

FEMA Building Science Activities

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Webinar Agenda

- Referenced Materials Review
- Sheltering Terminology
- Storm Shelters in the I-Codes
- Storm Shelters & Safe Rooms = Sustainable Structures
- Storm Shelters & Safe Rooms → Sustainable Communities
- Case Study Examples
- FEMA Safe Room Resources
- FEMA P-320 Design Plan Animations

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Referenced Materials Review
FEMA P-361 (2021)

- Covers community and residential safe rooms
- Planning, and operations and maintenance considerations
- Detailed design and construction criteria for hurricane, tornado, and combined safe rooms

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Referenced Materials Review
FEMA P-361 (2021)

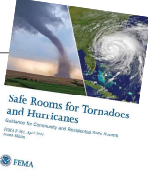
Intended Audience

Part A: Designers, building owners and operators, building officials, and emergency managers

- Information on planning, designing, and operating a safe room

Part B: Safe room designers

- Each chapter:
 - Corresponds to ICC 500 respective chapter
 - Identifies differences between FEMA Funding Criteria and ICC 500 requirements
- All safe rooms constructed with FEMA grant funds must adhere to FEMA Funding Criteria




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Referenced Materials Review
ICC 500-2020

- ICC partnered with NSSA to develop the first consensus standard for the design and construction of tornado and hurricane shelters
- First edition published in 2008
- Updated in 2014, 2020 (& 2023)
- Referenced by the IBC and IRC since 2009 editions
- Whenever storm shelters are constructed, ICC 500 must be met




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Referenced Materials Review: ICC 500-2020 & FEMA P-361 (2021)
What is the difference between a safe room and a storm shelter?

- Both safe rooms and storm shelters provide life-safety protection from hurricanes and tornadoes
- Storm shelters must comply with ICC 500
- Safe rooms must comply with ICC 500 and FEMA P-361 which is more conservative for some criteria
 - These are called "FEMA Funding Criteria"
- Because safe rooms comply with ICC 500, they also qualify as storm shelters
 - NOT all storm shelters are safe rooms**
 - All safe rooms are storm shelters**



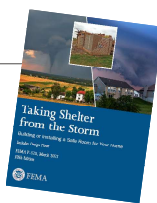


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Referenced Materials Review
FEMA P-320 (2021)

Guidance intended primarily for homeowners, builders, and contractors

- Chapter 1: Introduction
- Chapter 2: Understanding the Hazards
- Chapter 3: Planning Your Safe Room
- Chapter 4: Consumer Guidance
- Chapter 5: Building Your Site-Built Safe Room
- Chapter 6: Additional Resources, Emergency Planning and Supply Kit, and References




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Referenced Materials Review
FEMA P-320 (2021)

Design Drawings in FEMA P-320

- Residential applications
- Applicable to both tornado and hurricane hazards for design criteria identified in FEMA P-361 and ICC 500
- Sizes range from 8'x8' to 14'x14'
- Material options include CMU, CIP, ICF & wood frame



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Sheltering Terminology

Best Available Refuge Area (or BARA): The term BARA was developed to designate an area in an existing building that has been determined by an RDP to be the area least vulnerable to the life-threatening effects of extreme wind and wind-borne debris associated with a tornado or hurricane. **Regardless, because these areas were not specifically designed as safe rooms or storm shelters, their occupants may be injured or killed during an extreme-wind event.**

Recovery Shelter: Additionally, 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.

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Sheltering Terminology

TABLE A1-1: SHELTERING TERMINOLOGY MATRIX

	FEMA Safe Room	ICC 500 Storm Shelter	BARA	Recovery Shelter
Designed to minimum building code requirements	Yes	Yes	Maybe	Maybe
Determined by a registered design professional to be the building area least vulnerable to the life-threatening effects of extreme winds	N/A ^(a)	N/A ^(a)	Yes	No
Designed to provide life-safety protection per ICC 500	Yes	Yes	No	No
Designed to provide near-absolute protection per FEMA P-361 criteria (including operational and emergency planning criteria)	Yes	Maybe ^(b)	No	No
Intended for use following a high-wind event for people requiring temporary shelter as community recovery efforts begin	No	No	No	Yes

N/A = Not Applicable

Table notes:

(a) Safe room or storm shelter is building area least vulnerable to the life-threatening effects of extreme winds; determination by a registered design professional is unnecessary.

(b) Due to limited criteria differences between ICC 500 and FEMA P-361, some storm shelters may also qualify as safe rooms.



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Storm Shelters in the I-Codes

International Building Code (IBC) Requirements

2015 IBC was the first with code requirement for ICC 500 Storm Shelters in certain critical emergency operations centers and Group E occupancies.

