect to their ability to reach the safe room in a timely manner during an emergency

Some of the most vulnerable buildings are manufactured houses, which frequently fail during wind storms. For this reason, residents of manufactured housing parks must be regarded as highly vulnerable.

Note

MAXIMUM POPULATION AND ALLOWABLE TRAVEL TIME

Safe room owners, operators, and designers should ask their FEMA Regional office for the most current safe room policy on safe room population and maximum allowable travel time/distance to safe rooms. It is particularly important for those seeking HMA grants to obtain the most up-to-date policy.

Additionally, the site selected might need to accommodate people occupying public facilities, like hospitals, residential care facilities, schools, and child care centers, that house large populations; such populations may not be able to reach a remote safe room quickly enough during an emergency. Typically this type of facility is served by safe rooms inside the building or attached to it, minimizing evacuation problems.

In multi-building or campus situations where a safe room serves other buildings in addition to the building housing the safe room, having enclosed or underground walkways from the served buildings to the safe room is desirable, as there may be strong winds, heavy rain, or hail preceding the arrival of the tornado. If these solutions are not feasible, covered walkways should be considered.

B4.2.1.2 Safety

The safety of a site is evaluated on the basis of its exposure to multiple hazards. Sites exposed to flooding need to be carefully evaluated for safe rooms, not only because of the dangers flooding may pose for the occupants, but also because flooding can isolate the facility and its occupants, or make it inaccessible in an emergency. Other hazards that must be considered are seismic, landslides, and fires (especially the exposure of the site to wildfire). Chapter A2 provides information on assessing risk of hazards.

B4.2.1.3 Access

The accessibility of a site is directly related to the anticipated safe room service area and its proximity to the potential occupants. Potential users should be able to reach the safe room within the required time period using a designated pedestrian pathway. Unobstructed access is an important element of safe room design. The pathway to a safe room should not have restrictions or obstructions, such as multi-lane highways, railroad tracks, bridges, or similar facilities or topographic features. See also Section B4.2.1.5, *Siting Proximity to Occupants for Residential Safe Rooms*, and Section B4.2.1.6, S*iting Proximity to Occupants for Community Safe Room*, for maximum allowable travel time/distance.

> **CROSS-REFERENCE**
>
> Refer also to Chapter A4.5 for additional information on access and entry.

If obstructions exist along the travel route, or if the safe room is cluttered with non-essential equipment and storage items, orderly access to the safe room will be impeded. Hindering access in any way can lead to unnecessary increased travel time, chaos, or panic.

Building/site-related access issues

Siting factors that affect access should be considered. For example, vehicle parking at a community safe room built to serve a residential neighborhood should not impede access to the safe room; at a non-residential safe room, such as a facility at a manufacturing plant, equipment, parts handling and product storage should not impede access.

The location of a safe room on a building site is an important consideration of the design process for any safe room. The safe room should be located such that all persons designated to take refuge can reach the safe room quickly; this is of particular importance for tornado safe rooms. Safe rooms located at one end of a building or one end of a community, office complex, or school may be difficult for some users to reach in a timely fashion. Routes to the safe room should be easily accessible and well-marked. For more information on signage considerations in community safe rooms, see Section A4.3.2, *Signage*, and Section B5.2.4, *Signage for Community Safe Rooms*.

Flood-related access issues

Safe rooms located where flood depths are 3 feet and higher may become isolated if access routes are flooded. As a result, emergency services would not be available if some safe room occupants are injured. A safe room in a flood-prone area should be properly equipped to meet reasonably anticipated emergency medical, food, and sanitation needs during the time the occupants could be isolated by flooding.

Access to the safe room should be maintained during flooding conditions, if possible. If access is not possible by ground transportation during flooding, alternative access should be provided. An example of how alternative access can be achieved is the installation of a helicopter landing pad that is above the safe room design flood level, or ensuring that a loading dock or other area of the building could be used as a dock for small boats if the area is inundated. In all cases, both the designer and owner will need to work with local and State emergency managers to ensure that any alternative access methods are properly planned, both in the safe room design and construction and in emergency operation procedures. For more information on siting in relation to flood hazards, see Section B4.2.2.

Def

TERMINOLOGY

The requirements and best practices in Chapter B4 use the terms "SFHA" and "flood elevation having a 1-percent-annual-chance of being equaled or exceeded."

Special Flood Hazard Area (SFHA): The land area covered by the floodwaters of the flood having a 1 percent chance of being equaled or exceeded in any given year. This area is typically mapped on FEMA's Flood Insurance Rate Maps (FIRMs) as Zone A or Zone V.

Base Flood: The "flood elevation having a 1-percent-annual-chance of being equaled or exceeded" is also referred to as the base flood, and sometimes the "100-year flood."

B4.2.1.4 Siting Proximity to Other Buildings

When possible, safe rooms should be located away from large objects and multi-story buildings. Light towers, antennas, satellite dishes, and roof-mounted mechanical equipment can topple or become airborne during tornadoes or hurricanes, just as multi-story buildings can be damaged or fail structurally, collapsing onto an adjacent safe room or exposing it to large debris impact.
The impact forces associated with such large wind-borne debris are outside the design parameters of typical safe rooms.

B4.2.1.5 Siting Proximity to Occupants for Residential Safe Rooms (Reference: ICC 500 Sec 401)

There are a number of potential locations to construct a safe room inside of a home. Though tornado warnings are often issued with enough time for someone in one room of a home to travel to a safe room in another area of the home, mobility and ease of safe room ingress should be considered for all safe rooms.

A safe room can also be located outside of the home. To enter such a safe room, occupants will need to travel to the safe room from the home. ICC 500 requires that the access opening for a residential safe room be located such that the distance of the travel path is no more than 150 feet from an exterior door of the residence. Occupants will need to enter exterior safe rooms early to prevent injuries from storm wind and wind-borne debris as they travel to the safe room.

Both interior and exterior safe rooms can be either above or below grade. However, if constructing a safe room in a Special Flood Hazard Area (SFHA), siting the safe room below ground or below the design flood elevation is not recommended.

B4.2.1.6 Siting Proximity to Occupants for Community Safe Rooms

Safe room designers should consider the time needed for all occupants of a building or facility to reach the safe room. The NWS has made great strides in predicting tornadoes and hurricanes and providing warnings that allow time to seek shelter.

Note

HMA GUIDANCE

The FEMA HMA Guidance is udated periodically. The most current policy guidance can be downloaded from: www.fema.gov/hazard-mitigation-assistance.

Travel time requirements for tornado safe rooms
For tornadoes, the time span is often short between the NWS warning and the onset of the tornado. As of its Fiscal Year 2015 HMA Unified Guidance, FEMA requires that tornado safe rooms be sited so that occupants have

a maximum walking travel time of 5 minutes or a maximum driving travel distance of approximately 0.5 mile to reach the safe room. The actual travel route or pathway should not be restricted, bottlenecked, or obstructed by barriers such as multi-lane highways, railroad tracks, bridges, or similar facilities or by topographic features. When determining travel time, potential traffic congestion (including parking constraints) that may occur when potential at-risk occupant are moving to the safe room after a storm watch/warning notification has issued should be considered. Additionally, the walking speed of occupants going to the safe room should be considered. Using a 3 mph walking speed, a 5 minute of walking travel time corresponds to approximately ¼ mile.

Travel time requirements for hurricane safe rooms

For hurricane safe rooms, a different set of criteria applies. Since there is usually a substantial amount of warning time for hurricanes, and because mandatory evacuations may be issued ahead of severe hurricanes, the criteria to determine travel time for a hurricane safe room can be more complex.

Those not able to evacuate for a hurricane (first responders, critical and essential services personnel, and certain medical, or residential care facility occupants) would be the potential population for a hurricane safe room. See Chapter A4 for more information on considerations for the population traveling to the safe room, as well as the latest FEMA HMA Unified Guidance and its Addendum.

Travel time considerations for those with impaired mobility

Travel time may be especially important when safe room users are elderly or have disabilities that impair their mobility and may need assistance from others to reach the safe room. In addition, wheelchair users may need a particular route that accommodates wheelchairs. The designer should consider these factors to provide the shortest possible access time and most accessible route for all potential safe room occupants.

B4.2.1.7 Manmade Siting Hazards (Reference: ICC 500 Sec 402)

It is important that the designer consider other hazards at the building site, in addition to the wind, flood, and seismic hazards already mentioned.

One such consideration is the presence of a hazardous material on a site. Older buildings that are retrofitted for safe room use should be inspected for hazardous materials that may be stored near the safe room (e.g., gasoline, chlorine, or other chemicals) or that may have been used in the construction of the surrounding building (e.g., lead paint or asbestos). For example, asbestos may become airborne if portions of the surrounding building are damaged, resulting in the chemical contamination of breathable air. Live power lines, fire, and gas leaks are also safe room design concerns that may need to be addressed at some safe room sites. For example, the Wichita case study (Sheet P-1) available on the safe room website at www.fema.gov/legacy-fema-p-361-case-studies shows how a gas line, required for gas service to the safe room area when in normal daily use, was fitted with an automatic shutoff valve. This precaution greatly reduces the risk of a gas-induced fire occurring while the safe room is occupied.

MORE INFORMATION

Information on flood elevations associated with 100-year or 500-year flooding can usually be found on FEMA's Map Service Center website (www.msc.fema.gov). The FIRMs on the website show the flood zone and associated elevation, if applicable and available.

For information on storm surge, contact the State or local emergency management offices.

Additional sources for flood information include:

- Floodplain managers (see list at www.floods.org)
- Local building or zoning department
- U.S. Geological Survey (USGS) (including gage data)
- NOAA
- NWS
- State Sea Grant Extension Programs
- U.S. Army Corps of Engineers
- State or county highway department

B4.2.1.8 Other Criteria to Consider

Other factors may also need to be considered, including environmental and historic preservation, economic, zoning, or other administrative factors. These factors should be considered from the very start of the siting process.

B4.2.2 Flood Hazards (Reference: ICC 500 Sec 401 and Sec 404)

Flood hazards should be considered when designing and constructing a safe room. Designers should investigate all sources of flooding that could affect the use of the safe room. The functionality of a safe room can be affected by flooding in many different ways. Flooding can inundate a structure housing a safe room and can also affect the safe room by disrupting or blocking access when surrounding areas flood. Safe rooms in flood-prone areas are susceptible to damage from hydrostatic and hydrodynamic forces associated with rising floodwater and from debris carried in the water. Most importantly, flooding of occupied safe rooms can result in injuries or deaths. Areas with high groundwater tables should also be considered cautiously when considering installation of in-ground safe rooms, as buoyancy forces can potentially push the structure out of the ground.

B4.2.2.1 General Flood Hazard Siting / Elevation

BEST PRACTICE

This section outlines general flood related siting and elevation criteria for safe rooms. If the site is located outside of the SFHA, the 500-year floodplain, and the area inundated by coastal storm surge, the designer should include a statement in the design drawings documenting that the site is outside of the SFHA. For areas outside of the SFHA, ***the best practice is to include the closest adjacent base flood elevation (BFE) and 500-year flood elevation on the project plans.*** Project plans for hurricane shelters should also include the rainfall intensity and the hurricane storm surge elevation information.

Location of safe room within a Special Flood Hazard Area

Except in special circumstances, safe rooms should not be sited in FEMA-designated SFHAs unless consultation with local and State emergency management officials concludes there is no other feasible option. If it is not possible to locate a safe room outside of the SFHA, precautions must be taken to ensure the safety and well-being of anyone using the safe room. The lowest floor of the safe room should be elevated above the flood elevation as described in Table B4-1. All utilities or services supplied to the safe room should be protected from flooding as well. Additionally, the planning and design of a federally funded community safe room should be conducted according to the process mandated by 44 CFR Chapter 1 Subchapter A Part 9, *Floodplain management and protection of wetlands.*

In many flood hazard areas around the country, the Flood Insurance Study and accompanying Flood Insurance Rate Maps (FIRMs) may not specify flood elevations. This type of unspecified area is commonly referred to as unnumbered Zone A or approximate Zone A. In most cases the flood elevation requirements for safe rooms are still applicable even though the 1-percent- or 0.2-percent-annual-chance flood elevations are not defined by FEMA.

As Table B4-1 shows, tornado-only residential safe rooms are not required to elevate to the 0.2-percent-annual-chance flood elevation, but even these structures should be elevated to the 1-percent-annual-chance flood elevation (the BFE). However, hurricane and combined residential safe rooms, as well as community safe rooms (for either tornado or hurricane hazards) should be elevated to the 0.2-percent-annual-chance flood elevation.

The 1-percent- and 0.2-percent-annual-chance flood elevations should be either determined by consulting local, State, or Federal agencies, or calculated. The following may be sources of information on flood elevations:

- Local floodplain administrator
- State National Flood Insurance Program (NFIP) coordinator – some States have regulations or guidance on how to obtain regulatory data and some have repositories of data or may help conduct a new study
- Local flood control, sanitary, or watershed districts – like State agencies, these districts may have their own programs for developing new flood data
- U.S. Army Corps of Engineers, U.S. Department of Agriculture/ Natural Resources Conservation Service, or U.S. Geological Survey – these agencies may have knowledge of flood studies, unpublished reports, or other data that may pertain to the area in question.

MORE INFORMATION

Additional guidance can be found in FEMA 265, *Managing Floodplain Development in Approximate Zone A Areas: A Guide for Obtaining and Developing Base (100-Year) Flood Elevations* (1995), and a companion software program, QUICK-2 (available from FEMA at www.fema.gov/media-library/assets/documents/7894.

Designers should also consider if studies may have been performed for a nearby area. For instance:

- If a body of water forms a boundary between two communities, the community on the other side may have a detailed study; such base flood data are valid for both sides of a body of water
- If the property is along a stream that is near state highway structures such as bridges or culverts, the state highway department may have done a flood study to properly size the structure
- If the property is on a river with a power-generating dam, the dam owner may have had to conduct a study for federal licensing

If the required flood elevation information is not available, the local authority may be able to provide the requirements for determining the flood elevations in accordance with accepted engineering practices.

EXAMPLE

A proposed tornado safe room project is being planned in Greenville, MO. The safe room will be an addition to an existing building, with a normal-use function of educational classroom space. The existing building is located adjacent to a small stream. The safe room will be located outside the SFHA, approximately 80 feet from an approximate Zone A, with a portion of the existing building being located in the Zone A. An engineering analysis has already been completed to determine the elevation associated with the 1-percent-annual-chance flood; the analysis included the use of a regression equation for hydrology, the HEC-RAS software for the hydraulics, and a 10m digital elevation model (DEM) from the USGS. Since this was a basic analysis, field surveys were not completed, and hydraulic structures were not included in the model. Channel geometry was determined from the DEM. The vertical accuracy of the DEM is ±10 feet, or one-half the interval between contours on the USGS topographic map.

The BFEs are not published on the FIRM, though the water surface elevation used to determine the SFHA is included in the hydraulic model. The floodplain for the 0.2-percent-annual-chance flood event was not determined, nor was the water surface elevation for the 0.2-percent-annual-chance flood calculated.

Per safe room flood criteria in this publication as shown on Table B4-1 (see side bar image to the right), the lowest floor of the community safe room is the highest of the following elevations.

In this example, the community floodplain management ordinance requires 1 foot of freeboard above the BFE. Therefore, item #4 was less than item #5. The other items that community safe rooms should consider (per Table B4-1) did not apply; the area had been part of a flood hazard study (removing item #2 from consideration), and the safe room is being designed, constructed, designated, and used only as tornado safe rooms (satisfying the exception to item #3).

Based on information from the hydraulic model, the elevation of the 1-percent-annual-chance flood event was approximately 426.5 feet. The proposed finished floor elevation of the safe room was 429.45 feet. Since the proposed safe room floor elevation is greater than the BFE+ 2 feet, item #5 is satisfied.

The project team also had to compare the finished floor elevation to the 0.2-percent-annual-chance flood elevation. This was particularly important in this instance because the safe room location was so close to a flood source. Using the hydraulic model, a regression equation was used to determine the discharge for the 0.2-percent-annual-chance event, and the water surface elevation was calculated as 426.94 feet. Therefore, item #1 was satisfied and the project was able to move forward.

Portion of Table B4-1 Relevant to Case Study

FEMA Recommended Criteria for Safe Rooms
The lowest floor used for the occupied safe room and occupant support areas of a community safe room shall be elevated to or above the higher of the elevations determined by: 1. The flood elevation, including coastal wave effects, having a 0.2 percent annual chance of being equaled or exceeded in any given year[(b)]; or 2. The flood elevation corresponding to the highest recorded flood elevation if a flood hazard study has not been conducted for the area; or 3. The maximum flood elevation associated with any modeled hurricane category including coastal wave effects; or 4. The minimum elevation of the lowest floor required by the authority having jurisdiction for the location where the safe room is installed; or 5. Two feet above the flood elevation having a 1 percent annual chance of being equaled or exceeded in any given year.[(b)] <u>Exception:</u> **Item 3 (only)** shall not apply to safe rooms designed, constructed, designated and used only as tornado safe rooms.

In-ground safe rooms

In-ground safe rooms should not be installed in flood-prone areas unless the community has received a residential basement exception from FEMA.[1] Areas with high groundwater tables should also be considered cautiously for in-ground safe rooms or safe rooms that are partially below grade, as buoyancy forces can potentially push the

1 This exception has been granted in a small number of communities to allow in-ground tornado safe rooms to be constructed below the BFE.

structure out of the ground. Safe rooms extending below-grade should be designed and installed to resist buoyant forces under saturated soil conditions.

In-ground safe rooms should also be designed to prevent water (due to rainfall and runoff, or in the case of residential basement exception communities, above-ground floodwater) from rising above or entering the entrance to the safe room or any other openings. Sump pump systems may be required to make sure that any water entering a safe room is removed. These pump systems will need to be included in emergency or standby power considerations.

Tsunami

Tsunami hazards may be present in some jurisdictions where safe rooms are designed and constructed to provide protection from hurricanes. Although FIRMs are likely available for these areas, the FIRMs typically are not based on tsunami hazards.

MORE INFORMATION

For additional information on the design and construction of structures in tsunami inundation areas, see FEMA P-646, *Guidelines for the Design of Structures for Vertical Evacuation from Tsunamis* (June 2008), available at www.fema.gov/media-library/assets/documents/14708.

For additional information on the mapping of tsunami inundation zones, see the National Tsunami Hazard Mitigation Program website at nthmp.tsunami.gov/.

B4.2.2.2 Flood Design Criteria for Community Safe Rooms

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 community safe rooms are required to be located **outside** of the high-risk flood hazard areas detailed in Table B4-1 unless they are permitted by the Board of Appeals in accordance with the provisions of the IBC and have successfully completed the 8-step decision-making process. Community safe rooms located in the SFHA (such as in 1-percent-annual-chance and 0.2-percent-annual-chance flood areas) should also complete the 8-step decision-making process as identified in 44 CFR Part 9.6. This process would also need to be completed if the safe room would have any adverse effects on a wetland or increase a BFE. If the 1-percent-annual-chance and 0.2-percent-annual-chance flood elevations are unknown, those elevations should be obtained from the AHJ or determined in accordance with accepted hydrologic and hydraulic engineering practices used to define SFHAs.

Note

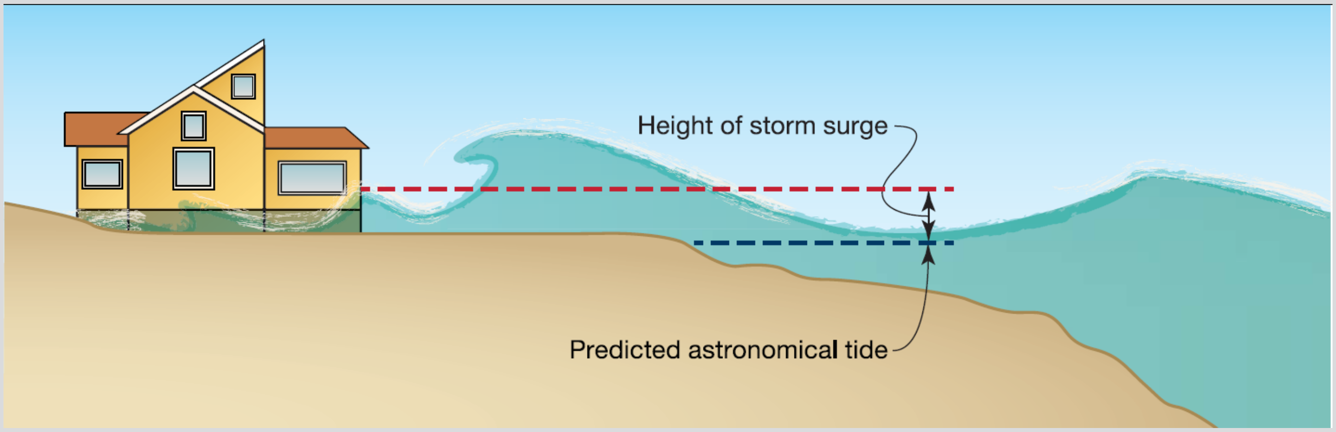
FEMA 8-STEP DECISION MAKING PROCESS

For the purpose of grant funding, the HMA Unified Guidance provides the criteria regarding floodplain management, including the 8-step decision-making process as identified in 44 CFR Part 9.6. For more information on this process, review the guidance provided in the most current HMA Unified Guidance publication, the HMA Guidance Job Aid (*8-Step Decision Making Process for Floodplain Management Considerations and Protection of Wetlands*), or contact your State NFIP coordinator or FEMA regional office.

