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On the cover: Tornados, earthquakes, hurricanes and floods—these threats put millions of Americans at risk each year. The Multihazard Mitigation Council (MMC) is working to reduce the total costs associated with these disasters and other related hazards to buildings by fostering and promoting consistent and improved multihazard risk mitigation strategies, guidelines, practices and related efforts.

FEMA Updates Safe Room Publications

By John Ingargiola, CFM; Tom Reynolds, PE; and Scott Tezak, PE

THIS ARTICLE IS A CONDENSED PRESENTATION OF THE updates in the latest versions of Federal Emergency Management Agency (FEMA) safe room publications, FEMA 320, *Taking Shelter from the Storm: Building a Safe Room for Your Home or Small Business,* and FEMA 361, *Design and Construction Guidance for Community Safe Rooms*, both dated August 2008 **(FIGURE 1** and **FIGURE 2)**.

Specifically, this article concentrates on the design updates for safe rooms constructed out of reinforced concrete and masonry. For more information, please contact FEMA directly via the information provided at the end of this article.

INTRODUCTION

In August 2008, FEMA released the third edition of FEMA 320 and the second edition of FEMA 361. First released in 1998 and last revised in September 2000, FEMA 320 is the benchmark publication that provides prescriptive designs to be used in the design and construction of residential and small community shelters, now classified by FEMA as safe rooms. These structures are intended to protect occupants from wind and debris associated with hurricanes and tornadoes. Originally released in July 2000, FEMA 361 provides technical guidance for the design and construction of community safe rooms intended to protect larger groups of occupants from wind and debris associated with hurricanes and tornadoes.

Since the publication of FEMA 320 in 1998 and FEMA 361 in 2000, thousands of safe rooms have been built using FEMA's criteria, many funded partly by FEMA. A growing number of these safe rooms have saved lives in actual events. Since the initiation of its safe room program, FEMA has provided federal funds through its Hazard Mitigation Assistance Program, totaling over $385,000,000, for the design and construction of more than 800 community safe rooms.

Through residential safe room initiatives over the same period, support for the design and construction of over 20,000 residential safe rooms occurred with federal funds totaling more than $75,000,000. These projects were completed in both tornado-prone and hurricane-prone regions of the country.

FEMA 320 and 361 were used as the basis for developing the new International Code Council/National Storm Shelter Association (ICC/NSSA) *Standard for the Design and Construction of Storm Shelters* (ICC 500) released in August 2008 **(FIGURE 3)**.

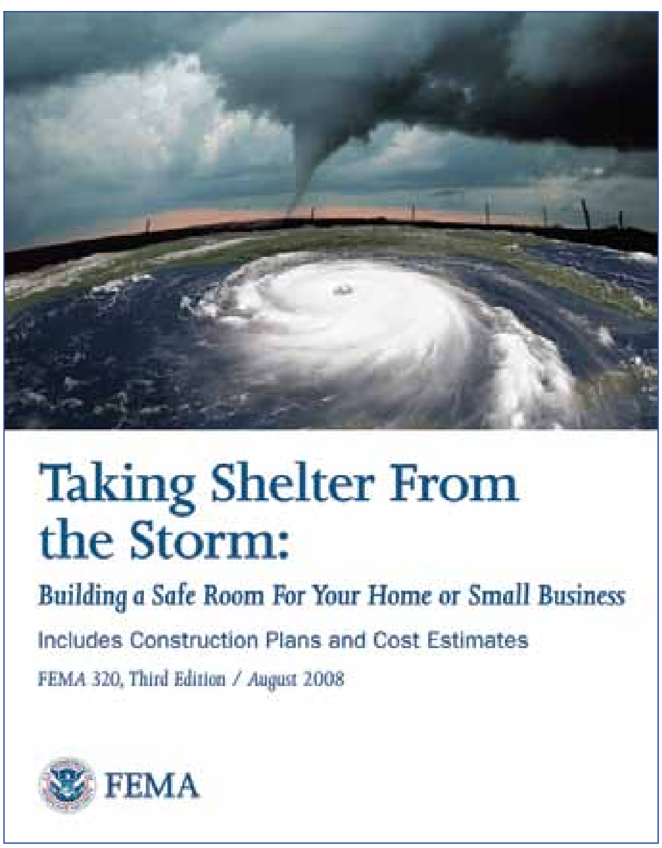

Figure 1. FEMA 320.