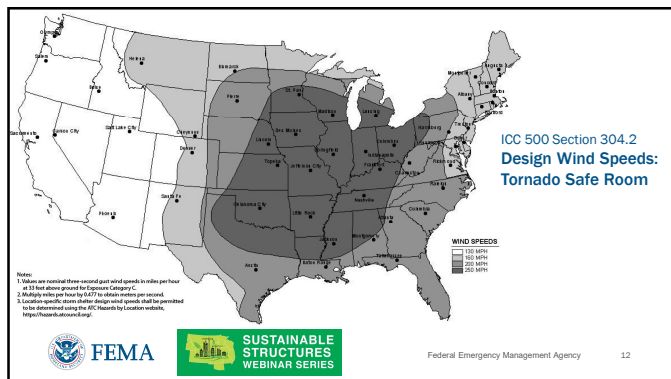
2015 IBC Section 423.3 Critical emergency operations.

In areas where the shelter design wind speed for tornadoes per Figure 304.2(1) of ICC 500 is 250 mph, 911 call stations, emergency operation centers and fire, rescue, ambulance and police stations shall have a storm shelter constructed in accordance with ICC 500.



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Storm Shelters in the I-Codes
International Building Code (IBC) Requirements

2015 IBC Section 423.4 Group E Occupancies.

In areas where the shelter design wind speed for tornadoes is **250 mph** per Figure 304.2(1) of ICC 500, **all Group E Occupancies with an occupant load of 50 or more shall have a storm shelter** constructed in accordance with ICC 500. The shelter shall be capable of housing the total occupant load of the Group E occupancy.

Exceptions:

1. Group E day care facilities
2. Group E occupancies accessory to places of religious worship
3. Buildings meeting the requirements for shelter design in ICC 500

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Storm Shelters in the I-Codes
International Building Code (IBC) Requirements

2018 IBC Section 423.4 Group E Occupancies.

In areas where the shelter design wind speed for tornadoes is **250 mph** per Figure 304.2(1) of ICC 500, **all Group E Occupancies with an occupant load of 50 or more shall have a storm shelter** constructed in accordance with ICC 500. The shelter shall be capable of housing the total occupant load of the Group E occupancy.

Exceptions:

1. Group E day care facilities
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3. Buildings meeting the requirements for shelter design in ICC 500







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Storm Shelters in the I-Codes
2021 IBC Requirements

- **Section 423.5.1 Required occupant capacity.** The required occupant capacity of the storm shelter shall include all of the buildings on the site and shall be the greater of the following:
 - The total occupant load of the classrooms, vocational rooms and offices in the Group E occupancy
 - The occupant load of the largest indoor assembly space associated with the Group E occupancy
- **Section 423.5.2 Location.** Storm shelters shall be located within the buildings they serve or shall be located where the maximum distance of travel from not fewer than one exterior door of each building to a door of the shelter serving that building does not exceed 1000'.


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Storm Shelters in the I-Codes
International Existing Building Code Requirements

2018 IEBC

- First edition with existing building code requirement for ICC 500 Storm Shelters with additions to Group E buildings (**Section 1106.1**)
- IEBC requirements paralleled IBC requirements for new Group E for shelter design occupant capacity and location BUT added exception: *if addition cannot accommodate occupants from all buildings, it must at least accommodate the addition's occupants*



2021 IEBC removed location requirement in recognition of siting challenges for existing campuses







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Safe Rooms = Sustainable Structures

- Storm shelters and safe rooms designed and constructed to provide life-safety protection from extreme wind events
- Storm-type-specific requirements for tornado, hurricane or combined (more stringent requirement governs) include:
 - Siting: flood hazard + laydown & falling debris
 - Structural: wind loads, WBD + concurrent non-wind hazards
 - Shelter environment (essential features & accessories)

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Safe Rooms = Sustainable Structures: Structural
Non-Wind Load Considerations (ICC 500 Sec 303.3)

Floor Live Loads:

- Tornado shelters are required to be designed for minimum uniform live floor loads for assembly occupancies.
- For hurricane shelters: design for normal-use occupancy

Flood Loads:

- Per ASCE 7 and applicable ASCE 24 requirements for any safe room element below the design flood elevation (DFE)
- Where applicable, minimum safe room floor elevations = DFE (note differences between ICC 500 and FEMA P-361 for community tornado safe rooms)

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Safe Rooms = Sustainable Structures: Structural
Roof Live Loads (ICC 500 Sec 303.3)

Roof live loads. Storm shelter roofs shall be designed for minimum live loads specified in the applicable code, but not less than the following:

- Tornado shelters: 100 pounds per square foot
- Hurricane shelters: 50 pounds per square foot

Where a storm shelter roof is subject to lay down or fall debris hazards, roof live loads shall also comply with Section 305.3