The Coastal High Hazard Area (Zone V) and Zone A areas seaward of the Limit of Moderate Wave Action (Coastal A Zone) are subject to damaging wave action, high velocity flow, floating debris, erosion, and scour, making them unsuitable areas for safe rooms. A floodway is part of the SFHA and is the channel of a river or other watercourse and the adjacent land area that must be reserved to ensure that there is little or no increase in upstream flood elevations during the base flood. A community safe room in the floodway would not only be at risk of flooding, but could increase flooding upstream.

TERMINOLOGY

Storm surge: 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 below) is usually estimated by subtracting the normal or predicted astronomical tide from the observed storm tide. The measurement of storm surge does not include wave height unless specifically noted, which can add 3 feet or more. References to storm surge in this document refer to the maximum flood elevation associated with any modeled hurricane category, including coastal wave effects. See Chapter B9, *References and Resources*, for a list of some websites with State-specific storm surge inundation maps.



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. 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-chance] floodplain) wherever possible.

If siting the safe room outside the 0.2-percent-annual-chance floodplain is not possible, the structure 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). When a safe room is installed in a SFHA or other flood-prone area, the top of the lowest floor for the safe room, and its occupant support areas, should be elevated at or above the highest flood elevation defined in Table B4-1.

Examples of proper and improper locations for community safe rooms

Figure B4-1 shows mapped flood zones. Indicated on the figure are acceptable and unacceptable locations for tornado and hurricane community safe rooms with respect to mapped flood hazard zones. The locations shown on the figure are acceptable assuming that elevation requirements are met. Figure B4-2 shows an example of a shoreline-perpendicular transect, complementing Figure B4-1, to indicate which flood zone areas community safe rooms may be sited within.

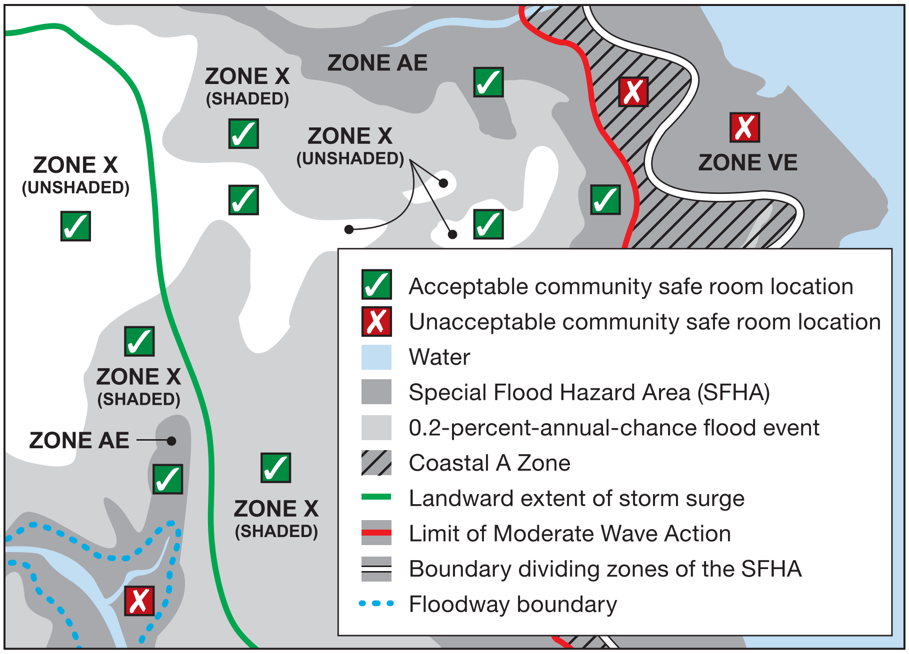


Figure B4-1. Example illustration of acceptable community safe room locations (assuming that elevation requirements are met)

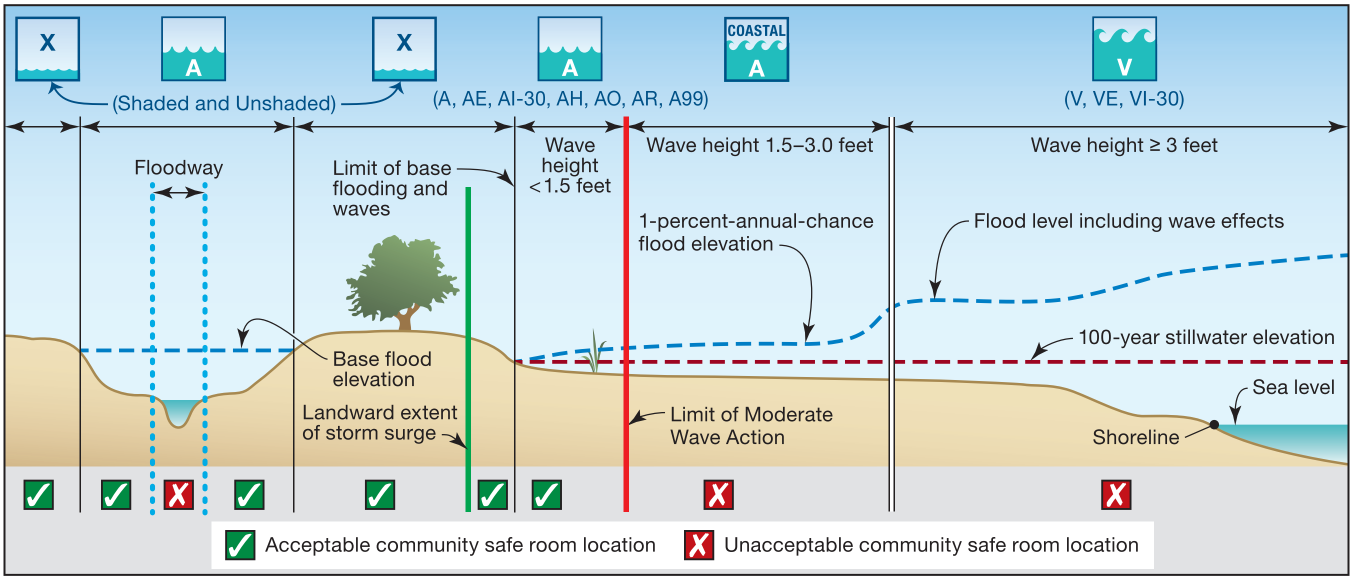


Figure B4-2. Example illustration of typical riverine cross section and shoreline transect showing stillwater and wave crest elevations and associated flood zones for acceptable community safe room siting (assuming that elevation requirements are met)

Figure B4-3 illustrates a safe room elevated to meet all of the flood elevation criteria for community safe rooms. Figure B4-3 is an example, so the relative height of each elevation shown on the figure is not necessarily applicable to all locations. For instance, the BFE + 2 feet may not always be higher than the 0.2-percent-chance flood elevation or the minimum elevation required by the AHJ).

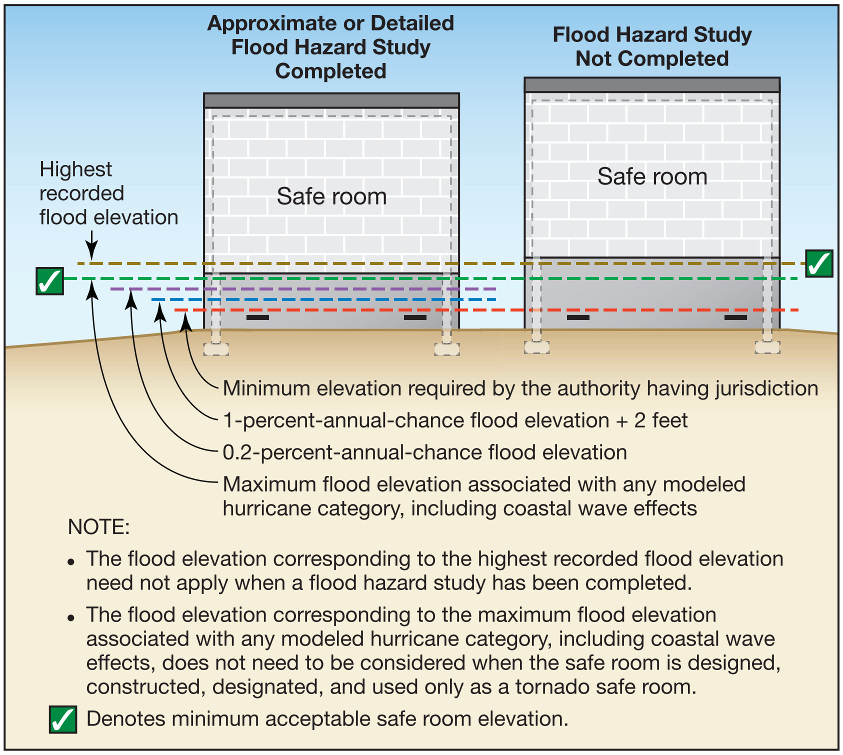
The flood elevation corresponding to the highest recorded flood elevation is not shown in Figure B4-3; while this flood elevation is part of the criteria, it does not need to be applied when the safe

CROSS-REFERENCE

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. See B3.2.3.2 for more information on flood load considerations.

room location is within a flood hazard study area and calculated flood elevations are known. In areas that have no flood hazard study, the elevation of the flood of record should be used. If the flood elevation is not available for a proposed safe room location, the elevations of the flood of record should be determined at other locations and used to estimate the record flood elevation at the safe room site.

Figure B4-3. Illustration of a community safe room example that meets flood elevation criteria (assuming siting requirements are met)



B4.2.2.3 Flood Design Criteria for Residential Safe Rooms

The design criteria for residential safe rooms are different than for community safe rooms. FEMA recommends residential safe rooms not be placed in any area that may be affected or inundated by coastal storm surge for any category hurricane.

A residential safe room, as prescribed in FEMA P-320 or designed to the criteria presented in Chapter B3, should not be located within the SFHA if at all possible (see Section B4.1). If it is not possible to install or place a residential safe room outside the SFHA, the residential safe room should at least be placed outside of the high hazard areas identified in Section B4.1, and (except for the residential basement exception communities [see Section B4.2.2.1, *In-ground safe rooms*]) the top of the safe room floor should be elevated to the highest flood hazard elevation identified in Section B4.1. Designers should be sure to refer to local floodplain management ordinances, which may have additional requirements that restrict the location and configuration (above or below ground) of a residential safe room.

Note

BFE REQUIREMENT

A subtle difference between the residential flood elevation criteria for ICC 500 and FEMA P-361 is that FEMA P-361 uses the BFE as one of the elevations (see Table B4-1). While this elevation may not always govern, it is important that residential safe rooms following Federal guidance or receiving Federal funding be constructed above the BFE in order to meet minimum recommendations in the NFIP.

The prescriptive designs presented in FEMA P-320 can only be elevated a few feet above existing grade (see design drawings in that publication for specific details and elevation limitations) and, therefore, may not comply with flood design criteria for residential safe rooms. In such situations, homeowner (or small business owner) alternatives would include: 1) retaining a structural engineer to design a site-specific foundation for the safe room, or 2) in cases where flow velocity and erosion are not expected during design conditions, build an exterior weatherproof safe room on a slab-on-grade elevated on fill above the flood elevation specified in Table B4.1.

Examples of proper and improper locations for residential safe rooms

Figure B4-4 shows mapped flood zones. Indicated on the figure are acceptable and unacceptable locations for residential safe rooms with respect to mapped flood hazard zones. The locations shown on the figure are acceptable assuming that elevation requirements are met. Figure B4-5 shows an example of a shoreline-perpendicular transect, complementing Figure B4-4, to indicate which flood zone areas residential safe rooms may be sited within.

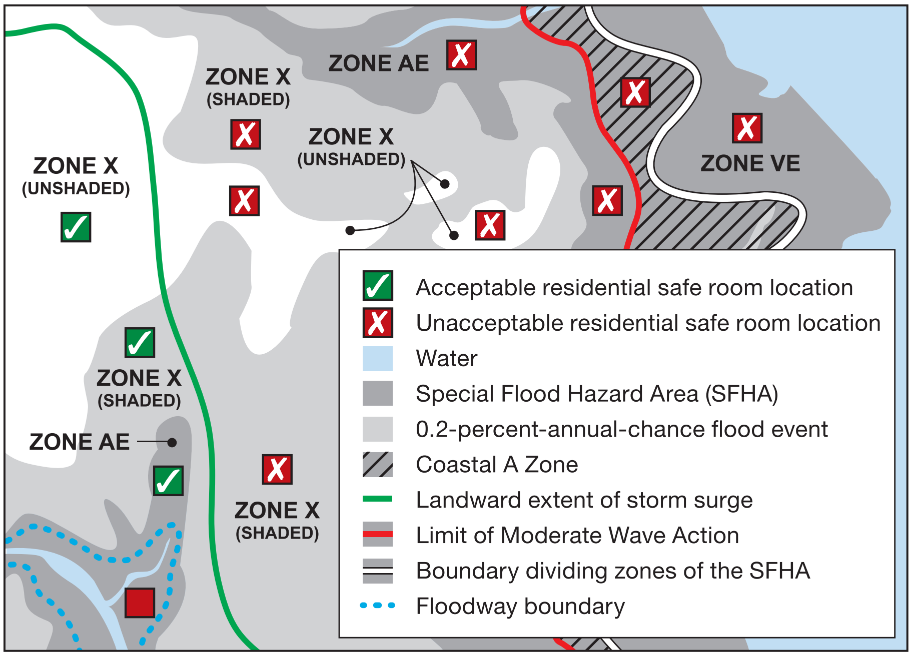


Figure B4-4. Example illustration of acceptable residential safe room locations (assuming that elevation requirements are met)

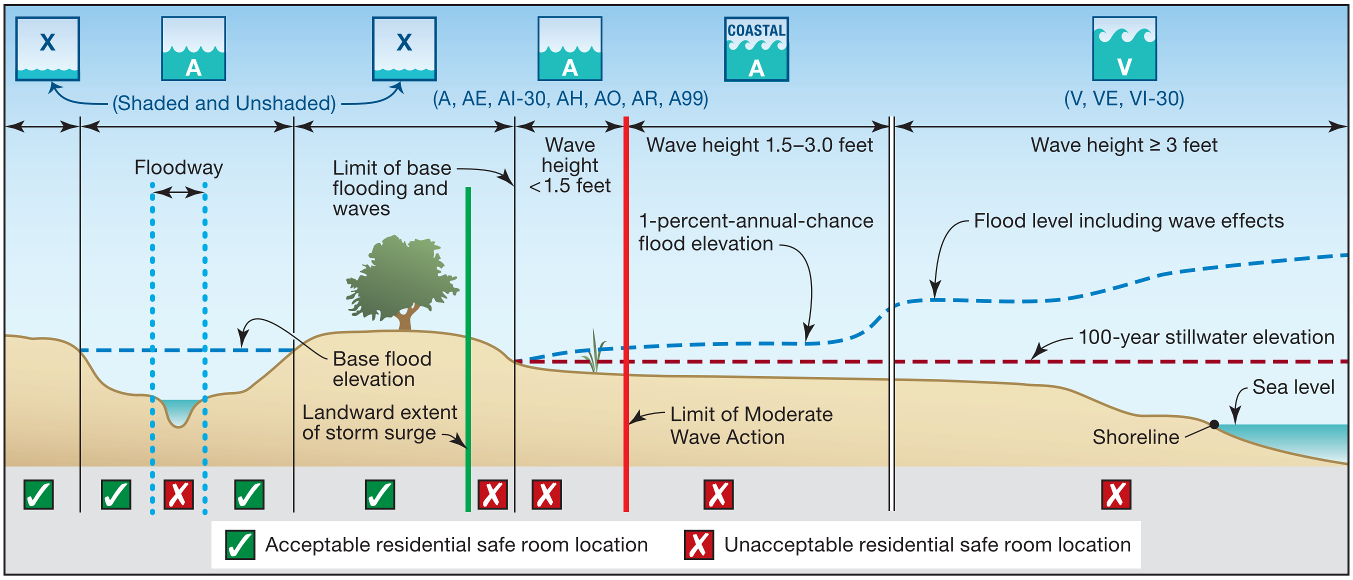


Figure B4-5. Example illustration of typical riverine cross section and shoreline transect showing stillwater and wave crest elevations and associated flood zones for acceptable residential safe room siting (assuming that elevation requirements are met)

Figure B4-6 illustrates a safe room elevated to meet all of the flood elevation criteria for residential safe rooms. Figure B4-6 is an example, so the relative height of each elevation shown on the figure is not necessarily applicable to all locations. For instance, the 0.2-percent-chance flood elevation may not always be higher than the minimum elevation required by the AHJ).

The flood elevation corresponding to the highest recorded flood elevation is not shown in Figure B4-6; while this flood elevation is part of the criteria, it does not need to be applied when the safe room location is within a flood hazard study area and calculated flood elevations are known. In areas that have no flood hazard study, the elevation of the flood of record should be used. If the flood elevation is not available for a proposed safe room location, the elevations of the flood of record should be determined at other locations and used to estimate the record flood elevation at the safe room site.

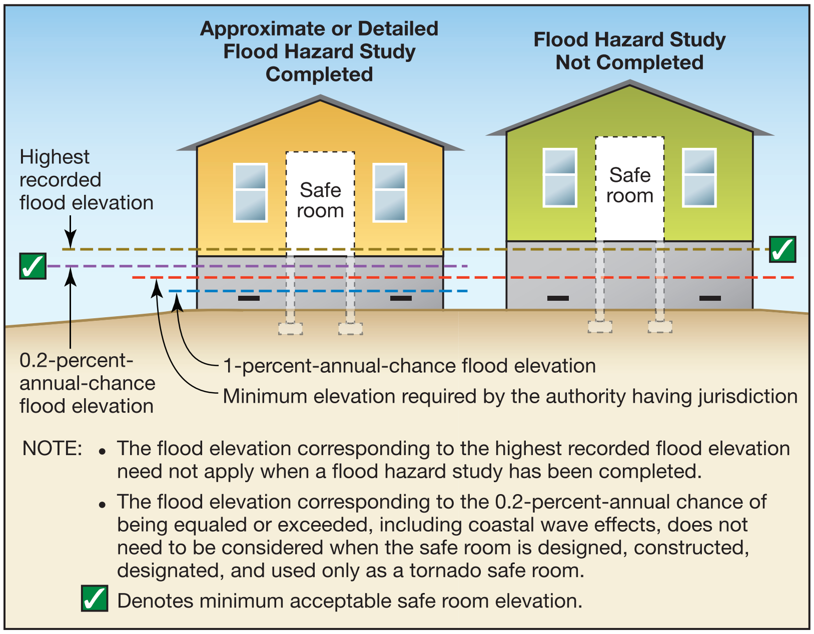


Figure B4-6. Illustration of a residential safe room example that meets flood elevation criteria (assuming siting requirements are met)

CHAPTER B5

Occupancy, Means of Egress, Access and Accessibility

This chapter uses Chapter 5 of ICC 500 as the referenced standard. This chapter also includes FEMA supplemental commentary on occupancy, means of egress, access and accessibility based on many years of field observations and investigations related to safe room performance.

B5.1 Criteria

Safe room occupancy, means of egress, access and accessibility should be designed and constructed in accordance with the provisions of Chapter 5 in ICC 500. FEMA does not recommend any additional criteria.

B5.2 FEMA Supplemental Commentary

FEMA offers the following commentary and background information as supplemental guidance to the registered design professional for the criteria referenced in ICC 500 Chapter 5.

Background on underlying building code criteria: The ICC 500 criteria for occupancy, egress, and access are intended to mirror those requirements set out in the IBC, where for multi-use safe rooms, the normal occupancy of the safe room is used, and for single-use safe rooms, occupancy Assembly 3 (A-3) is used.[1] Additional requirements, based on the specific type of safe room, are added to the requirements for the normal occupancy of the space. The minimum area criteria for safe rooms in ICC 500 are based on the use of the space during a storm event and are not intended to be space recommendations for a safe room that might be used for recovery purposes. For more information on operational considerations for safe rooms, see Chapter A4.

CROSS-REFERENCE

For more information on occupancy duration for both hurricane and tornado safe rooms, see Sections B7.2.1 and A4.1.3.

1 ICC 500 allows single-use safe rooms with fewer than 50 occupants to be designated as Group B occupancy.

Further, a fundamental concept in life safety is that a means of egress, adequately sized to accommodate all occupants, should be available at all times. Since many community safe rooms are located in spaces such as gymnasiums and cafeterias that are normally used for other purposes, the number of egress elements present may be adequate for their use as safe rooms.

B5.2.1 Community Safe Rooms (Reference: ICC 500 Sec 501)

From a design and construction standpoint, there is no limitation on the maximum population that a safe room may be designed to protect. However, there are size limitations for safe rooms funded by FEMA grants. Refer to FEMA safe room and BCA tools for guidance and criteria related to the maximum allowable population (for more information, see Section A1.1). Any group involved in designing and constructing a community safe room should also obtain the latest guidance from the FEMA Regional office.