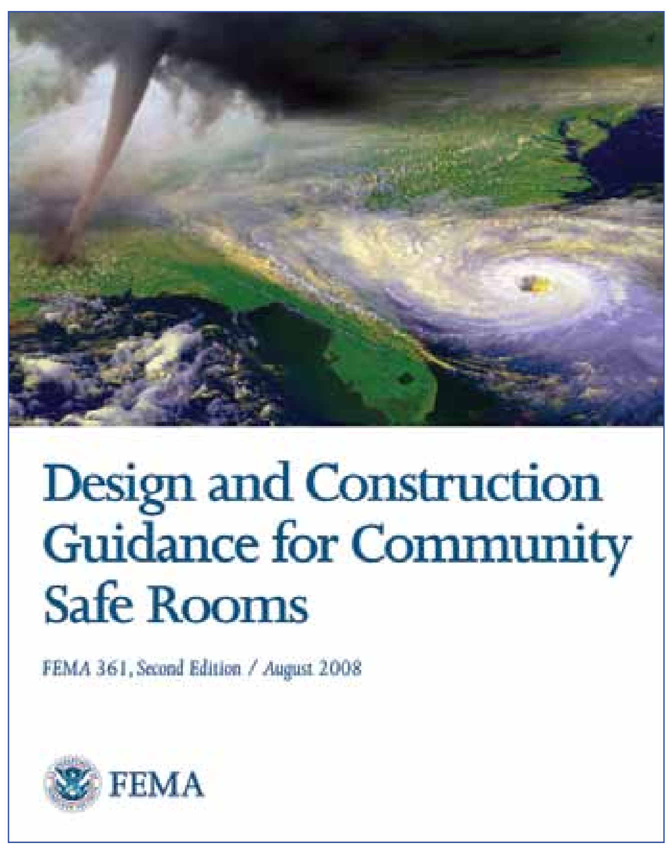

Figure 2. FEMA 361.

FEMA continues to support the development of consensus codes and standards that provide minimum acceptable requirements for the design and construction of hazard-resistant buildings. The ICC 500 successfully took many of the design and performance criteria presented in the earlier editions of FEMA's safe room publications, updated them and codified them through the consensus standard process.

Although most of the ICC 500 criteria are the same as the FEMA criteria (the documents share the same design wind speed maps), important differences exist with respect to design assumptions, windborne debris impact protection for the hurricane hazards, designing for flood hazards and emergency management guidance. Some highlights of the FEMA criteria are presented in the following section.

LEVELS OF PROTECTION: DEFINING A "SAFE ROOM"

"Safe room" and "shelter" are two terms that have been used interchangeably in past publications, guidance documents and other shelter-related materials. However, with the release of the ICC 500, there is a need to identify shelters that meet the FEMA criteria for life safety protection versus those that meet the ICC 500 standard.

FEMA refers to all shelters constructed to meet their criteria (whether for individuals, residences, small businesses, schools or communities) as safe rooms. All safe room criteria, as set forth in the FEMA publications, meet or exceed the shelter requirements of the ICC 500.

Safe rooms designed and constructed in accordance with guidance in FEMA 320 and 361 provide "near-absolute