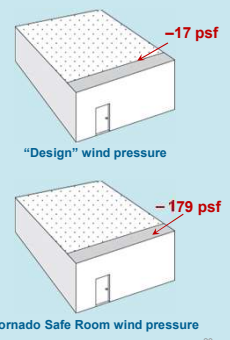


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Safe Rooms = Sustainable Structures: Structural
MWFRS Pressures (ICC 500 Sec 304)

“Design Wind” (Safe Room) Assumptions:

- Site exposure: B (C)
- Roof mean height = 15’ (15’)
- Basic wind speed = **120 mph (250 mph)**
- Enclosed building (partially enclosed)
- $K_z = 0.57 (0.85)$
- $K_d = 0.85 (1.0)$
- $K_{zt} = 1.0 (1.0)$
- $K_e = 1.0 (1.0)$








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Safe Rooms = Sustainable Structures: Structural
Debris Hazards (ICC 500 Sec 305)

- The entire safe room building envelope (walls, roof) must resist impacts from wind-borne debris
- Openings in the safe room envelope (doors, windows and utility penetrations) must also be protected
- ICC 500 missile impact criteria greatly exceed building code requirements for glazed openings in the wind-borne debris region
- Missile impact testing and assemblies that have passed previous tests are covered in Module B8

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Safe Rooms = Sustainable Structures: Structural

Tornado Community Safe Room Test Missile Criteria (ICC 500 Sec 305.1)

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

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



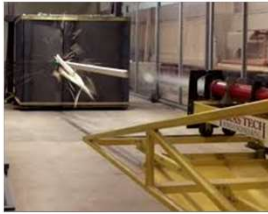
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Safe Rooms = Sustainable Structures: Structural

Storm Shelter Envelope Component Design & Testing (ICC 500 Sec 306)

- This section provides requirements for the storm shelter envelope component design and testing requirements
- Section specific references to: ICC 500 Chapter 8, *Test Methods for Impact and Pressure Testing*
- The section provides tolerances for:
 - Joints, gaps, or voids in the storm shelter envelope (Section 306.5)
 - Penetration of the storm shelter envelope by mechanical, electrical, and plumbing systems (Section 306.5)



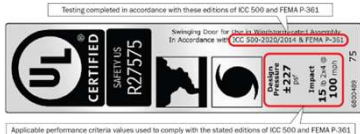
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Safe Rooms = Sustainable Structures: Structural

Listing and Labeling (ICC 500, Sec 112)

- Impact-protective systems are required to be listed and labeled denoting compliance with ICC 500
- All labeled products should be included in listing of evaluated products published by the third-party certification agency
- Listing supports installation of tested assemblies



Applicable performance criteria values used to comply with the stated editions of ICC 500 and FEMA P-361






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Safe Rooms = Sustainable Structures: Structural + Siting
Debris Hazard Loads: Laydown Hazards (ICC 500 Sec 305.3)

Laydown hazard: Adjacent building elements, other structures and natural objects that could fall onto the roof of a storm shelter, such as exterior walls of adjacent single-story structures, self-supporting towers, poles or large trees.

Apply impact load where safe room is within the radius of the laydown hazard (i.e., height of the hazard is greater than distance between the hazard and safe room)










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Safe Rooms = Sustainable Structures: Structural + Siting
Debris Hazard Loads: Falling Debris (ICC 500 Sec 305.3)

Falling debris hazard. Exterior components, cladding, and appurtenances, such as parapet walls, masonry cladding, or rooftop equipment, that could fall onto the roof of a storm shelter from wind damage to adjacent, taller buildings or taller sections of a host building.

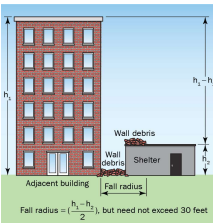






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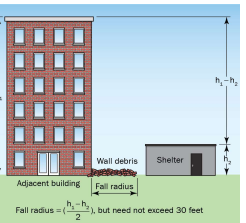
Safe Rooms = Sustainable Structures: Structural + Siting
Falling Debris Hazards (ICC 500 Sec 305.3)