Some aspects of the planning necessary for very-high-occupancy safe rooms that may be required in large, public venues (such as stadiums or amphitheaters) are beyond the scope of this publication. Although an owner or operator of such a venue should follow the applicable requirements presented in this publication, detailed guidance for operational aspects concerning very-high-occupancy safe rooms is not provided in this publication. The design of such safe rooms requires attention to human factor engineering issues that affect the life-safety of a large number of people. Egress timing for thousands of people in a stadium, how to manage a large group of individuals in a safe room, and security within a safe room are examples of human behavioral issues that should be addressed when protecting a large group of people.

All safe rooms are designed with maximum capacities, and all potential occupants of a safe room should be notified of the safe room location and policies related to its use. Confusion about who may use a safe room can result in overcrowding, or worse, people being turned away from a safe room.

The number of occupants anticipated in a safe room should be carefully considered so that sufficient space is afforded to occupants.

- For tornado safe rooms, where warning times are short, expected occupancy typically draws on a relatively small area of nearby residents.
- For hurricane safe rooms, where warning times are considerably longer and often mandatory evacuations are put into place for flood-prone areas, more complex considerations need to be made.

In the case of both hazards, the most recent HMA guidance should be consulted on how to determine the maximum occupancy based on the location of the safe room with respect to the surrounding population. In the case of hurricane safe rooms in particular, emergency management officials should be consulted to determine under what situations the safe room would and would not be used.

In determining the maximum number of people who will use the safe room, the registered design professional should assume that the safe room will be used at the time of day when the maximum number of occupants is expected. The planning process of the safe room should also consider the potential for an increase in the number of occupants over time. The failure to plan for future growth in the target population can result in a safe room being too small for all of the intended occupants in a few years.

However, any safe room owner, operator, or designer should request from the FEMA Regional office the current HMA safe room guidance addressing the safe room population issue, since that may be different from safe room design guidance in this publication. Regardless of the means by which the appropriate safe room population has been identified, the maximum occupancy should be posted in the safe room area.

ICC 500 Section 501.1 Background

The ICC 500 criteria for maximum population density for community safe rooms are included here to benefit planners who may not have access to ICC 500 and to provide specific context for the commentary.

Tornado safe rooms: ICC 500 Section 501.1.1 requires a minimum of 5 square feet per person for standing or seated occupants for tornado community safe rooms. This requirement is the same as that provided in past editions of FEMA P-361 and is an appropriate minimum for a tornado community safe room. For wheelchair-user and bedridden occupants, the required usable floor area per occupant is higher (10 and 30 square feet per occupant, respectively). These values are provided in Table B5-1; reference Section B5.2.1.1 for guidance on usability area calculations.

Table B5-1. Occupant Density for Tornado Community Safe Rooms

TORNADO SAFE ROOM OCCUPANT	MINIMUM USABLE FLOOR AREA[(a)] IN SQUARE FEET PER SAFE ROOM OCCUPANT
Standing or seated	5
Wheelchair-user	10
Medical bed-user	30

(a) See Section B5.2.1.1 for guidance on minimum usable safe room floor area.

Designers should be aware of the occupancy requirements of the building code governing the design and construction of the safe room. The occupancy loads in building codes have historically been developed for life-safety considerations. Most building codes require the maximum occupancy of the safe room to be clearly posted. Multi-use occupancy classifications are provided in the IBC and State and local building codes. There may be conflicts between the code-specified occupancy classifications for normal use and the occupancy when used as a safe room. The following is an example of a potential conflict for a tornado community safe room:

- According to the IBC, the occupancy classification for educational use is 20 square feet per person, but for a tornado safe room is 5 square feet per person (per FEMA P-361 and ICC 500).
- Using an area in a school as a safe room can create a potential conflict in the allowed numbers of persons in the safe room if it does not have proper signage and posted occupancy requirements.
- If both the normal and safe room maximum occupancies are posted, and the safe room occupancy is not based on a minimum less than 5 square feet per person, the safe room design should be acceptable to the AHJ. The IBC has provisions that allow occupancies as concentrated as 5 square feet per person.

Hurricane safe rooms: ICC 500 Section 501.1.1 requires a minimum of 20 square feet per person for hurricane community storm shelters (see Table B5-2 for usable space criteria for all types of hurricane safe room occupants).

Note

SQUARE FOOTAGE

The ICC 500 square-footage requirement is an increase over the first edition of FEMA P-361 hurricane community safe room criteria. The increase is a result of discussions among FEMA and the ICC 500 Standard Committee, and data gathered about shelters after hurricanes in 2004 and 2005. The ICC 500 Requirement is in line with recommendations in American Red Cross Publication No. 4496, *Standards for Hurricane Evacuation Shelter Selection (1992).*

Table B5-2. Occupant Density for Hurricane Community Safe Rooms

HURRICANE SAFE ROOM OCCUPANT	MINIMUM USABLE FLOOR AREA[(a)] IN SQUARE FEET PER SAFE ROOM OCCUPANT
Standing or seated	20
Wheelchair-user	20
Medical bed-user	40

(a) See Section B5.2.1.1 for guidance on minimum usable safe room floor area.

As with the tornado community safe room, conflicts may arise between code-specified occupancy classifications for normal use and the occupancy needed for hurricane community safe rooms. The following is an example of a potential conflict for a multi-use hurricane community safe room that is normally used for assembly space without fixed seats ("concentrated"); in this example, the occupancy conflict can directly affect egress requirements for the safe room set forth in the building code:

- According to the IBC, for a 4,900-square-foot safe room, the normal occupancy load is 4,900/7 = 700 people, while the safe room occupancy load is 4,900/20 = 245 people
- For both assembly and safe room uses, the IBC requires 0.20 inch of egress per person for buildings not equipped with a sprinkler system
- For normal (assembly) use, this calculates to 140 inches of required egress and, because of code, a minimum of two doors (exits); therefore, four 36-inch doors (144-inch total net egress) should be provided
- For safe room use, the requirement is for 49 inches and a minimum of two doors (exits); therefore, two 32-inch doors (64-inch total net egress) should be provided
- Although guidance on code compliance is provided in this publication, the conflicts between these two occupancy requirements for egress must be resolved with the AHJ

The number of standing, seated, or bedridden spaces should be determined based on the needs of the potential safe room users, as determined by the designer and approved by the AHJ. 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 within community safe rooms should have an accessible route in accordance with ICC/American National Standards Institute A117.1, *Accessible and Usable Buildings and Facilities* (ICC 2009).

B5.2.1.1 Calculation of Usable Floor Area of a Community Safe Room (Reference: ICC 500 Sec 501.1.2)

Determining usable space in a community safe room area is not always straightforward because of the configuration of the interior. Either of the calculation methods described in this section can be used to determine the usable space. For almost all spaces, the usable space is less than the building footprint because of interior columns, walls, or partitions; critical support elements (e.g., generator, mechanical, electrical, and plumbing equipment); bathroom or kitchen fixtures; permanently mounted desks, chairs, or tables; or the storage area required to store portable desks, chairs, and tables.

One method for determining the usable safe room floor area is to use the following percentages derived from FEMA's National Facility Survey and adjusted based on recommendations from ICC 500 committee members:

- Reduce the gross floor area of safe rooms with concentrated furnishings or fixed seating by at least 50 percent

- Reduce the gross floor area of safe rooms with unconcentrated furnishings and without fixed seating by at least 35 percent
- Reduce the gross floor area of safe rooms with open plan furnishings and without fixed seating by at least 15 percent

A second method for determining the usable safe room floor area is to subtract unusable areas from the gross area:

- Reduce the gross area of the safe room (the footprint) by excluding spaces, partitions and walls, columns, fixed or movable equipment, or any other features that cannot be moved during use as a safe room. The remaining area is considered the usable safe room area.
- ***As a best practice, once all unusable areas have been subtracted from the gross floor area, an additional 15 percent should be subtracted to account for egress.***

BEST PRACTICE

For safe rooms that have only preliminary or conceptual designs in place, the first method of using percentages based on the type of furnishings and fixtures in the area is much easier. In most cases, the usable area is calculated early in the design phase of the safe room, when detailed design drawings showing the type of obstructions in the second method are not available. Safe room designers and planners should also be aware that the percentages should be applied to the total gross area of the safe room, which includes the walls of the safe room area.

B5.2.1.2 Number of Doors for a Safe Room (Reference: ICC 500 Sec 501.2)

The number of doors to be used as means of egress from the safe room should be determined based on 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 on the occupant load.

Designers are encouraged to not only consider egress for safe rooms, but ingress as well. Safe rooms – particularly those in populated buildings such as schools – may have a large number of people attempting to get into the protected space at once. Employing common sense strategies such as sizing hallways and doorways to be equivalent widths (to reduce the bottleneck effect) and strategically locating entrances can help facilitate a continuous flow of occupants into the safe room during an emergency situation.

Note

DOOR SWING

The direction of the door swing 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 keys or special knowledge or effort.

One approach for improving safe room ingress demands for multi-use spaces is to consider egress requirements, but reverse the flow. However, designers should keep in mind that egress code requirements are based on fire hazard and demand a very rapid exit from the area; there may be more time for ingress movement of occupants into a tornado safe room. Further, designers considering adding openings should remember that the greater the number of openings in the safe room envelope, the greater the potential for the envelope to be compromised during a tornado or hurricane.

B5.2.1.3 Emergency Escape Opening (Reference: ICC 500 Sec 501.4)

Where the applicable building code requires only one means of egress for a safe room with 16 or more occupants, an emergency escape opening is required per Section 501.2 of ICC 500. The emergency escape opening should be an additional door or an opening with the following dimensions:

- Minimum area = 5.7 square feet
- Minimum height = 24 inches
- Minimum width = 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 regular means of egress by a minimum distance of one-third of the length of the maximum overall diagonal dimension of the area to be served. Designers should also note that only one of the minimum dimensions – height or width – may be used for any given emergency escape to satisfy the minimum area requirement of 5.7 square feet.

B5.2.1.4 Americans with Disabilities Act (Reference: ICC 500 Sec 501.6)

The needs of persons with disabilities requiring safe room space must be considered. The appropriate access for persons with disabilities must be provided in accordance with all Federal, State, and local ADA requirements and ordinances.

If the minimum requirements dictate only one ADA-compliant access point for the safe room, the registered design professional should consider providing a second ADA-compliant access point for use in the event that the primary access point is blocked or inoperable. Additional guidance for compliance with the ADA can be found in many privately produced publications.

All safe rooms should be managed in accordance with an O&M plan. Guidelines for preparing safe room operations plans are provided in Chapter A4 for community safe rooms intended to serve residential areas and for non-residential community safe rooms. The registered design professional can help safe room operators understand ADA requirements and assist the owner/operator of the safe room in developing the operations plan. Developing a sound operations plan is extremely important if compliance with ADA at the safe room site requires the use of lifts, elevators, ramps, or other considerations for safe rooms that are not directly accessible to non-ambulatory persons.

MORE INFORMATION

For more information about providing for the needs of persons with disabilities during emergencies, refer to FEMA's United States Fire Administration publication, *Emergency Procedures for Employees with Disabilities in Office Occupancies* (FA 154, undated).

Note

EVACUATION ORDERS

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 to disregard or not comply with a mandatory evacuation order issued by local emergency management officials or the AHJ.

The Rehabilitation Act of 1973, as amended, including Section 504, Programs, Services and Activities (29 U.S.C. § 794)
Federal agencies and those receiving Federal assistance must ensure that their programs are usable and accessible to persons with disabilities. Compliance may include making changes to policies, practices, procedures, and structures as a reasonable accommodation for individuals with disabilities in accordance with Section 504. Section 504 also applies to organizations and entities that receive Federal monies distributed through State or local agencies (sub-recipients).

B5.2.1.4.1 Travel Time and Access

Travel time and access are an important element of safe room design. If obstructions exist along the travel route, or if the safe room is cluttered with non-essential equipment and storage items, access to the safe room will be impeded. Travel time may be especially important when safe room users have disabilities that affect their mobility and may need assistance from others to reach the safe room. In addition, wheelchair users may need a particular route that accommodates wheelchairs. The designer should consider these factors in the initial safe room planning phase and provide the shortest possible access time and most accessible route for all potential safe room occupants.

B5.2.1.4.2 Access and Functional Needs

Public safe rooms must meet the accessibility requirements of the ADA and have a schematic identifying accessible pathways from the safe room entrance, accessible bathrooms, sites for backup power and electrical hookup to power necessary equipment, and where refrigeration is located. For guidance, refer to the *ADA Checklist for Emergency Shelters*, (www.ada.gov/pcatoolkit/chap7shelterchk.htm) and 2010 (or most current) *ADA Standards for Accessible Design* ("2010 Standards" or "Standards," www.ada.gov/regs2010/2010ADAStandards/2010ADAStandards_prt.pdf)." The 2010 Standards set minimum requirements, both scoping and technical, for newly designed and constructed or altered State and local government facilities, public accommodations, and commercial facilities to be readily accessible to and usable by individuals with disabilities.

MORE INFORMATION

For considerations related to planning safe rooms that may house occupants with access and functional needs, refer to *Guidance on Planning for Integration of Functional Needs Support Services in General Population Shelters* (FEMA 2010), which can be accessed at www.fema.gov/pdf/about/odic/fnss_guidance.pdf.

Strict requirements on issues such as egress, emergency lighting, and detection-alarm-communication systems are presented in Chapter 10 of the IBC and in the National Fire Protection Association (NFPA) *Life Safety Code* (NFPA 101) for health care facilities. The requirements for egress distances, door widths, and locking devices on doors for health care occupancies are more restrictive than those for occupancy classifications in non-health care facilities. Health care facilities also have additional requirements for automatic fire doors, maximum allowable room sizes, and maximum allowable distances to egress points. The need to consider the combination of all these requirements may lead to the decision to construct multiple small safe rooms in a health care facility rather than one large safe room.

Note

FEMA SAFE ROOM

To be considered a FEMA safe room, the structure must be designed and constructed to the guidelines specified in Part B of this publication and meet the requirements of all applicable Federal, State, and local codes.

B5.2.2 Residential Safe Rooms (Reference: ICC 500 Sec 502)

A residential safe room is defined as a safe room serving occupants of dwelling units and having an occupant load not exceeding 16 persons. The ICC 500 criteria for maximum population density per usable floor area in residential safe rooms are described below and included in Table B5-3 to benefit planners who may not have access to ICC 500 and to provide specific context for the commentary.

ICC 500 Section 502.4 requires a minimum of 3 square feet per person and 7 square feet per person for tornado and hurricane residential safe rooms, respectively, for one- and two-family dwellings. For residential safe rooms serving other types of dwellings, a minimum of 5 square feet per person and 10 square feet per person for tornado and hurricane safe rooms, respectively, is required.

Table B5-3. Occupant Density for Residential Safe Rooms

TYPE OF SAFE ROOM	MINIMUM USABLE FLOOR AREA IN SQUARE FEET PER SAFE ROOM OCCUPANT
Tornado	
One- and Two-Family Dwelling	3
Other Residential	5
Hurricane	
One- and Two-Family Dwelling	7
Other Residential	10

Calculation of usable floor area of a residential safe room (Reference: ICC 500 Sec 502.4.1)
The usable safe room floor area should be the gross floor area, minus the area of sanitary facilities or other items that impede usage of the safe room area, if any, and should include the protected occupant area between the safe room walls at the level of fixed seating, where fixed seating exists.

Number of doors for a residential safe room (Reference: ICC 500 Sec 502.2)
The number of doors as means of egress from the safe room should be determined based on the occupant load for the normal occupancy of the space in accordance with the applicable building code. An emergency escape opening, in addition to the egress door, is not required.

B5.2.3 Locks and Latching (Reference: ICC 500 Sec 503)

Model building codes and life-safety codes often include strict requirements for securing doors in public areas (areas with assembly classifications). These codes often require panic bar hardware, single-release mechanisms, or other hardware requirements. For example, the 2015 IBC and the NFPA life-safety codes requires panic bar hardware on doors with a lock or latch for assembly and educational occupancies of 50 persons or more. The registered design professional will need to establish what door hardware is required and what hardware is permitted.

Furthermore, most codes will not permit primary or supplemental locking mechanisms that require more than one action to achieve egress, such as deadbolts, to be placed on the door of any area with an assembly occupancy classification, even if the intended use would only be during an extreme-wind event. This restriction is also common for school occupancy classifications.

Please refer to Section B8.2.4.1 for commentary related to safe room door latch performance under pressure and missile impact.

WARNING

If panic hardware is used on a safe room door (and in many cases, they may be required by code), the swing of the door should be such that the placement of panic devices are on the interior of the safe room. Push bars are activated with only 15 pounds of force, so when placed on the exterior of the safe room they are likely to be triggered by high wind pressures or wind-borne debris, allowing the door to open. Additionally, doors with hardware trim on the exterior should have a locking mechanism that disables the exterior door handle so that debris hitting the door handle will not unlatch the hardware and potentially open the door.

B5.2.4 Signage for Community Safe Rooms (Reference: ICC 500 Sec 504)

Besides the specific signage requirements detailed in Section B1.2.4 and ICC 500 Section 108.1 that require all safe rooms, community and residential, to have signage with design information, community safe rooms are also required to have additional signage, as follows:

1. An entrance sign at every entrance to the safe room, indicating "Tornado Safe Room" or "Hurricane Safe Room."
2. An identifying sign, different from the entrance sign, depicting the general location of the safe room(s) and access ways. Identifying signs should be posted in prominent locations 60 inches above the finished floor to the centerline of the sign. An identifying sign is required in each of the following locations:
   a. Adjacent to access doors on the inside of the safe room
   b. The office of the facility manager, if present
   c. In the designated safe room manager's area within the safe room, if present

The community should alert its citizens to the presence of a public community safe room that is open to the public (refer to Section A4.3), including installing signs and publishing information on the safe room location, access routes, and the key personnel and associated contact information.

CROSS-REFERENCE

For more information on signage, refer to Section A4.3.

It is imperative for people to be able to reach community safe rooms quickly and without chaos. Main pathways should be marked to direct users to the community safe room. The interior or exterior of the community safe room should have a sign that clearly identifies the building as a community safe room, indicating whether it is a tornado, hurricane, or combined community safe room. All signage should conform to the requirements of ICC A117.1, *Accessible and Usable Buildings and Facilities* (ICC 2009). For more information on signage considerations from an operations perspective, see Section A4.3.2.

Building Signage at Schools and Places of Work

Signage for safe rooms at schools and places of work should be clearly posted and should direct occupants through the building or from building to building. If the safe room is open to the general public, a placard should be placed on the outside of the building designating it as a safe room (see Table B1-7 for examples). The sign should say whether the facility is a tornado, hurricane, or combined community safe room.

If the safe room is not open to the public, no placard should be placed on the exterior of the building. A safe room sign on the exterior of a non-public safe room is misleading, and may result in an undesired response from the public.

CHAPTER B6
Fire Safety

This chapter uses Chapter 6 of ICC 500 as the referenced standard. This chapter also includes FEMA supplemental commentary on fire safety based on many years of field observations and investigations related to safe room performance.

Criteria

Safe rooms should be designed and constructed in accordance with the fire safety provisions of Chapter 6 in ICC 500. FEMA does not recommend any additional criteria.

FEMA Supplemental Commentary

FEMA offers the following commentary and background information as supplemental guidance to the registered design professional for the criteria referenced in ICC 500 Chapter 6.

Fire Protection and Life Safety (Reference: ICC 500 Sec 601)

Safe rooms should comply with the fire protection and life-safety requirements of the model building code, the State code, or the local code (whichever is most stringent) governing construction in the jurisdiction where the safe room is constructed.

Safe room occupant load: For single-use safe rooms, the model building codes, life-safety codes, and engineering standards do not have square footage requirements or occupancy classifications. For multi-use safe rooms, the codes and standards address occupancy classifications and square footage requirements for the normal use of the safe room. The designer is advised to comply with all fire and life-safety code requirements for either the safe room occupant load or the normal use load, whichever is more stringent.

Fire barriers and horizontal assemblies: For community safe rooms, the ICC 500 requires fire barriers and horizontal assemblies separating spaces or areas designated as storm shelters from other building areas to have a minimum fire-resistance rating of 2 hours and be constructed in accordance with the applicable building code. Fire separation assemblies are not required for residential safe rooms or storm shelters.

Fire suppression systems: Guidance and requirements concerning fire protection systems are published in the model building codes and life-safety codes. Depending on the occupancy classification of the safe room (in normal use), automatic sprinkler systems may or may not be required. For safe rooms with automatic sprinkler systems, ***best practice considerations include providing a direct underground water supply to the safe room to decrease vulnerability to breakage from wind-borne debris.*** Storm-damaged water supply lines may result in a non-operating sprinkler system.

BEST PRACTICE

Any fire suppression system specified for use in safe rooms should be appropriate for use in an enclosed environment with human occupancy. If a fire occurs during a tornado or hurricane, it may not be possible for occupants of the safe room to ventilate the building immediately after the discharge of the fire suppression system.

Fire Extinguishers (Reference: ICC 500 Sec 602)

Community safe rooms should contain fire extinguishers (number based on occupancy type) appropriate for use in a closed environment with human occupancy, surface-mounted on the safe room wall. In no case should a fire extinguisher cabinet or enclosure be recessed into the interior face of the exterior wall of the safe room, unless the exterior wall has been designed to resist the design wind pressure and wind-borne debris impact with the recess present. This is necessary to ensure the integrity of the safe room walls is not compromised by the installation of fire extinguishers.

MORE INFORMATION

Section 4.4, *Emergency Planning and Emergency Supply Kit*, of FEMA P-320 recommends that residential safe rooms be equipped with an ABC-rated fire extinguisher.