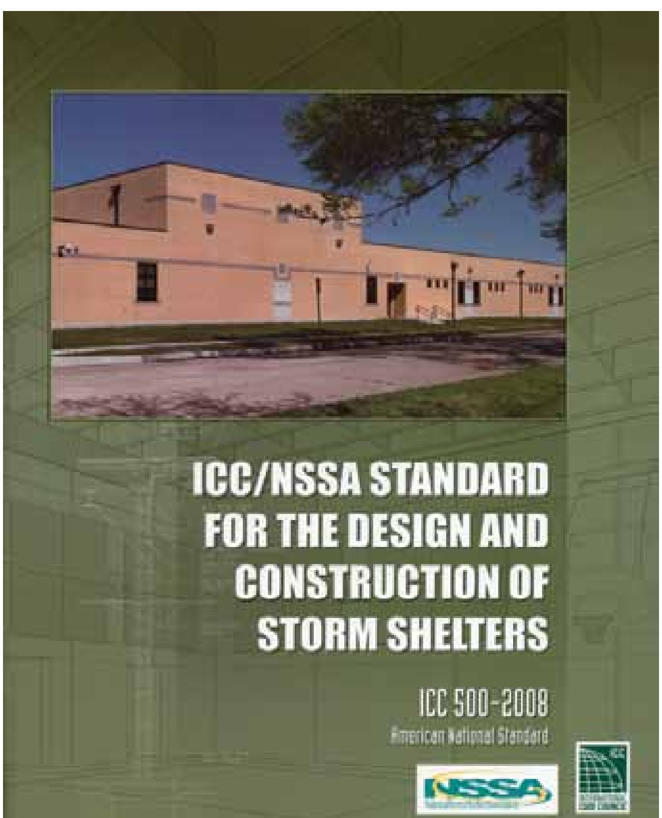

Figure 3. ICC 500.

protection" from extreme-wind events. FEMA 361 defines near-absolute protection as follows: "near-absolute protection means that, 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. Our knowledge of tornadoes and hurricanes is based on substantial meteorological records as well as extensive investigations of damage from extreme winds."

By comparison, the purpose of the ICC 500 standard was set forth as: "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."

Further, FEMA 361 defines a community safe room as a shelter that is designed and constructed to protect a large number of people from a natural hazard event. Specifically, the number of persons taking refuge in the safe room will be more than 16 and could be up to several hundred or more. Safe rooms for 16 or fewer occupants are addressed by the prescriptive designs for residential and small community safe rooms, presented in FEMA 320.

It is important to note, however, that the FEMA criteria for safe rooms are presented in a guidance document. It is up to a community or jurisdiction to determine if the level of protection they desire is that of a safe room, an ICC 500 shelter or another shelter that may provide some level of protection between that of an engineered building and the FEMA or ICC 500 levels of protection.

The 2009 *International Building Code* (IBC) and the *International Residential Code* (IRC) have adopted the ICC 500 as the code minimum requirements for the design and construction of tornado and hurricane shelters. As such, permits issued for a "shelter" in communities or jurisdictions that adopt the 2009 IBC and IRC will need to be in accordance to the requirements of the ICC 500.

The adoption of the ICC 500 is a significant step forward in improving the level of protection provided by shelters. Prior to the 2009 IBC and IRC, the codes and standards for the design and construction of buildings contained no provisions for providing life safety protection for building occupants during tornado and hurricane events.

FEMA PUBLICATION UPDATES

The new third edition of FEMA 320, *Taking Shelter From the Storm: Building A Safe Room For Your Home or Small Business,* 2008, presents updated hazard evaluation, prescriptive safe room designs and consumer guidance. The new second edition of FEMA 361 presents updated and refined design criteria for safe rooms when compared to the first edition's 2000 criteria. The changes to the prescriptive designs of FEMA 320 and the design criteria (for both tornado and hurricane hazards) of FEMA 361 are the result of post-disaster investigations into the performance of safe rooms and shelters after tornadoes and hurricanes.

Further, the changes in both documents also consider the new consensus standard from the ICC 500. The criteria presented in the publications address how to design and construct a safe room that provides near-absolute protection for groups of individuals sent to a building or structure expecting it to be capable of providing them life safety protection from wind, windborne debris and flooding.

FEMA 320 continues to provide prescriptive designs for safe rooms using concrete, masonry or wood. Essentially, the design parameters remain unchanged, with the prescriptive designs being developed for the most restrictive of criteria so they may be used for any hazard, anywhere in the country.