Impact loading required





Fall radius = $\frac{h_1 - h_2}{2}$, but need not exceed 30 feet

Impact loading NOT required

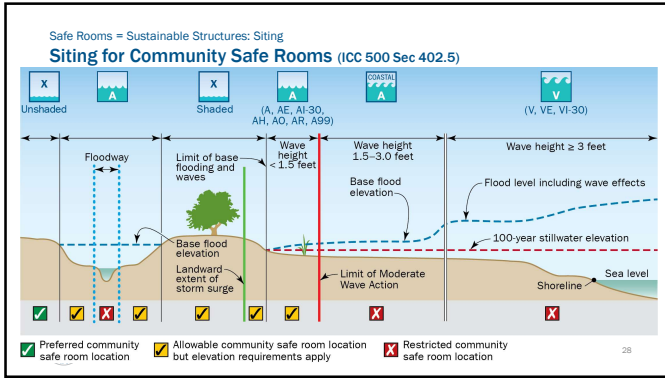


Fall radius = $\frac{h_2 - h_1}{2}$, but need not exceed 30 feet

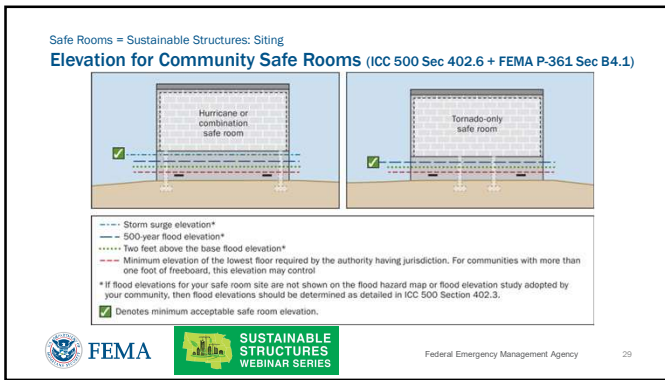



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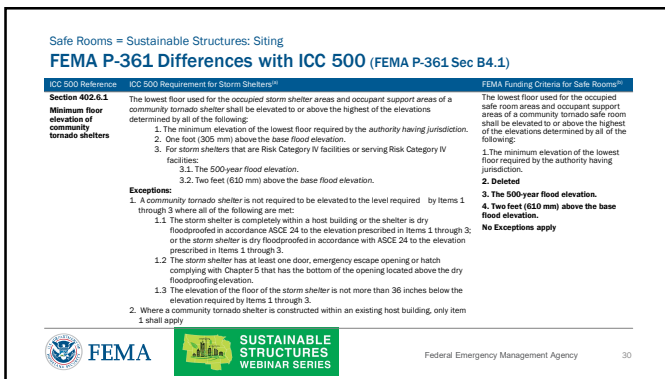
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Safe Rooms = Sustainable Structures: Essential Features and Accessories
Protection of Critical Support Systems (ICC 500 Sec 701)

Critical support systems are required to:

- Resist the same design wind pressures, wind-borne debris, and flood hazard as the safe room they serve
- Remain functional for at least as long as the minimum period of safe room occupancy for the designated safe room storm type
 - Tornado: 2-hour minimum
 - Hurricane: 24-hour minimum



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Storm Shelters — Sustainable Communities

- Protect the community's most valuable commodity: it's people
- With human resources protected, continuity of operations is possible
- IBC storm shelter requirements target critical emergency ops & schools
 - Protects vulnerable populations
 - Makes immediate and short-term recovery attainable



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Storm Shelter Design



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Storm Shelter Design



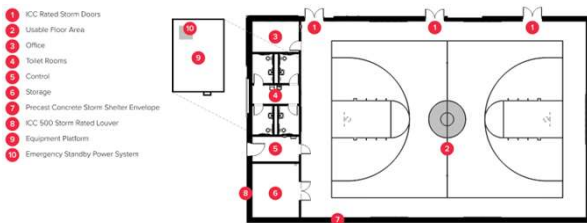
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Storm Shelter Design



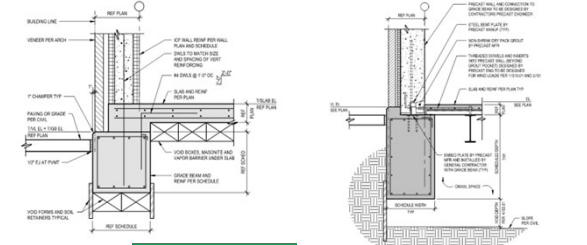
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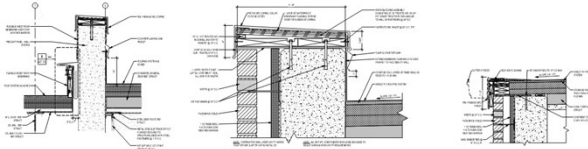
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FEMA Safe Rooms

FEMA Safe Room Resources Webpage
<https://www.fema.gov/emergency-managers/risk-management/safe-rooms/resources>

Additional resources:

- o Community Tornado Safe Room Doors Installation and Maintenance Fact Sheet
- o Best Available Refuge Area Checklist
- o Residential Tornado Safe Room Doors Fact Sheet
- o Foundation and Anchoring Criteria for Safe Rooms Fact Sheet
- o Highlights of ICC 500-2020
- o Flood Hazard Elevation and Siting Criteria for Community Safe Rooms
- o Flood Hazard Elevation and Siting Criteria for Residential Safe Rooms
- o Additional One-Page Safe Room Resources

Please send questions to Saferoom@fema.dhs.gov




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FEMA P-320, Safe Room Design Plans
Construction Animations

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