ABC refers to fires originating from three types of sources:

A – paper, wood, or fabric;

B – gasoline or oil; or

C – electrical.

CHAPTER B7
Essential Features and Accessories

This chapter uses Chapter 7 of ICC 500 as the referenced standard and includes a list of Recommended Criteria FEMA has identified as more conservative than the provisions found in Chapter 7 of ICC 500. This chapter also includes FEMA supplemental commentary on essential features and accessories based on many years of field observations and investigations related to safe room performance.

Essential features and accessories include occupancy duration, ventilation, sanitation management, lighting, emergency power, water supply, communications equipment, and emergency supplies.

FEMA SAFE ROOM GRANT REQUIREMENTS

Whenever a safe room is constructed using FEMA grant funds, the Recommended Criteria in Section B7.1 become requirements in addition to the requirements of ICC 500 Chapter 7.

B7.1 Criteria

Safe room essential features and accessories should be designed and constructed in accordance with the provisions of Chapter 7 in ICC 500 with the exception of FEMA's Recommended Criteria as shown in Table B7-1.

Table B7-1. Comparison of ICC 500 Requirements to FEMA Recommended Criteria

ICC 500 REFERENCE	ICC 500 REQUIREMENT FOR STORM SHELTERS	FEMA RECOMMENDED CRITERIA FOR SAFE ROOMS (a)
Section 702.4 First aid kit	A first aid kit shall be supplied in all tornado shelters with a shelter occupant load of greater than 50.	A first aid kit **rated for the number of safe room occupants, as listed in the construction documents,** shall be supplied in **all** tornado safe rooms.
Section 703.7First aid kit	A first aid kit shall be supplied in all community hurricane shelters.	A first aid kit **rated for the number of safe room occupants, as listed in the construction documents,** shall be supplied in all hurricane safe rooms.

Bolded text denotes differences between the ICC 500 Requirement and the FEMA Recommended Criteria.

Table note:

(a) Table only lists differences between FEMA P-361 and ICC 500 Chapter 7. All ICC 500 Chapter 7 requirements not listed in the table should also be met in their entirety.

B7.2 FEMA Supplemental Commentary

FEMA offers the following commentary and background information as supplemental guidance to the registered design professional for the criteria referenced in Chapter 7 of ICC 500.

Note

EMERGENCY SUPPLIES

Refer to Section A4.4.3 for a list of recommended emergency supplies.

B7.2.1 Occupancy Duration

Occupancy duration is an important factor that influences many aspects of safe room design, and it varies depending on the event for which the safe room is designed.

Since the guidance in this publication is intended to be for a cost-effective safe room, the Recommended Criteria shown in Table B7-1 do not include some items that could be incorporated to increase occupant comfort. However, examples of items that might help to make safe rooms more comfortable and functional during an event are discussed in this chapter, listed in Section A4.4.3, *Emergency Supplies*, and presented in in the sample O&M plans found on the FEMA safe room website at www.fema.gov/example-operations-and-maintenance-plans-community-safe-rooms.

CROSS-REFERENCE

For more information on occupancy density for both tornado and hurricane safe rooms, see Sections B5.2.1 and B5.2.2.

Tornado safe rooms

Occupancy duration in a tornado is typically 2 hours, much less than expected for a hurricane safe room. This short timespan allows for fewer provisions to provide occupancy comfort including sanitation, water supply, ventilation, and backup power. However, it is not unusual for tornado safe room occupancy duration to exceed 2 hours. For example, in the tornado outbreak in the spring of 2011, tornado warnings were occurring throughout the day and many safe rooms were occupied for much longer than 2 hours. ***A best practice would be to consider potentially longer occupancies for some provisions.*** In some cases, higher standards related to safe room occupant comfort may even be required by the AHJ (e.g., school district).

BEST PRACTICE

Hurricane safe rooms

Hurricane safe rooms typically have an occupancy time of up to 24 hours; however, it could be up to 2 or 3 days for very slow moving storms.[1] For this reason, the occupants of a hurricane safe room need more space and comfort measures than the occupants of a tornado safe room.

B7.2.2 Ventilation (Reference: ICC 500 Sec 702.1 and 703.1)

Ventilation for a safe room should comply with the building code or ordinances adopted by the local jurisdiction; the designer should use the current edition of IBC or IRC if the AHJ has not adopted a building code.

Ventilation

For safe rooms, ventilation criteria are driven by the IBC (with specific reference to Chapter 4 of the International Mechanical Code®) or IRC *and* Sections 702.1 and 703.1 of ICC 500 for tornado and hurricane safe rooms, respectively. If the normal-use occupancy of the multi-use safe room is used to design the

1 If the safe room will be used for a recovery shelter after the hurricane passes, the occupancy may be for several days. If also used as a recovery shelter, there are additional design and operation considerations that are beyond the scope of this publication.

mechanical ventilation system, the requirements of ICC 500 must still be satisfied either by designing protection for the mechanical systems (including all required components and standby power sources) to protect them from the safe room design event (see HVAC information below) or by ensuring enough openings are provided to meet ICC 500 passive ventilation criteria. Even if the mechanical system fails during an event when the space is used as a safe room, openings for the mechanical system may provide passive ventilation depending on the system. However, additional openings may be necessary.

In communities that have not adopted a model building or mechanical code, adhering to the requirements of the current edition of the IBC is recommended.

Air conditioning and heating

Mechanical systems that provide ventilation are typically part of larger systems that also supply air conditioning and heating. However, though heat may be required to prevent water lines from freezing for some safe rooms, air conditioning and heating system designs are not otherwise part of the criteria for safe rooms; therefore, they are not discussed in this publication (or the ICC 500). Although air conditioning and heating may increase occupant comfort, they are usually not necessary for life-safety protection from wind and wind-borne debris.

If any HVAC component is required to meet ventilation requirements of ICC 500 Chapter 7, then those components, their connections, and required standby power sources would be classified as critical support systems (refer to Chapter B2, *Definitions*) and should be protected from safe room design event conditions.

Continued operation of essential equipment

When a safe room will be constructed in a building that supports medical or other life-critical operations, the designer should consider appropriate design, maintenance, and operations plans to ensure continuous operation of all critical mechanical and electrical equipment during and after a tornado or hurricane. Failure of the critical equipment in these buildings can have a severe effect on continuity of operations.

MORE INFORMATION

Continuity of operations guidance for critical facilities struck by a tornado is provided in FEMA P-908, *Recovery Advisory 6, Critical Facilities Located in Tornado-Prone Regions: Recommendations for Architects and Engineers* (2012).

Another useful publication is FEMA P-424, *Design Guide for Improving School Safety in Earthquakes, Floods and High Winds* (2010).

For hurricane safe rooms, refer to FEMA P-577, *Design Guide for Improving Hospital Safety in Earthquakes, Floods, and High Winds* (2007).

B7.2.3 Sanitation Management (Reference: ICC 500 Sec 702.2 and 703.2)

The minimum number of sanitation facilities – either toilets or hand-washing facilities – or tornado and hurricane safe rooms is specified in ICC 500, which also includes requirements that apply to safe room sanitation support systems. Sanitation support systems may include water supply to the safe room and/or waste containment devices like tanks or bladders.

The safe room sanitation facilities support system must be capable of supplying water and containing waste for the design capacity of the safe room. Accordingly, the system should be protected underground or by an enclosure designed to the same criteria as the safe room since unprotected systems could become inoperable during extreme-wind events. If the safe room water supply is from a well, then the pump, pump house, and associated equipment need to be protected and have an alternate power supply. If the safe room is sited within a host building, a dedicated sanitation support system independent of the host building system may prove to be a cost-effective design strategy.

BEST PRACTICE

For all single-use safe rooms, and multi-use safe rooms where the number of required sanitation facilities exceed the normal (alternate) use, additional sanitation facilities can include temporary sanitary fixtures, chemical toilets, or other means approved by the AHJ. ***Best practice includes providing a room or private area where toilets may be used; this privacy may be possible through the use of portable screens.*** Designers should include at least one toilet that meets ADA requirements for community safe rooms.

Residential safe rooms (tornado and hurricane) serving one- and two-family dwellings are not required to have toilet facilities, but residential safe rooms serving other dwelling types are required to have at least one toilet. Hand-washing facilities are not required for residential safe rooms.

Tornado community safe rooms

Although the short duration of a tornado might suggest that toilets and hand-washing facilities are not essential for a tornado safe room, safe room owners are advised to provide both for safe room occupants in accordance with Table 702.2 of ICC 500. Tornado community safe rooms that serve from 51 to 500 occupants should have a minimum of two toilets, but a single toilet is allowed for smaller safe rooms (50 occupants or less). One additional toilet is required for every additional 500 occupants (or potion thereof). For example, a minimum of three toilets would be needed for a tornado community safe room designed to protect from 501 to 1000 occupants.

Tornado community safe rooms having more than 50 occupants require at least one hand-washing facility for every 1000 occupants.

Hurricane community safe rooms

Hurricane safe room owners should install sanitation facilities in accordance with ICC 500 Table 703.2. Because of the long duration of hurricanes, more toilets and hand-washing facilities are required in hurricane community safe rooms than tornado community safe rooms when designed to protect more than 100 occupants. Instead of one additional toilet per 500 occupants (or portion thereof), hurricane community safe rooms must provide one additional toilet facility for every additional 50 occupants. For example, two toilets are needed for a hurricane safe room designed to protect 100 occupants, but three are needed when it is designed for 101 to 150 occupants. Similarly, one hand-washing facility is required for hurricane community safe rooms designed to accommodate greater than 50 occupants, with one additional facility required for every 100 occupants.

MORE INFORMATION

FEMA and American Red Cross publications about food and water storage in safe rooms are available at www.fema.gov and www.redcross.org.

FEMA P-543, *Design Guide for Improving Critical Facility Safety from Flooding and High Winds* (FEMA, 2007) has guidance on continuity of water service for critical facilities and notes that bottled water may suffice for facilities that only need drinking water for occupants.

B7.2.4 Lighting (Reference: ICC 500 Sec 702.3 and 703.4)

Spaces designated for emergency use (such as a safe room), are required by code to have emergency lighting. This applies to emergency lighting for assembly occupancies in multi-use facilities. Natural lighting provided by windows and doors is often a local design requirement, but is not required by the IBC for assembly occupancies. A reliable lighting system in a community safe room will help calm safe room occupants during a disaster. Failing to provide proper illumination in a safe room may make it difficult for the owners/operators to minimize the agitation and stress of the safe room occupants during the event.

A standby power source for lighting is essential during a disaster because the main power source is often disrupted. A battery-powered system is recommended as the standby power source because it can be located, and fully protected, within the safe room with relative ease, although for hurricane safe rooms, a more significant standby power supply (i.e., an emergency generator) is recommended (see also Section B7.2.5). Flashlights stored in cabinets are useful as a secondary lighting provision, but should not be used as the primary backup lighting system with the exception of tornado residential safe rooms and community safe rooms with less than 50 occupants (see ICC 500, Chapter 7). If the emergency generator is not contained within the safe room, it should be protected with an enclosure designed to the same criteria as the safe room.

B7.2.5 Standby (Emergency) Power (Reference: ICC 500 Sec 702.3, 703.4, 703.5 and 703.6)

Safe rooms designed for tornadoes and hurricanes will have different standby (emergency) power needs. These needs are based upon the length of time the safe rooms will be occupied. The standby power systems and all associated components essential to operating the system should be protected from the safe room design event conditions. Associated components may include fuel supply, transfer switch, distribution panel, and wiring between the generator and safe room. Such protection is especially important if the generator is not located adjacent to the safe room and connections will be exposed to hazard conditions between the generator and the safe room. Generators usually should not be placed underground because of considerations related to maintenance access, exhaust, cooling, and potential for flooding.

MORE INFORMATION

Extensive flood damage to equipment located in sub-grade portions of buildings was observed by the FEMA MAT after Hurricane Sandy (see Section 4.1.3, Critical Building Systems, of FEMA P-942, *Hurricane Sandy in New Jersey and New York* [FEMA 2013]).

Tornado safe rooms

ICC 500 requires standby power systems to be designed to provide the required output capacity for a minimum of 2 hours and to support the mechanical ventilation system, when applicable.

For tornado safe rooms, the most critical use of standby power is for lighting (see Section B7.2.4). Standby power may also be required to meet the ventilation recommendations described in Section B7.2.2. Safe rooms used by specific occupant groups (medical facilities etc.) may have user-specific needs for additional standby power. However, most tornado community safe rooms do not require additional standby power beyond the requirements of ICC 500.

Hurricane safe rooms

ICC 500 requires the standby electrical system to have sufficient capacity to power all the required critical support systems and circuits at the same time continuously for a minimum of 24 hours.

For hurricane community safe rooms, the local building code may require standby power for both lighting and ventilation. Since provision of standby power is particularly important for safe rooms in hospitals and other residential care facilities, ICC 500 requires a standby power for life safety systems. Emergency generators, along with their fuel tanks and associated connections, should be protected with an enclosure designed to the same criteria as the safe room.

B7.2.6 Water Supply (Reference: ICC Sec 703.3)

ICC 500 requirements related to protection of water supply when required for sanitation support (refer to Section B7.2.3) should also apply when relied upon to satisfy safe room potable water requirements. If the water supply source is a well, then the wellhead, pump house, and power supply should also be protected from the safe room design event conditions.

BEST PRACTICE

Tornado safe rooms

Despite the typically short duration of occupancy for tornado safe rooms, ***as a best practice, potable water should be made available as needed for all safe room occupants.*** In some cases, bottled water may be an economical option.

BEST PRACTICE

Hurricane safe rooms

Providing safe drinking water in hurricane safe rooms is especially important because of the potentially long duration of occupancy. ICC 500 Section 703.3 specifies requirements for potable water supply and wastewater storage for hurricane storm shelters designed to accommodate more than 50 occupants, though ***as a best practice, potable water should be provided in all safe rooms.***

Water storage capacity should be included in the design of the safe room, and water storage and distribution should be addressed in the operations plan for the safe room. FEMA P-543, *Design Guide for Improving Critical Facility Safety from Flooding and High Winds* (FEMA, 2007) has guidance on continuity of water service for critical facilities and notes that bottled water may suffice for facilities that only need drinking water for occupants.

CHAPTER B8
Test Methods for Impact and Pressure Testing

This chapter uses Chapter 8 of ICC 500 as the referenced standard and includes FEMA supplemental commentary based on many years of field observations and investigations related to safe room performance.

B8.1 Criteria

Impact and pressure testing should be conducted in accordance with the provisions of Chapter 8 in ICC 500. FEMA does not recommend any additional criteria.

B8.2 FEMA Supplemental Commentary

This chapter discusses the research performed to identify the representative test missiles to use for tornado and hurricane hazards and the speeds at which these representative missiles should be tested. It provides direction on how to test building components to resist wind pressures using the test protocols outlined in Chapter B3 for both tornado and hurricane hazards using ICC 500 Chapter 8 test procedures. This chapter also gives insight into the performance characteristics of different wall, roof, door, glazing, and other protective systems. The systems have been tested to meet the most restrictive design criteria (a test missile represented by a 15-pound 2x4 wood board [2x4] traveling horizontally at 100 mph).

Because of the limited research and testing done with regard to the effects of debris impact on buildings and building components intended to provide life-safety protection, much of what is presented in this chapter is based on the testing and use of a 15-pound 2x4 traveling horizontally at 100 mph. Many products have been tested and approved to meet lower debris impact design criteria (i.e., a 9-pound 2x4 traveling horizontally at 34 mph). However, those systems are not presented here because they do not meet the protection criteria for life safety, nor can they provide similar levels of protection at impact. This chapter provides information on the performance of safe rooms, safe room envelope components, and impact protective systems in resisting debris impact. It links that performance to testing that has been performed at universities that conduct research on this topic. However, any products and systems described or referenced herein still need to be verified to comply with Chapter 8 of ICC 500.

B8.2.1 Wind-borne Debris in Tornadoes and Hurricanes

The quantity, size, and force of wind-borne debris generated by tornadoes and hurricanes are unequaled by those generated in other windstorms. Wind-borne debris is a danger to buildings because it can damage structural elements or breach the building envelope and injure or kill occupants. Although there is a substantial body of knowledge on penetration and perforation of small, high-speed projectiles (such as bullets and other ammunition), relatively little testing has been performed on lower-speed missiles representative of wind-borne debris. In the design of community safe rooms, wind pressures are likely to govern the structural design, including the exterior wall and roof structure. However, the design of door and glazing assemblies are typically governed by missile impact requirements. Consequently, after the safe room has been designed to withstand wind pressures, the proposed wall and roof sections should be tested for impact resistance from missiles.

Figure B8-1. Metal door breached by wind-borne debris (this door was not designed to resist debris). (Tuscaloosa, AL, 2011 tornado)
(SOURCE: FEMA P-908)

Although safe room doors are designed to resist test missiles, a door may be struck by debris that has greater momentum than the test missile. If a missile breaches the building envelope, wind may enter and increase the internal pressure of the building (Figure B8-1). Therefore, as a conservative measure, ***best practices in Section B3.2.4.2.2 recommend the use of the internal pressure coefficient for partially enclosed buildings.***

BEST PRACTICE

Most experts group wind-borne debris into three classifications. Table B8-1 lists the classifications, presents examples of debris, and describes observed damage to buildings that were not designed as safe rooms. Figures B8-2 and B8-3 show examples of medium debris. Figures B3-13 through B3-17 and B8-4 through B8-9 show examples of large debris.

Table B8-1. Wind-borne Debris Classifications for Tornadoes and Hurricanes

DEBRIS SIZE	TYPICAL DEBRIS	OBSERVED DAMAGE
Small (Light Weight)	Roof aggregate, roof shingles, tree limbs, pieces of wood framing members, bricks	Broken glazing and punctured roof coverings
Medium (Medium Weight)	Appliances, HVAC units, long wood framing members, wood sheathing, steel decking, dumpsters, pieces of roof coverings, furniture	Breached doors, punctures through wall and roof assemblies
Large (Heavy Weight)	Structural columns, beams, joists, roof trusses, precast concrete panels, large tanks, vehicles, trees	Punctures/crushing of wall and roof assemblies, spalling from the interior side of concrete and CMU walls and concrete roofs

Note:
HVAC = heating, ventilation, and air-conditioning
CMU = concrete masonry units

Figure B8-2. Medium debris: Pieces of a built-up roof from Hurricane Katrina (MS, 2005)
(SOURCE: FEMA P-424)

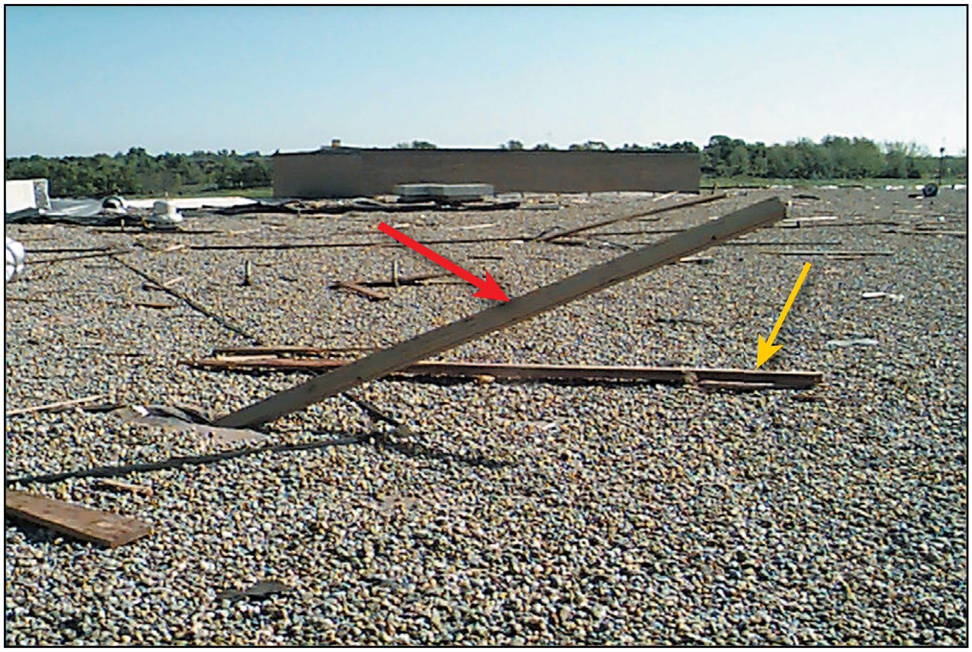


Figure B8-3. Medium debris: Double 2x6 wood boards (red arrow) sticking 13 feet out of the roof. The boards penetrated a ballasted EPDM roof membrane, 3 inches of polyisocyanurate insulation, and a steel roof deck. The yellow arrow indicates a 16-foot-long 2x10 wood board. (Moore, OK, 1999 tornado)
(SOURCE: FEMA P-342)