The safe rooms are designed to resist wind forces generated from a 250 mph (402 km per hour) wind (3-second gust) and debris impact from a 15 lb, 2x4 projectile traveling horizontally at 100 mph (160 km per hour). Refinements in the design criteria include the use of the "partially enclosed" value for internal pressure so that these designs can be used for both residential and small community safe room applications. The flood hazard design criteria have also been refined to provide more detailed guidance when flood hazards are present.

FEMA 361 sets forth the detailed criteria for designing and constructing a safe room. The focus of FEMA 361 is to guide designers through the design of a community safe room but the details of the FEMA 320 prescriptive design criteria are now provided as well.

The design process is outlined in FEMA 361, along with the criteria. One of the primary differences in a building's structural system designed for use as a safe room, rather than for conventional use, is the magnitude of the wind forces it is designed to withstand. Conventional (normal) buildings are designed to withstand forces associated with a certain wind speed (termed "design [basic] wind speed") presented in design standards such as the American Society of Civil Engineers (ASCE) 7-05, *Minimum Design Loads for Buildings and Other Structures*.

The highest design wind speed used in conventional construction, near the Atlantic and Gulf coasts, is in the range of 140 to 150 mph (225 to 240 km per hour), 3-second gust. By contrast, the design wind speed recommended by FEMA for safe rooms in these same areas is in the range of 200 to 225 mph (321 to 362 km per hour), 3-second gust, and is intended to ensure that safe rooms can provide "near-absolute protection" for occupants.

FIGURE 4 presents the two wind speed maps from FEMA 361. Two wind speeds maps are provided in the publication to address both tornado-specific and hurricane-specific hazards.

For envelope or cladding systems, the governing design criterion is windborne debris, commonly referred to as missiles. Windows and glazing in exterior doors of conventional buildings are not required to resist windborne debris, except when the buildings are located within windborne debris regions where openings must have impact-resistant glazing systems or protection systems. These systems can be laminated glass, polycarbonate glazing, shutters or other products that have been tested per requirements set forth in the building code and standards.

The ASCE 7-05 missile criteria were developed to minimize property damage and improve building performance. They were not developed to protect occupants and notably, do not require walls and roof surfaces to be debris impact resistant.

To provide occupant protection for a life safety level of protection, the criteria used in designing safe rooms include greater resistance to penetration from windborne debris. Sections 3.3.2, 3.4.2 and 3.5.2 of FEMA 361 present the debris impact-resistance performance criteria for the tornado, hurricane and residential safe rooms, respectively.

In general, the tornado debris impact protection criteria are to resist a 15 lb, 2x4 projectile traveling at 80 to 100 mph (128 to 160 km per hour), depending on the safe room design wind speed. Similarly, the hurricane debris impact protection criteria are to resist a 9 lb, 2x4 projectile traveling at 80 to 128 mph (128 to 205 km per hour), depending on the safe room design wind speed.

The technical differences between updated FEMA 361/320 and the ICC 500 are based on the different levels of protection offered by the FEMA safe rooms and the emergency management guidance that are part of the FEMA criteria. As such,