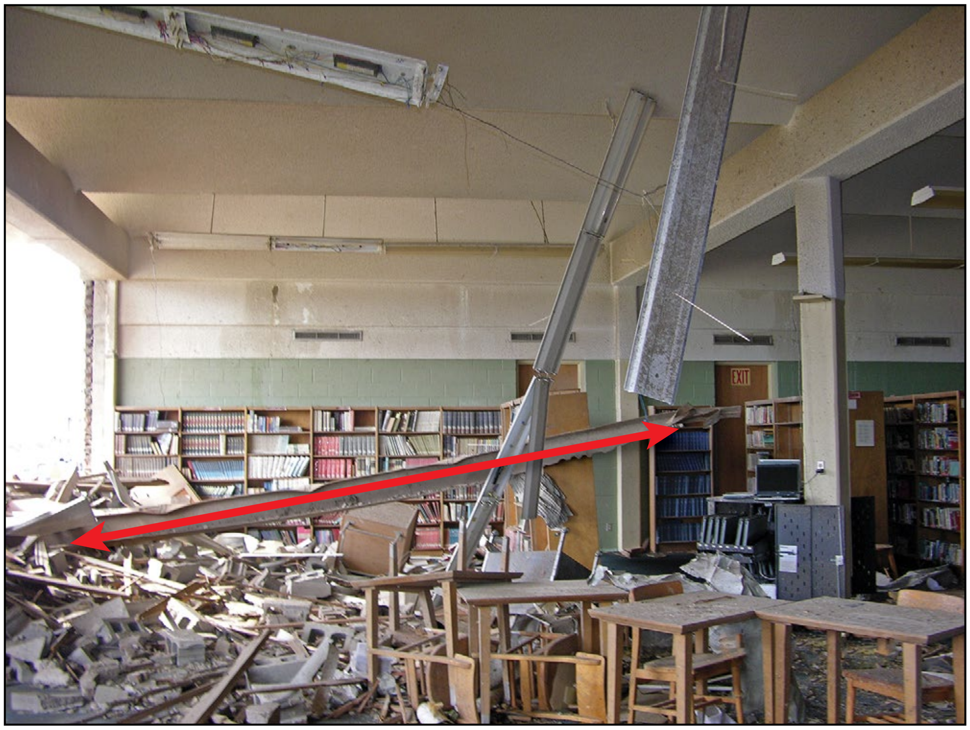


Figure B8-4. Large debris: Steel beam that blew into a school (Greensburg, KS, 2007 tornado)

Figure B8-5. Large debris: Steel roof trusses that blew off a school (U.S. Virgin Islands, 1995 Hurricane Marilyn)
(SOURCE: FEMA P-424)

Figure B8-6. Large debris: Roof precast twin tees (red arrows) blew off a hospital and struck another portion of the building (see inset; yellow arrow shows direction of view). One of these flew approximately 80 feet. The building damage at this site was indicative of an EF3 tornado. (Greensburg, KS, 2007 tornado)
(SOURCE: FEMA P-577)

Figure B8-7. Large debris: Propane tank that was blown from its original location. (Midwest tornadoes, 2007)

Figure B8-8. Large debris: A school bus was lifted atop a school. (Caledonia, MS, tornado, 2008)

Figure B8-9. Large debris: Laydown of a large tree onto a nursing home. (Tuscaloosa, AL, 2011 tornado)

(SOURCE: FEMA P-908, RECOVERY ADVISORY 6)

B8.2.1.1 Debris Potential at Safe Room Sites

Debris impacting buildings during tornadoes and hurricanes can originate from the building itself (Figures B8-1, B8-2, B8-5, and B8-6). As buildings break apart, roof and wall coverings are typically the first elements to fail. However, as shown in Figure B3-15, failure sometimes initiates when the entire roof structure blows off. With loss of the roof structure or roof decking, exterior walls are often blown down. During violent tornadoes, failure progresses until many or all of the interior walls are also blown away. Debris can also originate from the surrounding area (Figures B8-3 and B8-7 through B8-9).

During safe room design development, the registered design professional should review the site vicinity to assess potential wind-borne debris sources and laydown and collapse hazards (as discussed in Section B3.2.5.5). In urban, suburban, and forested rural areas, the designer should assume that small and medium wind-borne debris (as classified in Table B8-1) will likely occur in the vicinity of the safe room. Figure B8-10 illustrates the quantity, size, and type of wind-borne debris that is often generated by a strong or violent tornado in urban and suburban areas.

Figure B8-10. Representative quantity, size, and type of debris that is often generated by a strong or violent tornado. The building damage at this site was indicative of an EF3 tornado. (Greensburg, KS, 2007)
(SOURCE: FEMA P-577)

The wind-borne debris performance criteria in Section B3.2.5 of this publication are sufficiently conservative for small and medium classes of wind-borne debris. The criteria are also sufficiently conservative for large classes of debris if design provisions are made to avoid spalling from the interior side of concrete and concrete masonry unit (CMU) walls and concrete roofs (see Section B3.2.5.5). Lay-down of very large towers (Figure B3-12) or impact of exceptionally large debris may generate loads that exceed the performance criteria described in Chapter B3. If a site-specific analysis identifies the potential for exceptionally large debris, the designer should consider adjusting the location of the proposed safe room or further strengthening the safe room (see Section B3.2.5.5).

B8.2.1.2 Representative Missiles for Debris Impact Testing

This section presents historical background information on the basis for selecting tornado and hurricane test missiles.

As previously discussed and shown in several figures, the size, mass, and speed of wind-borne debris in tornadoes and hurricanes varies widely. However, debris velocity has been measured directly only a few times. Such measurements require using photogrammetric techniques to analyze videos of tornadoes that show identifiable debris. Unfortunately, very few studies (in the field or using photogrammetry) have been done to produce a more technically documented choice for the representative test missiles. For this reason, choosing the test missiles that a safe room should be designed to withstand is somewhat subjective. Based on 30 years of post-disaster investigations after tornadoes and hurricanes, the NWI[1] at TTU concluded by 1999 that the missile that best represents tornado wind-borne debris likely to perforate common building assemblies is a 2x4 weighing up to 15 pounds (FEMA 342, 1999).

The trajectories of wind-borne debris of various shapes have been the subject of research at TTU, University of Florida, Louisiana State University, and the University of Western Ontario.[2] Some of this research is further discussed in Section B8.2.2.1. This work includes trajectory trials on wind-tunnel models and validated numerical models. As part of this work, debris was categorized by its shape and flying characteristics into “compact,” “rod,” and “plate/sheet” types. Compact objects, usually generalized as cubes or spheres, are driven by wind drag forces; they have downward-directed trajectories from their initial point of flight and often hit the ground before hitting a downwind building. On the other hand, the rod and plate types are subjected to significant lift forces and can fly up before eventually attaining a downward trajectory under the influence of gravity. Therefore, the rod and plate types have more potential to stay in flight and accelerate to damaging horizontal speeds before impacting a downwind building. These characteristics are consistent with the observed distances traveled and damage observed after tornadoes and hurricanes.

The test missile chosen for much of the research on minimizing building damage or protecting building occupants is a nominal 2x4. This test missile was selected based on numerous tornado and hurricane investigations, which found that much of the wind-borne debris consisted of wood boards that came from buildings that were torn apart by wind-induced pressures or other wind-borne debris. The 2x4 was selected as the test missile to represent a variety of damaging plate/sheet and rod type objects that have been commonly observed during tornado and hurricane investigations. These objects include roof tile, roof sheathing and decking, and metal roof panels, as well as wood studs, joists, and rafters. Furthermore, the 2x4 has more perforation potential than many other common types of debris, including 2x6 wood boards (Figure B8-11) of the same length traveling at the same speed (although, as shown at Figures B8-3 and B8-11, 2x6s do have significant perforation potential.) Based on the foregoing, a 2x4 board was chosen as the test missile for safe room design. The speed with which wind-borne debris travels is a function of the type of wind (straight-line, tornado, or hurricane) as well as the wind speed. The speeds of the test missiles are discussed in Section B8.2.2.

Although large pieces of wind-borne debris are often found in the aftermath of tornadoes and hurricanes, heavy pieces of debris that become airborne are not likely to be carried at speeds as fast as test missiles. Therefore, if large missiles (as classified in Table B8-1) become airborne, they are less likely than the test missile to perforate a safe room. However, laydown of very large towers (Figure B3-12) or collapse impact of exceptionally large debris may allow debris to enter the safe room (see Section B3.2.5.5).

1 Formerly the WISE Research Center.

2 This research includes James R. McDonald, *Rationale for Wind-Borne Missile Criteria for DOE Facilities*, Institute for Disaster Research, Texas Tech University, September 1999; Bahareh Kordi, Gabriel Traczuk, and Gregory A. Kopp, “Effects of wind direction on the flight trajectories of roof sheathing panels under high winds,” *Wind and Structures*, Vol. 13, No. 2, 2010, pp. 145–167; and Bahareh Kordi and Gregory A. Kopp, “Effects of initial conditions on the flight of wind-borne plate debris,” *Journal of Wind Engineering and Industrial Aerodynamics*, 2011, pp. 601–614.

Figure B8-11. Refrigerator pierced by a 2x6. The portion of the 2x6 that is visible was 4 feet 8 inches long. It went several inches into the freezer compartment. (Oklahoma City, OK, 1999 tornado)
(SOURCE: FEMA P-342)

B8.2.1.2.1 Tornado Test Missile

Following the Oklahoma and Kansas tornado outbreaks of May 3, 1999, both FEMA and TTU investigated the tornado damage and debris fields and concluded that the 15-pound 2x4 test missile was reasonable for tornado safe room design (FEMA 342). A test missile larger than this does not appear justified at this time.

B8.2.1.2.2 Hurricane Test Missile

None of the U.S. building codes or ASCE 7 addressed wind-borne debris at the time Hurricane Andrew struck South Florida in 1992. In the aftermath of that event, the 1994 edition of the South Florida Building Code (SFBC) adopted wind-borne debris requirements to protect exterior glazing to minimize building damage from the entrance of wind-driven rain and development of high internal pressure. Although the importance of glazing resistance to wind-borne debris had long been known, prior to Hurricane Andrew, building code officials were not receptive to adding glazing protection requirements to the model codes.

The 1995 edition of ASCE 7 incorporated wind-borne debris provisions for portions of hurricane-prone regions. ASTM E1996 (first published in 1999) specifies hurricane test missiles, including a steel ball (representing small roof aggregate) and 2x4s of various masses and test speeds. The 9-pound 2x4 (approximately 9 feet long) is the heaviest test missile in E1996. This is referred to as the "large hurricane test missile." The 2000 edition of the IBC was the first U.S. model building code to adopt wind-borne debris provisions.

Note

DESIGN TEST MISSILES

The first use of the 9-pound 2x4 as a design (test) missile dates back to 1975 in the *Darwin Area Building Manual* (Darwin Reconstruction Commission). This building code provision was in response to the devastation caused in Australia by Tropical Cyclone Tracy in 1974.

The SFBC, ASCE, and IBC wind-borne debris requirements were all developed and promulgated to minimize building damage rather than protect the occupants. Hence, because safe rooms are intended to provide occupant protection, the design (test) missile impact criteria given in Tables B3-5, B3-6, and B3-7 are more stringent than the impact criteria for other types of buildings. The hurricane safe room test missile is the same as the large test missile referenced in ASTM E1996 (i.e., 9-pound 2x4); however, the safe room test missile has a much higher impact test speed.

B8.2.2 Resistance to Test Missile Loads and Successful Testing Criteria

After a safe room is designed to meet wind load requirements, its roof and wall assemblies, doors, glazing, and opening protective systems should be checked for resistance to missile impacts. Designing small residential safe rooms to resist wind loads is relatively straight forward.[3] The biggest challenge for residential safe rooms is protecting them from missile perforation, as discussed in Chapter B3.

For larger safe rooms, the design challenge is providing the structural integrity necessary to resist wind loads. Roofs with reinforced concrete and walls with reinforced concrete or reinforced masonry designed to resist safe room design wind loads normally prevent perforation by wind-borne debris.

Relationships between wind speeds and missile speeds have not been studied extensively. For a 250 mph wind speed (the highest safe room design wind speed), the horizontal speed of a 15-pound 2x4 test missile is calculated to be 100 mph based on a simulation program developed at TTU. The vertical speed of a falling 2x4 is considered to be two-thirds the horizontal missile speed, or 67 mph when the horizontal speed is 100 mph.

Although 2x4s are not the only type of debris that is carried by tornadoes and hurricanes (as illustrated in Figures B8-2 and B8-11), the 2x4 test missiles specified in Tables B3-5 through B3-7 are considered reasonably representative for design and testing. This conclusion is based on numerous post-storm damage observations in which 2x4s were the type of wind-borne debris that most often perforated building assemblies. In considering perforation of a safe room's roof and wall assemblies, doors, glazing, and impact protective systems, worst-case test conditions are assumed (i.e., blunt [square-faced] boards striking perpendicular to the test surface).[4]

The horizontal wind speeds of all types of wind-borne debris increase progressively with distance traveled and duration of flight because the horizontal wind forces continue to act in the direction of the wind until the debris speed reaches the wind speed. However, the debris invariably strikes the ground or a building well before this speed is reached. Thus, the horizontal speed at which a given piece of debris strikes a building depends on several factors: the gust wind speed (most debris flight durations are less than 3 seconds), the weight and shape of the debris, the initial angle at release, and the distance it travels before impact. A discussion on the basis for the horizontal speeds of the test missiles is presented in Section B8.2.2.1.

B8.2.2.1 Debris Impact Test Speeds for Representative Missiles

Chapter B3 provides impact test speeds for tornado and hurricane safe room test missiles. The speeds at which the test missiles are propelled are correlated to the safe room design wind speed at a given site. For tornadoes, the horizontal test missile speed ranges from 80 to 100 mph. This range equals about 0.4 to 0.6 times the safe room design wind speed. For hurricanes, the horizontal test missile speed ranges from 80 to 118 mph. This range equals 0.5 times the safe room design wind speed. The following section addresses how these test speeds were selected.

Experimental and numerical studies of rod-type wind-borne debris have shown how long it takes for debris to speed up while being propelled horizontally through the wind field (Holmes et al. 2005). The referenced research indicates that a 2x4 accelerates to about:

- 0.5 times the local 3-second gust wind speed after a distance of about 10 meters (33 feet) downwind from the source
- 0.6 times the 3-second gust speed after a distance of about 20 meters (66 feet)
- 0.8 times the 3-second gust speed after about 60 meters (197 feet)

3 A number of designs for safe rooms capable of withstanding a 250 mph design wind speed are presented in FEMA P-320 (2014).

4 Testing at TTU determined that blunt (square-faced) boards are more likely than pointed ones to perforate building assemblies.

The closer to the ground the debris is during flight, the slower the debris speed because the surface roughness reduces the wind speed. Conversely, the farther from the ground the debris is during flight, the faster the debris speed. Therefore, when considering debris speed, an assumption must be made about what height the debris is released from. A simplistic approach is to assume the same elevation used for the design wind speed: 33 feet above grade. Alternatively, instead of considering the debris speed as a function of its elevation above grade, the debris speed can be assumed to be constant (regardless of height) as detailed in the paper referenced above, Holmes et al. (2005).

Hurricane winds are considered straight-line winds without an upward component of velocity (which is a distinct difference between tornado and hurricane wind fields). Hurricane winds also reach their maximum speed more slowly than tornadoes and there is no sudden APC in hurricanes. The wind speed at the time wind-borne debris is released can be much faster in tornadoes than in hurricanes, so tornado debris can travel farther. As a result, a constant ratio (or factor) of the design wind speed for the horizontal test missile speed is used in designing hurricane safe rooms. Conversely, design of tornado safe rooms uses a gradation of test missile speeds as a function of the design wind speed as presented in Table B3-4 (i.e., the test missile varies from 0.400 to 0.615 times the safe room design wind speed).

The paper titled "Trajectories of Wind-Borne Debris in Horizontal Winds and Applications to Impact Testing" (Lin 2007) was considered specifically in determining an appropriate factor to be applied to the hurricane safe room design wind speed to generate the hurricane horizontal test missile speed. The Lin paper built on the findings described above (Holmes et al. [2005]) and demonstrated that a 2x4 test missile will reach 0.4 times the wind speed after approximately 16 feet (5 meters) of horizontal displacement, and will reach 0.5 times the wind speed after approximately 33 feet (10 meters) of horizontal displacement. The vertical distance traveled by the debris is irrelevant to this consideration beyond affecting the horizontal displacement (a greater amount of lift for an object typically results in greater horizontal displacement). While the Lin paper finds more research on the mechanics and aerodynamics of wind-borne debris is necessary, it concludes that the speed achieved by wind-borne debris is a function of the horizontal displacement and wind speed.

Based on findings from FEMA MAT reports, hurricanes can easily produce rod-like wind-borne debris that travels beyond 16 feet, and therefore exceeds 0.4 times the wind speed. Based on numerous recorded observations of horizontal displacement in the range of 16 to 33 feet, the 0.5 factor was selected for use in this publication. Figure B8-12 shows an example of wind-borne debris determined to have traveled in excess of 30 feet.

Figure B8-12. Impact of structural wood members in the gable end from a neighboring house (Pine Island, FL)
(SOURCE: FEMA P-488)

B8.2.2.2 Induced Loads from the Test Missile and Other Debris

The static force equivalent of the dynamic impact of a test missile or wind-borne debris into a component of the safe room envelope is difficult to calculate, and a direct conversion to a static load often results in extremely large loads. The following discussion is provided for background and understanding of impact loads.

Determining static design loads from a test missile or wind-borne or free-falling debris is a complex computation that depends on a number of factors, including:

- Material that makes up the test missile or debris
- Material of the roof, wall, door, or glazing assembly being impacted
- Stiffness of the individual elements being impacted
- Stiffness of the structural system supporting the elements being impacted
- Angle of test missile or debris impact

Generally, a safe room that is designed, tested, and constructed to resist the test missiles given in Tables B3-5, B3-6, and B3-7 will provide adequate resistance to wind-borne debris. However, if a site-specific evaluation suggests that designing for large wind-borne debris (as defined in Table B8-1) is preferred, then impact momentum can be calculated for a site-specific design. The difficulty with this approach is finding test data to substantiate that the proposed assemblies will adequately resist the wind-borne debris.

Wind-borne debris and falling objects are two of the risks that safe rooms are designed to mitigate. These objects can be described in terms of their mass, shape, impact velocity, angle of impact, and motion at impact (i.e., linear motion or tumbling). The mass and impact velocity can be used to calculate an upper bound for impact momentum (I_m) by assuming linear motion of the debris striking perpendicular to the surface. In this instance, the impact momentum is calculated using Formula B8-1, where W is the weight of the debris, g is the acceleration of gravity, and V is the impact velocity. I_m is the impact momentum for simple linear impacts perpendicular to the surface.

Formula B8-1. Impact Momentum

$$I_m = (W/g)\ (V)$$

where:

I_m	=	impact momentum
W	=	weight of debris
g	=	acceleration of gravity
V	=	impact velocity

Formula B8-1 yields a reasonable estimate of impact momentum for compact debris, where the length-to-diameter ratio is less than about two, striking perpendicular to the surface. It also produces a reasonable estimate for slender rigid body debris striking on end, perpendicular to the surface, when there is very little rotation of the debris. For off-angle impacts of compact debris (i.e., impacts at some angle to the surface), the normal component of the impact momentum can be estimated with Formula B8-1 if the impact velocity (V) is replaced by an effective velocity (V'), where $V' = V \cos(\Theta)$ and the angle Θ is measured relative to the axis normal to the surface.

Note

IMPACT ENERGY

Mass and impact velocity can also be used to calculate impact energy (I_e) using this formula:

$$I_e = (\tfrac{1}{2})\,(W/g)\,(V^2)$$

where:

I_e	=	impact energy
W	=	weight of debris
g	=	acceleration of gravity
V	=	impact velocity

Research conducted by National Association of Home Builders (NAHB) concluded that momentum rather than energy could be expected to more consistently depict the outcome of collisions involving debris of differing degrees of elasticity or plasticity (NAHB 2002). Florida's Division of Emergency Management (FDEM) research also found that impact momentum rather than impact energy showed the best correlation between test missiles of different mass and speed (FDEM 2008). Therefore, this publication discusses impact momentum rather than impact energy.

For slender, rigid-body debris, such as wood structural members, pipes, or rods, where the length-to-diameter ratio is greater than about four, the angle of impact and the motion characteristics at impact become very important. Research has shown that the normal component of the impact drops off more rapidly than a simple cosine function for linear impact of long objects because the debris begins to rotate at impact (Pietras 1997). Figure B8-13, based on data from Pietras 1997, shows the reduction in normal force as a function of angle as compared to a cosine function reduction. For tumbling debris, the equivalent impact velocity has been estimated using a complex equation (Twisdale 1985; Twisdale and Dunn 1981).

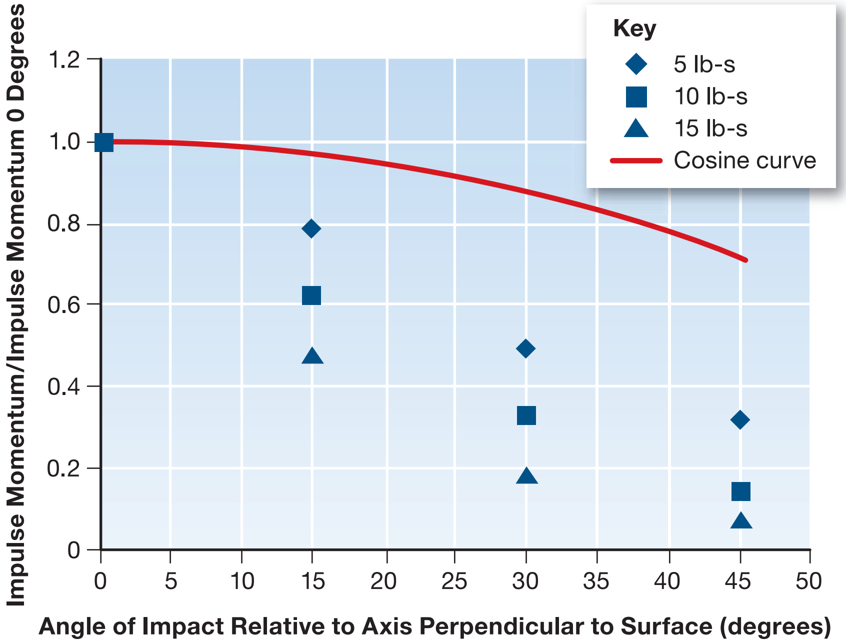


Figure B8-13. Variations of impact impulse as a function of impact angle

The wind-borne debris impacts can apply extremely large forces to a safe room over a very short time. The magnitudes of the forces are related to the masses of the objects and the deceleration times as the debris impacts the safe room. The magnitudes of the forces also depend on the mechanics involved in the collision. For example, inelastic crushing of the debris or the assembly being struck will absorb some of the impact momentum and reduce the force level applied to the assembly. Similarly, large elastic or inelastic deformation of the assembly being impacted can increase the duration of the deceleration period and, therefore, reduce the magnitude of the impact forces. For a perfectly elastic impact, the impulse force exerted on the assembly being impacted is equal to twice the impact momentum because the debris will rebound with a speed of equal magnitude to the impact velocity but in the opposite direction. For a perfectly plastic impact, the debris would not rebound, and the impulse force would be equal to the impact momentum.

Figure B8-14 illustrates the impulse loading applied by a 4.1-pound southern yellow pine 2x4 striking a rigid impact plate at a velocity of 21 mph (42.3 feet per second [fps]). Note that the entire impulse force is applied over a period of 1.5 milliseconds and the peak force approaches 10,000 pounds. Similar tests with a 9-pound 2x4 at 34 mph (50 fps) generated peak forces of around 25,000 pounds. The dotted (raw) line represents the measured impulse force and includes some high-frequency response of the impact plate. The solid line in Figure B8-14 represents the filtered signal in which the high-frequency response of the impact plate has been removed to illustrate the expected impulse force's time history.

Impact test results for southern yellow pine 2x4s striking the impact plate (Figure B8-14) illustrate the complex nature of the impact phenomenon (Sciaudone 1996).

Figure B8-14. Raw and filtered forcing functions measured using impact plate for the impact from a 4.1-pound 2x4 moving at 42.3 fps
(SOUCE: SCIAUDONE 1996)

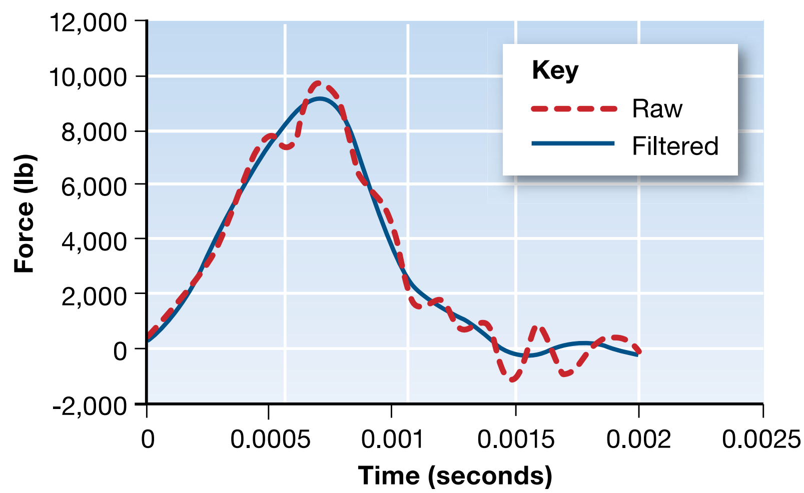


Figure B8-15 compares the impulse force measured with the impact plate against the initial momentum of a test missile. At low velocities, the impulse is characteristic of an inelastic impact where the impulse is equal to the initial momentum. This is likely due to localized crushing of the wood fibers at the end of the test missile. As the test missile speed increases (initial momentum increases), the impulse increases toward a more elastic impact response because the impulse force increases to a value that is substantially greater than the initial momentum.

Design considerations should include local failures associated with wind-borne debris perforation as well as global structural failure. Sections B8.2.3 and B8.2.4 focus on local failures. Global failures are usually related to overall wind loading of the structure or the very rare impact of extremely large wind-borne debris. Falling debris, such as elevated precast concrete panels from an adjacent building, could cause a buckling failure of a roof structure if it hit near the middle of the roof.

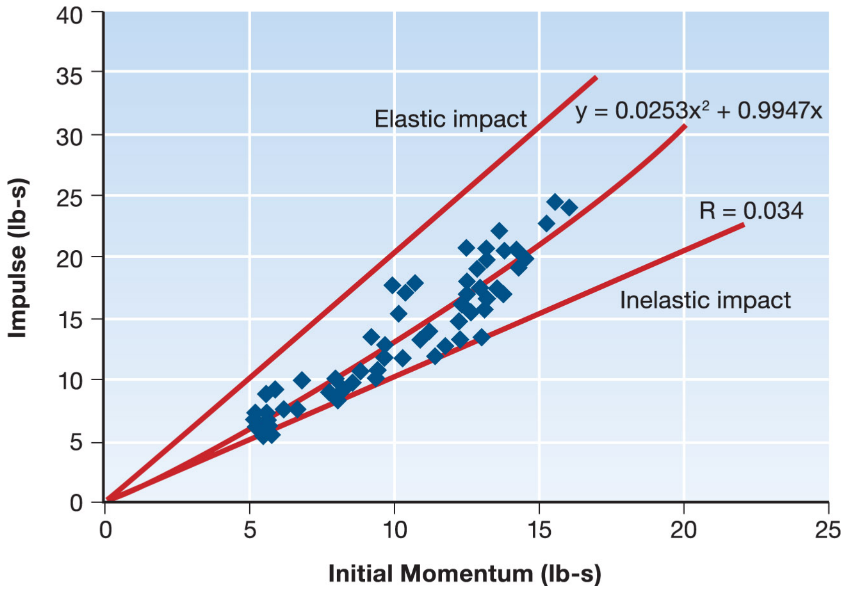


Figure B8-15. Impulse as a function of initial momentum for a 2x4 test missile

B8.2.3 Performance of Wall and Roof Assemblies during Tornado Missile Impact Tests

Wall assemblies must be rigorously tested to evaluate impact resistance because there is no adequate method to model the impact-induced complex interactions of wall components. Currently, the best way to determine whether a given wall assembly is capable of resisting test missile perforation is to build and test a full-scale wall assembly. The test assembly must accurately replicate the proposed wall assembly design (including the same type, size, and thickness of materials; same type, size, and spacing of fasteners; and configuration [arrangement] of all components). Figure B8-16 illustrates impact locations required by ICC 500 Section 804 for a roof or wall assembly that has panel joints.

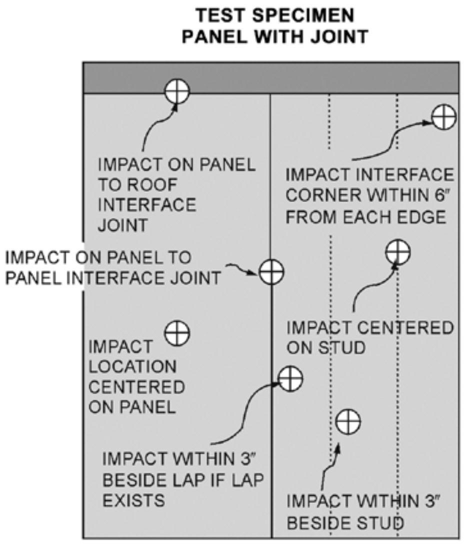


Figure B8-16. Impact test locations for a panel or framed roof or wall assembly

(SOURCE: ICC 500 FIGURE 804.9.1(2); USED WITH PERMISSION)

Various roof and wall assemblies tested at TTU have performed successfully during years of testing. To provide an understanding of what type of assemblies have performed well, this section presents a summary of information on assemblies composed of common materials that have successfully passed the largest and fastest tornado test missile (i.e., the 15-pound 2x4 traveling horizontally at 100 mph) specified in Chapter B3. For more detail on these assemblies, see *Wall Sections that Passed Previous Missile Impact Tests* on the safe room website at www.fema.gov/wall-sections-passed-previous-missile-impact-tests.

See Section B8.2.4 regarding openings in the safe room envelope.

Note

RIGOROUS TESTING

Tests have shown that missiles that impact some wall assemblies next to a stud can cause perforation, while impacting midway between studs results in permanent deformations but not perforation. Testing has also shown that joints between wall assembly components are sometimes the weak link in the assembly. To ensure that potential wall assembly vulnerabilities are discovered during impact testing, Section B3.2.5 refers to the testing requirements in ICC 500 Section 804. The Section 804 test protocol contains criteria pertaining to the test apparatus, calibration, impact procedure, test missile properties and speed, test temperature, impact angle, impact locations, number of impacts, and pass/fail criteria. Figure B8-16 illustrates impact locations for a roof or wall assembly that has panel joints.

B8.2.3.1 Impact Resistance of Wood Wall Assemblies

TTU conducted extensive testing of wall assemblies that use plywood sheathing. The most effective designs, in terms of limiting the number of layers of plywood necessary, incorporate masonry infill of the wall cavities or integration of 14-gauge steel panels as the final layer in the assembly. For more detail on wall assemblies that have passed the tornado missile impact test, see *Wall Sections that Passed Previous Missile Impact Tests* on the safe room website at www.fema.gov/wall-sections-passed-previous-missile-impact-tests.

For conventional light-frame construction, the side of the wall where the sheathing or protective material is attached and the method of attachment can affect the performance of the wall in resisting wind-borne debris. The impact of debris on wall components attached to the exterior side of a wall pushes the material against the wall studs. Wall components attached to the inside of the wall (i.e., interior side of the safe room) can be knocked loose from the studs and pushed into the safe room interior if the components are not adequately attached to the studs. Additionally, wall components on the exterior of the wall are susceptible to being pulled off the studs by wind suction pressures if the wall components are not adequately attached to the studs.

Consequently, sheathing materials should be securely attached to the framing members. Tests have shown that sheathing attached using wood adhesive complying with ASTM D3498 and code-approved #8 screws (not drywall screws) penetrating at least 1½ inches into the framing members and spaced not more than 6 inches on center provides sufficient capacity to withstand the tornado design wind loads if the sheathing is attached to the exterior surface of the wall studs. These criteria are also sufficient to keep the sheathing attached when struck by the tornado test missile when the sheathing is attached to the interior surface of the studs.

B8.2.3.2 Impact Resistance of Wall Assemblies with Steel Sheathing

TTU tested wall wood frame assemblies that incorporate various gauges of cold-rolled ASTM A569[5] and A570 Grade 33 steel sheets. When properly configured, the steel sheathing stops the missile by deflecting and spreading the impact load to other wall assembly components. When improperly configured, the wall assembly can be perforated, as illustrated by the following test results:

- When the steel is 14 gauge or lighter and backed by a substrate that prevents deflection of the steel, the test missile perforates the steel
- When 14-gauge or lighter steel sheets are placed between plywood layers, the test missile perforates the steel because the steel does not have the ability to deflect

5 ASTM A569 and A570 were withdrawn and replaced by ASTM A1011 in 2000.

Refer to Figure B8-17 for two examples of wood frame wall assemblies with steel sheathing that have passed safe room testing. For more examples, see *Wall Sections that Passed Previous Missile Impact Tests* on the safe room website at www.fema.gov/wall-sections-passed-previous-missile-impact-tests. Prescriptive wood frame solutions for residential safe rooms (including wall assemblies with 14 gauge steel sheathing) are available in FEMA P-320.

TTU found that 12-gauge or heavier steel sheets always pass the tornado missile impact test. Test configurations included 12-gauge steel directly over studs and the steel sheet mounted over plywood. Test samples used the standard stud spacing of 16 inches on center. Wider stud spacing affects the permanent deformation of the steel sheet. Permanent deformation of 3 inches or more into the safe room is deemed unacceptable. Tests have not been performed to determine the maximum stud spacing that would control the 3-inch permanent deformation limit.

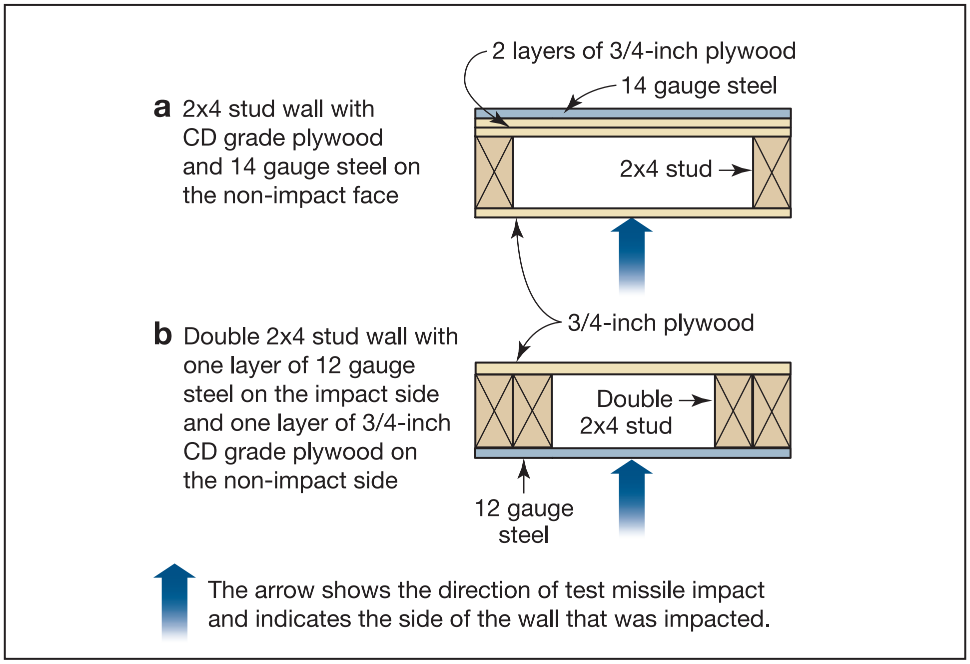


Figure B8-17. Use of steel sheet metal in wall assemblies

B8.2.3.3 Impact Resistance of Concrete Masonry Unit Wall Assemblies

TTU found that 6-inch CMU walls that are fully grouted with ASTM C476 grout and reinforced with #4 rebar at 36 inches on center, and 8-inch CMU walls that are fully grouted and reinforced with #5 rebar at 48 inches on center, can withstand the tornado test missile (Figure B8-18). However, more reinforcing steel may be required to resist wind loads.

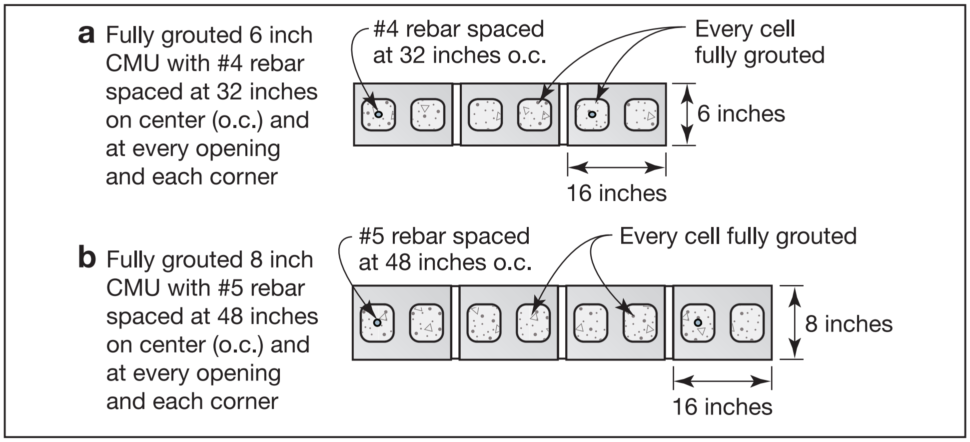


Figure B8-18. CMU wall assemblies

B8.2.3.4 Impact Resistance of Reinforced Concrete Wall and Roof Assemblies

Research related to the design of nuclear power facilities has produced a relatively large body of information and design guides for predicting the response of reinforced concrete walls and roofs to the impact of wind-borne debris.[6] The failure modes have been identified as penetration, spalling, barrier perforation, and complete debris perforation, as described in the text box.

The design of reinforced concrete walls for wind-borne debris impact protection should focus on establishing the minimum wall thickness to prevent threshold spalling under the design (test) missile impact. Wall designs should be validated by impact testing per ICC 500 Section 804; pass/fail criteria is provided in Section 804.10.

Twisdale and Dunn (1981) have published some of the design equations developed for nuclear power plant safety analysis. Steel pipes and rods were the design missiles used to develop the analytical models for the nuclear industry. The nuclear industry models are expected to generate conservative estimates of performance for softer wind-borne debris, such as a wood structural member, impacting a wall. However, at some sites, wind-borne debris may include steel joists, beams, or pipe columns (Figures B8-19 and B8-20).

Def

TERMINOLOGY

Penetration: When wind-borne debris penetrates into, but not through, the wall assembly. This condition is of no consequence unless it creates spalling.

Spalling: When concrete is ejected into the safe room. Spalling occurs when the shock wave produced by the impact creates tensile stresses in the concrete on the interior surface that are large enough to cause a segment of concrete to burst away from the wall. Threshold spalling is when spalling is just being initiated, and is usually characterized by small fragments of concrete being ejected. When threshold spalling occurs, a person struck by the spall debris might be injured, but is not likely to be killed. However, as the size of the spall increases, so does the velocity with which it is ejected from the wall or roof. A person struck by large spall debris will likely be injured and possibly die, particularly if the spall falls from high up on a wall or the roof. ICC 500 pass/fail criteria for spalling employs a witness screen on the interior side of the storm shelter wall (or roof section) to determine whether or not test missile-induced spalling could potentially endanger occupants.

Barrier perforation: When wind-borne debris creates a hole through the wall (the debris may bounce off the wall or it may become stuck in the hole). A plug of concrete about the diameter of the impacting debris is knocked into the safe room. The plug can cause injury or death.

Complete debris perforation: When the wind-borne debris itself enters the safe room. The debris or dislodged wall fragments can cause injury or death.

Source: Twisdale and Dunn (1981)

6 For example, James R. McDonald, Rationale for Wind-Borne Missile Criteria for DOE Facilities, Institute for Disaster Research, TTU, September 1999.

Figure B8-19. Steel porch column debris from an apartment complex where columns that were 7 feet 9 inches long and 4¼ inches in diameter (see red arrows) had a significant upward trajectory and flew approximately 230 feet (Tuscaloosa, AL, 2011 tornado)

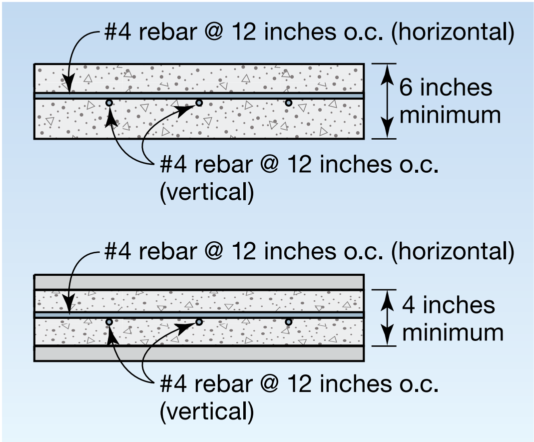
Figure B8-20. Steel beam debris (Greensburg, KS, 2007 tornado)

Test results from a number of investigations (Twisdale and Dunn 1981) suggest that 6-inch-thick reinforced concrete walls are needed to stop a 15-pound wood 2x4 test missile impacting at 100 mph without threshold spalling. TTU research indicates that a 6-inch reinforced concrete wall (Figure B8-21, illustrations [a] and [b]) can resist this test missile. Reinforced concrete walls constructed with insulating concrete forms (ICFs) with a uniform concrete section at least 4 inches thick (Figure B8-21, illustration [b]) can also provide sufficient protection.

Figure B8-21. Reinforced concrete wall [a] and reinforced concrete "flat" wall constructed with insulating concrete forms [b]

a Reinforced concrete wall, at least 6 inches thick, reinforced with #4 rebar every 12 inches both vertically and horizontally

b Insulated concrete form (ICF) flat wall assembly at least 4 inches thick, reinforced with #4 rebar every 12 inches both vertically and horizontally



Note: These wall assemblies may be impacted on either face.

When using ICF, the wall design and construction must not have discontinuities that would allow wind-borne debris to enter the safe room. Figure B8-22 shows an ICF waffle grid wall of an occupied "tornado shelter" that was perforated when struck by a tornado. Two pieces of metal tube debris perforated the wall (i.e., the tubes extended into the interior of the room); as visible in the photograph, the wall had numerous air voids that weakened the section's resistance to wind-borne debris. Based on these observations, the wall assembly did not comply with FEMA P-361 or ICC 500. Extreme care should be taken when vibrating concrete for all reinforced concrete wall types and for mortar used with masonry walls to ensure proper consolidation and elimination of voids.

Figure B8 22. Red arrows show a steel tube that perforated a waffle grid ICF wall. Inset shows the tube in the "as found" condition and main photograph shows the tube after it was partially pulled out of the wall.
(Moore, OK, 2013 tornado)
(SOURCE: FEMA P-1020)

The TTU research also shows that a 4-inch-thick reinforced concrete roof slab on removable forms or on steel decking is able to resist a 15-pound wood 2x4 test missile impacting at 67 mph (the free-falling missile impact speed given in Tables B3-5 through B3-7). For more detail on wall and roof assemblies that have passed the tornado missile impact test, see *Wall Sections that Passed Previous Missile Impact Tests* on the safe room website at www.fema.gov/wall-sections-passed-previous-missile-impact-tests.

B8.2.4 Performance of Door, Glazed Openings, and Impact Protective Systems during Debris Impact and Pressure Tests

This section discusses impact test performance of door assemblies, glazed opening assemblies (including fixed and operable windows, door vision panels, sidelites, transoms, and skylights), and impact protective systems in the safe room envelope. The text box about testing at the beginning of Section B8.2.3 is also applicable to this section.

Various door and glazed opening assemblies tested at TTU have performed successfully during years of testing. To provide an understanding of what type of assemblies have performed well, this section presents a summary of information on assemblies that have successfully passed the tornado design wind loads and the largest and fastest tornado test missile (i.e., the 15-pound 2x4 traveling horizontally at 100 mph) given in Tables B3-5 through B3-7. For more detail on assemblies that have passed the tornado missile impact test, see *Door Assemblies and Components* on the safe room website at www.fema.gov/door-assemblies-and-components.

B8.2.4.1 Door Assemblies

A door assembly includes the door, vision panel (if there is one), hardware (locks and hinges), frame, and attachment devices used to anchor the door frame to the safe room wall. The safe room door assembly installed must use the same type, size, configuration of materials, and swing direction used for the tested assembly. Untested steel doors commonly used in residential and commercial construction (refer to Figure B8-23) cannot withstand the impact of the wind-borne debris, or test missiles, that a tornado can propel, and their failure has resulted in serious injury and even death during tornadoes.

For safe room doors to reliably provide life-safety protection during a tornado or hurricane, they must be rigorously designed, constructed, and tested. FEMA does not certify products, but the manufacturer(s) of safe room door assemblies must certify their products have passed ICC 500 testing to meet or exceed FEMA safe room criteria. Designers and consumers alike should request documentation from the supplier and/or installer to verify the door assembly's compliance with this publication or ICC 500 for the pressure and impact resistance required for the designated safe room wind hazard and wind speed. Large single and door pair assemblies have passed safe room testing, as have door pair assemblies with and without center mullions and removable mullions. For a compilation of the test information available to date, refer to *Door Assemblies and Components* on the safe room at website www.fema.gov/door-assemblies-and-components.

Note

FEMA APPROVALS

FEMA does not endorse, approve, certify, or recommend any contractors, individuals, firms, or products. Contractors, individuals, or firms shall not claim they or their products are "FEMA approved" or "FEMA certified."

Note

RESIDENTIAL SAFE ROOM DOORS

For more information and guidance on finding an adequate door for residential tornado safe rooms, please see the *Tornado Safe Room Door Fact Sheet* on the safe room website or at www.fema.gov/media-library/assets/documents/99139.

Figure B8-23. This metal door was damaged by wind-borne debris generated by a weak tornado. The bottom hinge was damaged, but the single latch was able to resist the modest wind and impact load. The door was on the verge of failing.
(St. Louis, MO, 2013 tornado)

To evaluate wind pressure resistance, door assemblies are laboratory tested with positive pressure. During testing, the assemblies are configured to apply positive pressure on in-swinging as well as out-swinging doors, thus simulating positive and negative pressures. The door assemblies are tested from both sides with positive pressure because they cannot be adequately sealed to provide a vacuum. For impact resistance testing, the door assembly is struck on the face that is intended to be on the exterior side of the safe room.

Note

SAFE ROOM DOORS

Most tornado safe room doors evaluated prior to January 2000 were equipped with latching mechanisms composed of three individually activated deadbolts. Since that time, multiple latching mechanisms activated by a single lever or by a panic bar release mechanism have been tested and shown to resist the tornado wind loads and tornado test missile.

B8.2.4.2 Glazed Opening Assemblies

A glazed opening assembly includes the glazing, glazing frame, and attachment devices used to anchor the glazing frame to the wall. Wind-borne debris-resistant glazing is laminated glass, polycarbonate, or a combination of these materials. The glazing assembly installed at a safe room must use the same type, size, and configuration of materials used for the tested assembly.

ICC 500 Section 804.10 stipulates pass/fail criteria for impact testing. Glazing is permitted to break, provided that: (1) the test missile did not perforate the glazing, (2) the glazing remained attached to the frame, and (3) ejected glass fragments did not perforate the ICC 500-required witness screen and were therefore harmless.

When evaluating missile impact test reports, it is important to differentiate between impact testing performed for safe rooms versus that performed for buildings other than safe rooms located in wind-borne debris regions of hurricane-prone regions. The test missile for a hurricane safe room is the same type and size as used for other buildings in wind-borne debris regions (i.e., a 9-pound 2x4). However, the safe room missile has a much higher test speed, and hence a much higher momentum. Also, although the test missile used for other buildings is often referred to in test reports as a "large missile," the tornado safe room missile is much larger. Test missiles used for other buildings should be called "test missile D" or "test missile E," rather than "large missiles."

Note

GLAZING

Hurricane safe room glazing: If the glazing is protected by a shutter (see Section B8.2.4.3), the shutter should be on the exterior side of the assembly to avoid water infiltration into the safe room in the event that the glazing breaks. When the shutter is on the exterior side of the assembly, the glazing is only required to be tested for pressure per ICC 500 Section 306.3.2, Exception 1.

Tornado safe room glazing: If the glazing is protected by a shutter (see Section B8.2.4.3), the shutter should be on the interior side of the assembly so that it can be closed quickly. In this case, the glazing assembly is not required to be tested for pressure or missile impact per ICC 500 Section 306.3.2, Exception 2.

Combined tornado/hurricane safe room glazing: For tornadoes spawned during hurricanes, it is preferable to place shutters on the exterior side of the assembly to avoid water infiltration as discussed above. For tornadoes not spawned during hurricanes, shutters should be on the interior side of the assembly so they can be closed quickly. Hence, shutters on the inside of the assembly provide more conservative life-safety.

B8.2.4.3 Impact Protective Systems

Impact protective systems include shutters, shields, and cowlings. Shields and cowlings are used to protect openings at louvers, grates, grilles, precast panel joints more than $^3/_8$-inch wide, plumbing vents, roof drains, and emergency generator exhaust vents. These items are excluded from pressure testing when they are permanently anchored, but are required to be tested for resistance to missile impact.

B8.2.5 Test Laboratory Accreditation

To help ensure that the impact and pressure testing specified in ICC 500 are properly conducted and reported, the testing should be conducted by approved agencies. Tested product literature (including test report) should bear the name of the laboratory and the test protocol to which the system was tested. For more information on approved testing agencies, please contact your local building official or AHJ.

CHAPTER B9
References and Resources

References

AASE (American Association for Wind Engineering). 2004. "Performance of Storm Shelters During Hurricanes Charley and Ivan." In the *Newsletter of the American Association for Wind Engineering*. December 2005.

ADA Standards for Accessible Design "2010 Standards" or "Standards (www.ada.gov/regs2010/2010ADAStandards/2010ADAStandards_prt.pdf)."

ACI (American Concrete Institute) 318-14. 2014. *Building Code Requirements for Structural Concrete*. ACI 318-14. American Concrete Institute. Farmington Hills, MI.

American Red Cross. 1992. Publication No. 4496, *Standards for Hurricane Evacuation Shelter Selection*.

ASCE (American Society of Civil Engineers) 7-10. 2010. *Minimum Design Loads for Buildings and Other Structures*. ASCE/SEI 7-10. American Society of Civil Engineers. Reston, VA.

ASCE 24-14. 2014. *Flood Resistant Design and Construction*. ASCE/SEI 24-14. American Society of Civil Engineers. Reston, VA.

Clemson University Department of Civil Engineering. 2000. *Enhanced Protection from Severe Wind Storms*. Clemson University, Clemson, SC. January.

Darwin Reconstruction Commission. 1975. *Darwin Area Building Manual*. Cranberra, Australia. Available for review at http://catalogue.nla.gov.au/Record/2764422.

FEMA Publications (all available for download from the FEMA library at www.fema.gov/resource-document-library. Some documents have multiple editions. The most current edition is listed as the year published and older editions are noted in the reference.

- FEMA P-265. 1996. *Managing Floodplain Development in Approximate Zone A Areas: A Guide for Obtaining and Developing Base (100-Year) Flood Elevations*. Washington, DC. The companion software program, QUICK-2, is available from FEMA at www.fema.gov/media-library/assets/documents/7894.
- FEMA P-750. 2009. *NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures*. Washington, DC.

- FEMA P-320. 2014. *Taking Shelter from the Storm: Building a Safe Room for Your Home or Small Business*. Washington, DC. Earlier editions were published in 1998, 1999, and 2008.
- FEMA P-342. 1999. *Midwest Tornadoes of May 3, 1999: Observations, Recommendations, and Technical Guidance.* October. Washington, DC.
- FEMA P-361. 2015. *Safe Rooms for Tornadoes and Hurricanes: Guidance for Community and Residential Safe Rooms* Washington, DC. Earlier editions were published in 2000 and 2008.
- FEMA P-431. 2009. *Tornado Protection: Selecting Refuge Areas in Buildings*. October. Washington, DC. Earlier edition was published in 2003.
- FEMA P-424. 2010. *Design Guide for Improving School Safety in Earthquakes, Floods and High Winds*. December. Washington, DC.
- FEMA P-488. 2005. *Hurricane Charley in Florida*. April. Washington, DC.
- FEMA P-543. 2007 *Design Guide for Improving Critical Facility Safety from Flooding and High Winds*. January. Washington, DC.
- FEMA P-577. 2007. *Design Guide for Improving Hospital Safety in Earthquakes, Floods, and High Winds*. Washington, DC.
- FEMA P-646. 2008. *Guidelines for the Design of Structures for Vertical Evacuation from Tsunamis*. June. Washington, DC.
- FEMA P-908. 2012. *Mitigation Assessment Team (MAT) Report Spring 2011 Tornadoes: April 25–28 and May 22*. Washington, DC.
- FEMA P-1020. 2014. *Formal Observation Report Tornado: Moore, Oklahoma, May 20, 2013 Safe Room Performance, Observations, and Conclusions*. August. Washington, DC.
- FEMA P-942. 2013. *Hurricane Sandy in New Jersey and New York*. Washington, DC.
- FEMA. 2013. *Alerting the Whole Community*. FEMA Integrated Public Alert and Warning System. Available at: www.fema.gov/media-library-data/0e2d22efbeed4442f1a6f62d85a469a1/alerting_whole_community_june2013_final.pdf.
- FEMA. 2015. *Hazard Mitigation Assistance Unified Guidance: Hazard Mitigation Grant Program, Pre-Disaster Mitigation Program, and Flood Mitigation Assistance Program and Addendum*. Washington, DC.

FEMA and U.S. Fire Administration (USFA). Undated. *Emergency Procedures for Employees with Disabilities in Office Occupancies*. FA 154. Washington, DC. Available at www.usfa.fema.gov/downloads/pdf/publications/fa-154.pdf.

Florida Division of Emergency Management. 2008. *2008 Statewide Emergency Shelter Plan*. Appendix K: "Guidance for Selection of Impact Resistant Constructed Wall and Roof Assemblies." Tallahassee, FL. Available at www.floridadisaster.org/Response/engineers/2008sesp.htm.

Hollister R-V School District. 2013. *Community Safe Room Operations Plan: Hollister R-V School District Site B – High School and Middle School Community Tornado Safe Room*. Hollister R-V School District, Hollister, MO.

Holmes, J.D., C.W. Letchford, and N. Lin. 2005. "Investigations of plate-type windborne debris, Parts I and II." *Journal of Wind Engineering and Industrial Aerodynamics*, Volume 94.

IBC (International Building Code). 2015. *International Building Code. International Code Council*. Country Club Hills, IL. Earlier editions published in 2000, 20003, 2006, 2009, 2012.

ICC (International Code Council). 2014. *Standard on the Design and Construction of Storm Shelters*. International Code Council & National Storm Shelter Association. ICC 500. Country Club Hills, IL. Earlier edition published in 2008.

ICC. 2009. *Accessible and Usable Buildings and Facilities*. International Code Council and American National Standards Institute. ICC A117.1. Country Club Hills, IL.

IRC (International Residential Code). 2015. *International Residential Code for One- and Two-Family Dwellings*. International Code Council. Country Club Hills, IL. Earlier editions published in 2000, 20003, 2006, 2009, 2012.

Kordi B., G. Traczuk, and G. A. Kopp. 2010. "Effects of wind direction on the flight trajectories of roof sheathing panels under high winds," in *Wind and Structures*, Vol. 13, No. 2, 2010, pp. 145–167.

Kordi, B. and G. A. Kopp. 2011. "Effects of initial conditions on the flight of windborne plate debris," in *Journal of Wind Engineering and Industrial Aerodynamics*, 2011, pp. 601–614.

McDonald. J.R. 1999. *Rationale for Wind-Borne Missile Criteria for DOE Facilities*, Institute for Disaster Research, TTU, September 1999.

Mehta, K.C. 1970. "Windspeed Estimates: Engineering Analyses." I. 22-24 June 1970, Lubbock, TX. pp. 89-103.

Mehta, K.C. and R.R. Carter. 1999. "Assessment of Tornado Wind Speed From Damage to Jefferson County, Alabama." *Wind Engineering into the 21st Century: Proceedings, 10th International Conference on Wind Engineering*, A. Larsen, G.L. Larose, and F.M. Livesey, Eds. Copenhagen, Denmark. June 21-24. pp. 265-271.

Mehta, K.C., Minor, J.E., and McDonald, J.R. 1976. "Wind Speed Analysis of April 3-4, 1974 Tornadoes." *Journal of the Structural Division,* ASCE, 102(ST9). pp. 1709-1724.

NAHB (National Association of Home Builders). 2002. *Wind-Borne Debris Impact Resistance of Residential Glazing*. Upper Marlboro, MD.

NIST (National Institute of Standards and Technology). 2013. *Technical Investigation of the May 22, 2011 Tornado in Joplin, Missouri*. March. Available at www.nist.gov/customcf/get_pdf.cfm?pub_id=915628.

Phan, L.T., and Simiu, E. 1998. *The Fujita Tornado Intensity Scale: A Critique Based on Observations of the Jarrell Tornado of May 27, 1997*. NIST Technical Note 1426. U.S. Department of Commerce Technology Administration, National Institute of Standards and Technology, Washington, DC. July.

Pietras, B. K. 1997. "Analysis of Angular Wind Borne Debris Impact Loads." *Senior Independent Study Report*. Department of Civil Engineering, Clemson University, Clemson, SC. May.

Sciaudone, J.C. 1996. *Analysis of Wind Borne Debris Impact Loads*. MS Thesis. Department of Civil Engineering, Clemson University, Clemson, SC, August.

TTU (Texas Tech University). 1998. *Design of Residential Shelters From Extreme Winds*. Texas Tech University Wind Science and Engineering Center, Lubbock, TX. July.

TTU. 2006. *A Recommendation for an Enhanced Fujita Scale (EF-Scale)*. Texas Tech University Wind Science and Engineering Center. Lubbock, TX.

Twisdale, L.A. 1985. "Analysis of Random Impact Loading Conditions." *Proceedings of the Second Symposium on the Interaction of Non-Nuclear Munitions with Structures*. Panama City Beach, FL. April 15-18.

Twisdale, L.A. and W.L. Dunn. 1981. *Tornado Missile Simulation and Design Methodology*. EPRI NP-2005 (Volumes I and II). Technical Report. Electric Power Research Institute, Palo Alto, CA. August.

Vickery, P.J., P.F. Skerlj, and L.A. Twisdale, Jr. 2000. "Simulation of hurricane risk in the U.S. using an empirical track model," *Journal of Structural Engineering*. ASCE, Vol. 126, No. 10, October 2000.

Vickery, P.J., J.X. Lin, P.F. Skerlj, and L.A. Twisdale, Jr., and K. Huang. 2006. "HAZUS-MH Hurricane Model Methodology. I: Hurricane Hazard, Terrain and Wind Load Modeling." *Natural Hazards Review*. ASCE, Vol. 7, No. 2, May 2006.

Vickery, P., D. Wadhera, J. Galsworthy, J. Peterka, P. Irwin, and L. Griffis. 2010. "Ultimate Wind Load Design Gust Wind Speeds in the United States for Use in ASCE-7." *Journal of Structural Engineering*. Volume 136(5), 613–625.

Youker, Emily. 2014. "Joplin school district readies community safe rooms for storm season." *The Joplin Globe*. April 17, 2014.

Resources

ACI, The Masonry Society (TMS), and the American Society of Civil Engineers (ASCE). 2013. *Building Code Requirements and Specifications for Masonry Structures*, ACI 530-13/ASCE 5-13/TMS 402-13, ACI 530.1-13/ASCE 5-13, and TMS 602-13. Boston, MA.

American Meteorological Society. 2014. *Glossary of Meteorology*. Online version available at http://glossary.ametsoc.org/wiki/Main_Page.

American National Standards Institute and the American Forest & Paper Association. 2015. *National Design Specification® for Wood Construction*. NDS-2015.

Batts, M.E., M.R. Cordes, L.R. Russell, J.R. Shaver, and E. Simiu. 1980. *Hurricane Wind Speeds in the United States*. NBS Building Science Series 124. National Bureau of Standards, Washington, DC. pp. 41.

Carter, R. R. 1998. *Wind-Generated Missile Impact on Composite Wall Systems*. MS Thesis. Department of Civil Engineering, Texas Tech University, Lubbock, TX. May.

Coats, D. W. and R.C. Murray. 1985. *Natural Phenomena Hazards Modeling Project: Extreme Wind/Tornado Hazard Models for Department of Energy Sites*. UCRL-53526. Rev. 1. Lawrence Livermore National Laboratory. University of California, Livermore, CA. August.

Durst, C.S. 1960. "Wind Speeds Over Short Periods of Time." *Meteorology Magazine*, Number 89. pp.181-187.

FEMA. 1999b. *National Performance Criteria for Tornado Shelters*. May 28.

Fujita, T.T. 1971. *Proposed Characterization of Tornadoes and Hurricanes by Area and Intensity. Satellite and Mesometeorology Research Project*. SMRP No. 91. University of Chicago, Chicago, IL.

Lindbergh, C., M. R. Harlan, and J. L. Lafrenz. 1996. *Structural Evaluation of Existing Buildings for Seismic and Wind Loads*. Available at cedb.asce.org/cgi/WWWdisplay.cgi?98301.

Kelly, D.L., J.T. Schaefer, R.P. McNulty, C.A. Doswell III, and R.F. Abbey, Jr. 1978. " An Augmented Tornado Climatology." *Monthly Weather Review*, Vol. 106, pp. 1172-1183.

Krayer, W.R. and Marshall, R.D. 1992. *Gust Factors Applied to Hurricane Winds. Bulletin of the American Meteorology Society*, Vol. 73, pp. 613-617.

Minor, J.E., J.R. McDonald, and R. E. Peterson. 1982. "Analysis of Near-Ground Windfields." *Proceedings of the Twelfth Conference on Severe Local Storms*. San Antonio, TX. January 1982. American Meteorological Society. Boston, MA.

National Concrete Masonry Association (NCMA). 1972. *Design of Concrete Masonry Warehouse Walls*. TEK 37. Herndon, VA.

NCMA. 2003. *Investigation of Wind Projectile Resistance of Concrete Masonry Walls and Ceiling Panels with Wide Spaced Reinforcement for Above Ground Shelters*. NCMA Publication MR 21. Texas Tech University Wind Science and Engineering Research Center.

O'Neil, S. and J.P. Pinelli. 1998. *Recommendations for the Mitigation of Tornado Induced Damages on Masonry Structures*. Report No. 1998-1. Wind & Hurricane Impact Research Laboratory, Florida Institute of Technology. December.

Powell, M.D. 1993. "Wind Measurement and Archival Under the Automated Surface Observing System (ASOS): User Concerns and Opportunity for Improvement." *Bulletin of American Meteorological Society*. Vol. 74, 615-623.

Powell, M.D., S.H. Houston, and T.A. Reinhold. 1994. "Standardizing Wind Measurements for Documentation of Surface Wind Fields in Hurricane Andrew." *Proceedings of the Symposium: Hurricanes of 1992*. Miami, FL, December 1-3, 1993. ASCE, New York. pp. 52-69.

Steel Joist Institute. *Steel Joist Institute 75-Year Manual 1928-2003*.

U.S. Department of Energy. 2002. *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities*. DOE-STD-1020-2002. Washington, DC. January. Available at www.wbdg.org/ccb/DOE/TECHSTDS/std1020.pdf.

Zain, Mohammed, A. Budek, and E. Kiesling. undated. *Size Limits for Above-Ground Safe Rooms*. Texas Tech University. Lubbock, TX.

B9.1 Storm Surge Inundation Data

The Sea, Lake and Overland Surges from Hurricanes (SLOSH) model is used for hurricane evacuation and emergency management purposes. Details on the model can be found at www.nhc.noaa.gov/surge/slosh.php and www.fema.gov/region-iii-mitigation-division/national-hurricane-program.

In order to perform detailed site evaluations, as described in Chapter B4 of this publication, storm surge information may be obtained from the following sources:

1. NOAA has mapped SLOSH storm surge inundation depths above ground for the coast between North Carolina and Texas. The results are available here noaa.maps.arcgis.com/apps/StorytellingTextLegend/index.html?appid=b1a20ab5eec149058bafc059635a82ee, and can be used for preliminary evaluation of potential safe room sites in those States. For other States, storm surge information can be obtained from many State or county emergency management agencies, or by using NOAA's SLOSH Display Program. The SLOSH Display Program can be obtained from www.nhc.noaa.gov/surge/slosh.php#SDISPLAY.
2. Readers should contact USACE District Offices www.usace.army.mil/Locations.aspx or State/County Emergency Management Agencies and request the latest FES surge inundation and elevation data.

Users should note that the surge elevations produced by SLOSH are referenced to the mean sea level (MSL) datum, which is a tidal datum that is different than geodetic datums (e.g., NAVD, NGVD) used for building design and construction. MSL elevations will need to be converted to the geodetic datum required by the local building code and flood hazard map.

State-specific data sources

This section provides a list of storm surge inundation data or related hurricane evacuation system data currently available on the internet for selected States. This list is not exhaustive and is subject to change. It has been provided to allow the reader to see how these data may be displayed and provided for use.

Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont
www.nae.usace.army.mil/Missions/ProjectsTopics.aspx

New York
www.dhses.ny.gov/oem/safety-info/publicsafety/documents/nys-hurricane-storm-surge-areas.pdf

Maryland
http://mdtdr.bluewateri.net/INDEX.cfm

Virginia
www.vaemergency.gov/readyvirginia/stay-informed/hurricane/storm-surge
vatdr.bluewateri.net/INDEX.cfm

South Carolina
coast.noaa.gov/hes/docs/hes/SC_HER.zip

Georgia
gema.sharefile.com/download.aspx?id=6123658ba0be4f01

Florida
www.floridadisaster.org/res/

Texas
www.txdps.state.tx.us/dem/downloadableforms.htm#hurricane

Appendices

APPENDIX A
Acronyms

ACI	American Concrete Institute
ACI-CRSI	American Concrete Institute - Concrete Reinforcing Steel Institute
ADA	Americans with Disabilities Act
AHJ	Authority having jurisdiction
APC	atmospheric pressure change
ASCE	American Society of Civil Engineers
ASD	Allowable Stress Design
BCA	benefit-cost analysis
BCR	benefit-cost ratio
BFE	Base flood elevation
C&C	components and cladding
CFR	Code of Federal Regulations
CMU	Concrete masonry units
C_p	external pressure coefficient for main wind force resisting system
DEM	digital elevation model
DI	Damage indicators
DOD	Degree of damage
EF Scale	Enhanced Fujita Scale
EMS	Emergency Medical Services

E.O. Executive Order

EOC Emergency Operation Center

F Scale Fujita Scale

FAA Federal Aviation Administration

FDEM Florida Division of Emergency Management

FIRM Flood Insurance Rate Map

fps Feet per second

G Gust-effect factor for main wind force resisting system

GC_p External pressure coefficient for components and cladding

GC_{pi} internal pressure coefficient

GIS geographic information system

HMA Hazard Mitigation Assistance

HVAC heating, ventilation, and air-conditioning

IBC International Building Code

ICC International Code Council

ICF insulating concrete form

I_m impact momentum

IRC International Residential Code

K_d Directionality factor

K_z exposure factor

K_{zt} topographic factor

L_r Roof live load

LRFD Load and Resistance Factor Design

MAT Mitigation Assessment Team

MRI Mean recurrence interval

MWFRS main wind-force resisting system

NAHB National Association of Home Builders

NEHRP National Earthquake Hazards Reduction Program

NFIP National Flood Insurance Program

NFPA National Fire Protection Association

NHC National Hurricane Center

NOAA National Oceanic and Atmospheric Administration

NSSA National Storm Shelter Association

NWI National Wind Institute

NWS National Weather Service

O&M operation and maintenance

QA/QC Quality assurance/ quality control

SFBC South Florida Building Code

SFHA Special Flood Hazard Area

TTU Texas Tech University

USGS U.S. Geological Survey

V Velocity

W Wind load

APPENDIX B
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The Federal Emergency Management Agency would like to acknowledge the significant contributions made by following individuals in developing the Third Edition of this publication.

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The Federal Emergency Management Agency would like to acknowledge the significant contributions made by following individuals in developing the Second Edition of this publication. (Note: All affiliations and titles were current at the time of publication of the first edition in August 2008.)

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The American Red Cross, Clemson University, the International Code Council® (ICC®), Texas Tech University, and the U.S. Department of Education assisted FEMA in the preparation of the first edition of the manual by providing invaluable guidance and participating on the project Review Committee.

The following individuals made significant contributions to the first edition of the manual. (Note: All affiliations and titles were current at the time of publication of the first edition in July 2000.)

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APPENDIX C
Designer Checklist

Checklist

Safe Rooms for Tornadoes and Hurricanes
using FEMA P-361, third edition (2015)

Blue – User Input	Gray – Program Generate		Date:		
Project Name:					
Location:					
Designer/Lead Authority			Completed by:		
1	General Design and Drawings				
2	Type of [community] safe room	Tornado/ Hurricane/ Both			
3	Do the structural drawings include a statement that the safe room was designed to FEMA P-361?	Yes/No			
4	Is the design wind speed stated on the drawings?	Yes/No			Wind speed should be obtained from Section B3.2.4.1 of FEMA P-361
5	Are other structural and envelope design parameters identified on the drawings?	Yes/No			See Section B1.2.3 and B1.2.4 of FEMA P-361
6	Has the safe room (s) to be incorporated been identified on the drawings?	Yes/No			See Section B1.2.3 of FEMA P-361
7	Is space provided for safe room supplies within each safe room area?	Yes/No			
8	Wind Loading – Identify Appropriate Safe Room Hazard Criteria				
9	**Tornado Safe Room –** Go to Line 17 if this is not a Tornado Safe Room				
10	Determine safe room location on the Safe room design wind speed for tornadoes map.				Figure B3-1 of FEMA P-361
11	What is the design wind speed for the tornado safe room?			mph	Wind speed should be obtained from Figure B3-1 of FEMA P-361
12	What is the site exposure category?				See Section B3.2.4.2.1 of FEMA P-361
13	Building enclosure classification – how was Atmospheric Pressure Change (APC) considered? A. Designed as a partially enclosed building B. Designed as an enclosed building with APC value added	A or B			See Section B3.2.4.2.2 of FEMA P-361
14	What ASCE 7 edition and method (ASCE 7 section reference) were used in calculating MWFRS wind pressures?				See Section B3.2.4.2.2 of FEMA P-361 for ASCE 7-10 Directional Method
15	What ASCE 7 edition and method (ASCE 7 section reference) were used in calculating C&C wind pressures?				See Section B3.2.4.2.2 of FEMA P-361
16	Go to Line 32 (Walls/Openings/Door Assemblies/Window and Window Assemblies)				

17	**Hurricane Safe Room** – Go to Line 23 if this is a Tornado/Hurricane (Combined Hazard) Safe Room				
18	What is the design wind speed for the hurricane safe room? (in mph)			mph	Wind speed should be obtained from Figure B3-2 of FEMA P-361
19	What is the site exposure category?				See Section B3.2.4.2.1 of FEMA P-361
20	Building enclosure classification? A. Designed as a partially enclosed building B. Designed as an enclosed building	A or B			See Section B3.2.4.2.2 of FEMA P-361
21	What ASCE 7 edition and method (ASCE 7 section reference) were used in calculating MWFRS wind pressures?				See Section B3.2.4.2.2 of FEMA P-361 for ASCE 7-10 Directional Method
22	What ASCE 7 edition and method (ASCE 7 section reference) were used in calculating C&C wind pressures?				See Section B3.2.4.2.2 of FEMA P-361
22	Go to Line 32 (Walls/Openings/Door Assemblies/Window and Window Assemblies)				
23	**Tornado/Hurricane (Combined Hazard) Safe Room**				
24	Determine safe room location on the Safe room design wind speed for tornadoes map.				Figure B3-1 of FEMA P-361
25	What is the design wind speed if designed as a tornado safe room?			mph	Wind speed should be obtained from Figure B3-1 of FEMA P-361
26	What is the design wind speed if designed as a hurricane safe room?			mph	Wind speed should be obtained from Figure B3-2 of FEMA P-361
28	What is the site exposure category?				See Section B3.2.4.2.1 of FEMA P-361
29	Building enclosure classification – how was Atmospheric Pressure Change (APC) considered? A. Designed as a partially enclosed building B. Designed as an enclosed building with APC value added	A or B			See Section B3.2.4.2.2 of FEMA P-361
30	What ASCE 7 edition and method (ASCE 7 section reference) were used in calculating MWFRS wind pressures?				See Section B3.2.4.2.2 of FEMA P-361 for ASCE 7-10 Directional Method
31	What ASCE 7 edition and method (ASCE 7 section reference) were used in calculating C&C wind pressures?				See Section B3.2.4.2.2 of FEMA P-361
32	Walls/Openings/Door Assemblies/Window and Window Assemblies				
33	Have the walls of the safe room area been successfully tested for the identified hazard criteria for tornados, hurricanes, or both? Identify hazard and criteria.	Yes/No			See Section B8.2.3 of FEMA P-361
34	Have the roof deck systems of the safe room area been successfully tested for the identified hazard criteria for tornados, hurricanes, or both? Identify hazard and criteria.	Yes/No			See Section B8.2.3 of FEMA P-361

35	Have any openings or opening protection systems of the safe room area been successfully tested for the identified hazard criteria for tornados, hurricanes, or both? Identify hazard and criteria.	Yes/No			
36	Have any glazing or glazing systems of the safe room area been successfully tested for the identified hazard criteria for tornados, hurricanes, or both? Identify hazard and criteria.	Yes/No			See Section B8.2.4 of FEMA P-361
37	Have any door assemblies of the safe room area been successfully tested for the identified hazard criteria for tornados, hurricanes, or both? Identify hazard and criteria.	Yes/No			See Section B8.2.4 of FEMA P-361
38	Are windows or openings protected by shutter systems? If yes, and for tornado safe rooms, are these shutter systems readily available?	Yes/No			Openings should be protected to resist wind pressures and debris impacts
39	Flood Hazards (FEMA P-361)				
40	Is the safe room located on a FIRM in a mapped A, B, or shaded X zone?	Yes/No			See Section B4.2.2.1, B4.2.2.2, B4.2.2.3 of FEMA P-361
41	Is the safe room located on a FIRM in a mapped Zone V,VE zone, or Coastal A Zone?	Yes/No			
42	Is the safe room located in a mapped floodway?	Yes/No			
43	Is the safe room located behind a non-certified levee?	Yes/No			
44	Is the safe room located in an area subject to storm surge inundation?	Yes/No			
45	What is the mapped BFE (100-year flood elevation) at the site, if applicable?	Yes/No			
46	What is the mapped 500-year flood elevation at the site, if applicable?	Yes/No			
47	What is the (proposed) elevation of the top of the safe room floor?	Yes/No			
48	Was Section B4.2.2.1 and 4.2.2.2 of FEMA P-361 used to select this elevation?	Yes/No			
49	If the surrounding area is flooded, is access to the safe room possible?	Yes/No			
50	Other Hazards (FEMA P-361)				
51	Is the safe room designed to resist damage from the collapse of adjoining or adjacent structures?	Yes/No			See Section B3.2.5.5 of FEMA P-361
52	If non-safe room portions of adjoining structures are attached to the safe room, would collapse cause damage to the safe room?	Yes/No			
53	Is the safe room designed in accordance with the latest National Earthquake Hazards Reduction Program (NEHRP) seismic recommendations?	Yes/No			
54	Ventilation (FEMA P-361)				
55	Is ventilation provided by passive (P) or Mechanical (M) methods?	(P/M)			See Section B7.2.2 of FEMA P-361
56	Are ventilation openings protected?	Yes/No			

57	Is the ventilation equipment protected from wind forces and debris impacts?	Yes/No			
58	Air exchanges per hour provided:				
58	Square Footage/Occupancy Criteria (FEMA P-361)				
59	Maximum expected occupancy (number of people)				
60	Net available square footage (ASF) – Open areas			sf	See Section B5.2.1.1 of FEMA P-361
61	Net available square footage (ASF) – Restrooms, kitchens, storage areas, etc.			sf	See Section B5.2.1.1 of FEMA P-361
62	Total Usable square footage			sf	
63	Recommended Square Footage (RSF) Calculations				
64	Expected number of standing or seated occupants				
65	Expected number of wheelchair-user occupants				
66	Expected number of bedridden occupants				
67	Total number of occupants described for the safe room				
68	Total number of recommended square footage (RSF) based on number of occupants listed above			sf	
69	ADA Requirements (FEMA P-361)				
70	Is the safe room accessible to individuals with access and functional needs? (Assume a power-off condition, where the elevator is not functioning, unless a protected generator or standby power source is present.)	Yes/No			See Section B5.2.1.4.2 of FEMA P-361
71	Toilets				
72	Number of toilets provided				
73	Are appropriate toilets available in each separate safe room area?	Yes/No			See Section B7.2.3 of FEMA P-361
74	Special Inspection				
75	Has or will a Special Inspection Program and a QA/QC plan been/be developed?	Yes/No			See Sections B1.2.2 and B1.2.3.1 of FEMA P-361

APPENDIX D
Comparison Matrix of Differences Between ICC 500 Requirements and FEMA Recommended Criteria

ICC 500 REFERENCE	ICC 500 REQUIREMENTS FOR STORM SHELTERS	FEMA RECOMMENDED CRITERIA FOR SAFE ROOMS[(a)]
Section 107.1 General	Where required by the authority having jurisdiction, construction documents shall be prepared. Such documents shall contain information as required by the applicable building code and this section.	**For all safe rooms** construction documents shall be prepared **and maintained.** Such documents shall contain information as required by the applicable building code and this section.
Section 107.2.1 Design Information	For the areas of a building designed for occupancy as a storm shelter, the following information shall be provided within the construction documents: 2. A statement that the wind design conforms to the provisions of the *ICC/NSSA Standard for the Design and Construction of Storm Shelters*, with the edition year specified.	2. A statement that the wind design conforms to the provisions of the ICC/NSSA Standard for the Design and Construction of Storm Shelters, with the edition year specified **and to the provisions of FEMA P-361, with the edition year specified.**
Section 304.2 Design Wind Speed	For tornado shelters, the design wind speed shall be in accordance with Figure 304.2(1). For hurricane shelters, the design wind speed shall be in accordance with Figure 304.2(2).[(b)]	**For all residential safe rooms, the design wind speed shall be 250 mph, regardless of location.**

ICC 500 REFERENCE	ICC 500 REQUIREMENTS FOR STORM SHELTERS	FEMA RECOMMENDED CRITERIA FOR SAFE ROOMS[a]
Section 401.1.1 Minimum floor elevation of community shelters	The lowest floor used for the occupied shelter and occupant support areas of a community shelter shall be elevated to the higher of the elevations determined by: 1. The flood elevation, including coastal wave effects, having a 0.2 percent annual chance of being equaled or exceeded in any given year; or 2. The flood elevation corresponding to the highest recorded flood elevation if a flood hazard study has not been conducted for the area; or 3. The maximum flood elevation associated with any modeled hurricane category including coastal wave effects; or 4. The minimum elevation of the lowest floor required by the authority having jurisdiction for the location where the shelter is installed; or 5. Two feet above the flood elevation having a 1 percent annual chance of being equaled or exceeded in any given year. Exception: Items no. 1 and 3 shall not apply to shelters designed, constructed, designated, and used only as tornado shelters.	The lowest floor used for the occupied safe room and occupant support areas of a community safe room shall be elevated to or above the higher of the elevations determined by: 1. The flood elevation, including coastal wave effects, having a 0.2 percent annual chance of being equaled or exceeded in any given year[c]; or 2. The flood elevation corresponding to the highest recorded flood elevation if a flood hazard study has not been conducted for the area; or 3. The maximum flood elevation associated with any modeled hurricane category including coastal wave effects; or 4. The minimum elevation of the lowest floor required by the authority having jurisdiction for the location where the safe room is installed; or 5. Two feet above the flood elevation having a 1 percent annual chance of being equaled or exceeded in any given year.[c] Exception: **Item 3 (only)** shall not apply to safe rooms designed, constructed, designated and used only as tornado safe rooms.
Section 401.1.2 Minimum floor elevation of residential shelters	The lowest floor used for the occupied shelter area of a residential shelter shall be elevated to the higher of the elevations determined by: 1. The flood elevation, including coastal wave effects, having a 0.2-percent annual chance of being equaled or exceeded in any given year; or 2. The flood elevation corresponding to the highest recorded flood elevation if a flood hazard study has not been conducted for the area; or 3. The maximum flood elevation associated with any modeled hurricane category, including coastal wave effects; or 4. The minimum elevation of the lowest floor required by the authority having jurisdiction for the location where the shelter is installed. Exception: Items 1 and 3 shall not apply to shelters designed, constructed, designated, and used only as tornado shelters.	The lowest floor used for the occupied residential safe room shall be elevated to the higher of the elevations determined by: 1. The flood elevation, including coastal wave effects, having a 0.2 percent annual chance of being equaled or exceeded in any given year(c); or 2. The flood elevation corresponding to the highest recorded flood elevation if a flood hazard study has not been conducted for the area; or **3. Not Applicable**[d] 4. The minimum elevation of the lowest floor required by the authority having jurisdiction for the location where the shelter is installed. **5. The flood elevation having a 1 percent annual chance of being equaled or exceeded in any given year.**[c] Exception: **Item 1 (only)** shall not apply to safe rooms designed, constructed, designated, and used only as tornado safe rooms.

ICC 500 REFERENCE	ICC 500 REQUIREMENTS FOR STORM SHELTERS	FEMA RECOMMENDED CRITERIA FOR SAFE ROOMS[a]
Section 404.1 Community Shelter Siting	Community shelters shall be located outside of the following high-risk flood hazard areas: 1. Flood hazard areas subject to high-velocity wave action (V zones) 2. Floodways Exception: Community shelters shall be permitted in flood hazard areas subject to high-velocity wave action (V zones) where permitted by the Board of Appeals in accordance with the provisions of the International Building Code.	Community safe rooms shall be located outside of the following high-risk flood hazard areas: 1. Flood hazard areas subject to high-velocity wave action (V zones) **and Coastal A zones**[d] 2. Floodways Exception: Community safe rooms shall be permitted in flood hazard areas subject to high-velocity wave action (V zones) **and Coastal A zones**[d] where permitted by the Board of Appeals in accordance with the provisions of the International Building Code **and after completing the 8-step Decision Process for Executive Order (EO) 11988, as amended, and as provided by Title 44 of the Code of Federal Regulations Part 9.6, Decision-Making Process.**
Residential Shelter Siting	*[ICC 500 does not provide restrictions for siting residential shelters in flood hazard areas]*	Residential safe rooms shall be located outside of the following high-risk flood hazard areas: **1. Flood hazard areas subject to high-velocity wave action (V zones) and Coastal A zones[e];** **2. Floodways;** **3. Any areas subject to storm surge inundation associated with any modeled hurricane category, including coastal wave effects.**
Section 702.4 First aid kit	A first aid kit shall be supplied in all tornado shelters with a shelter occupant load of greater than 50.	A first aid kit **rated for the number of safe room occupants, as listed in the construction documents,** shall be supplied in **all** tornado safe rooms.
Section 703.7 First aid kit	A first aid kit shall be supplied in all community hurricane shelters.	A first aid kit **rated for the number of safe room occupants, as listed in the construction documents,** shall be supplied in **all** hurricane safe rooms.

***Bolded text** denotes differences between the ICC 500 Requirement and the FEMA Recommended Criteria.

Table notes:

(a) Table only lists differences between FEMA P-361 and referenced ICC 500 Chapter. All ICC 500 requirements not listed in the table should also be met in their entirety.

(b) ICC 500 tornado wind speeds for all storm shelters range from 130 mph to 250 mph. ICC 500 hurricane wind speeds for all storm shelters range from 160 mph to 235 mph.

(c) Where an approximate or detailed flood hazard study has been completed but the 1-percent- and/or 0.2-percent-annual-chance flood elevations have not been determined, those elevations should be obtained from the authority having jurisdiction or determined in accordance with accepted hydrologic and hydraulic engineering practices used to define Special Flood Hazard Areas.

(d) Not applicable because residential safe rooms should not be located in areas subject to storm surge inundation associated with any modeled hurricane category; refer to Residential Shelter Siting with respect to flood hazards in this table.

(e) Coastal A Zones are defined as the area landward of Zone V or landward of an open coast without mapped Zone V. The inland limit of the Coastal A Zone is the Limit of Moderate Wave Action if delineated on a Flood Insurance Rate Map or designated by the authority having jurisdiction.

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FEMA P-361
Catalog No: 08274-1

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