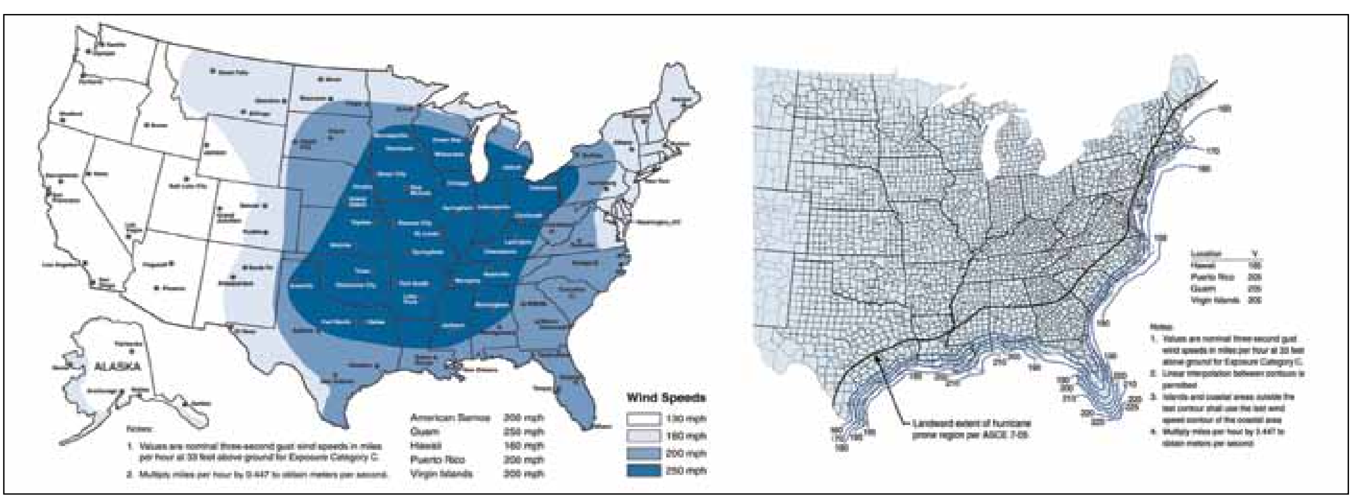

Figure 4. Tornado and hurricane safe room design wind speed maps from FEMA 361 (2008).

Table 1: Differences in Design Criteria Between FEMA 361 and the ICC 500	
FEMA 320/361	**ICC 500 Standard**
Use Exposure C only.	Use Exposure C, with some Exposure B.
Partially enclosed design, strongly encouraged for: • Tornado safe room; and • Hurricane safe room.	**Enclosed or partially enclosed design,** allowed for: • Tornado may also use Atmospheric Pressure Change (APC) calculation; and • Hurricane may be designed as enclosed.
Hurricane debris impact criteria **0.5 x safe room design wind speed**.	Hurricane debris impact criteria **0.4 x shelter design wind speed**.
Flood design criteria **restricts placement** of safe rooms.	Flood design criteria **allows placement** of shelters anywhere.
Peer review triggered at **50 occupants**.	Peer review triggered at **300 occupants**.

FEMA maintains more stringent criteria than ICC 500. TABLE 1 highlights a few of the key differences between the FEMA and ICC 500 guidelines. For additional information, see Chapter 3 of FEMA 361.

FEMA provides up-to-date best practices and design guidance on all types of hazard resistance construction (from residential buildings to critical facilities). The information developed for FEMA's various guidance documents was used to update FEMA 320/361. Therefore, if safe room designers, operators and emergency managers implement FEMA criteria in their projects, they can feel confident that they've used 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 debris associated with extreme-wind events.

CONCRETE AND MASONRY

The inherent physical characteristics of properly reinforced concrete and masonry make them ideal for withstanding high pressures and windborne-debris impacts. With the addition of an exterior finish capable of preventing water infiltration during flood events, these systems can provide exceptional protection under design events. It is for these reasons that concrete and masonry are among one of the most preferred construction materials for safe rooms. Most safe rooms are typically constructed with conventional cast-in-place concrete and concrete masonry units (CMUs).

A few examples of how concrete and masonry can be used in the construction of residential and small community safe rooms are provided in the following descriptions. For safe rooms, other than the prescriptive designs in FEMA 320, the design criteria in FEMA 361 should be followed. FEMA 361 (2008) criteria include improved design wind speeds, design factors and missile impact resistance criteria.

Cast-in-place concrete and precast

FEMA 320 provides prescriptive solutions for safe rooms using both of these construction methods. In the updated publication, the cast-in-place concrete and precast concrete details remain very similar to the previous publication. For a standard 8 x 8 ft (2 x 2 m) safe room, the wall thickness is 6 inches (15 cm) minimum with #4 vertical bars at 12 inches (30 cm) on center. However, FEMA 320 now provides prescriptive solutions for a 14 x 14 ft (4 by 4 m) residential or small community safe room (FIGURE 5). See Drawing AG-01 in FEMA 320 for more details.

Insulating concrete forms

In an effort to assist homebuilders and homeowners with building economical safe rooms for new and existing homes, the Portland Cement Association, American PolySteel and

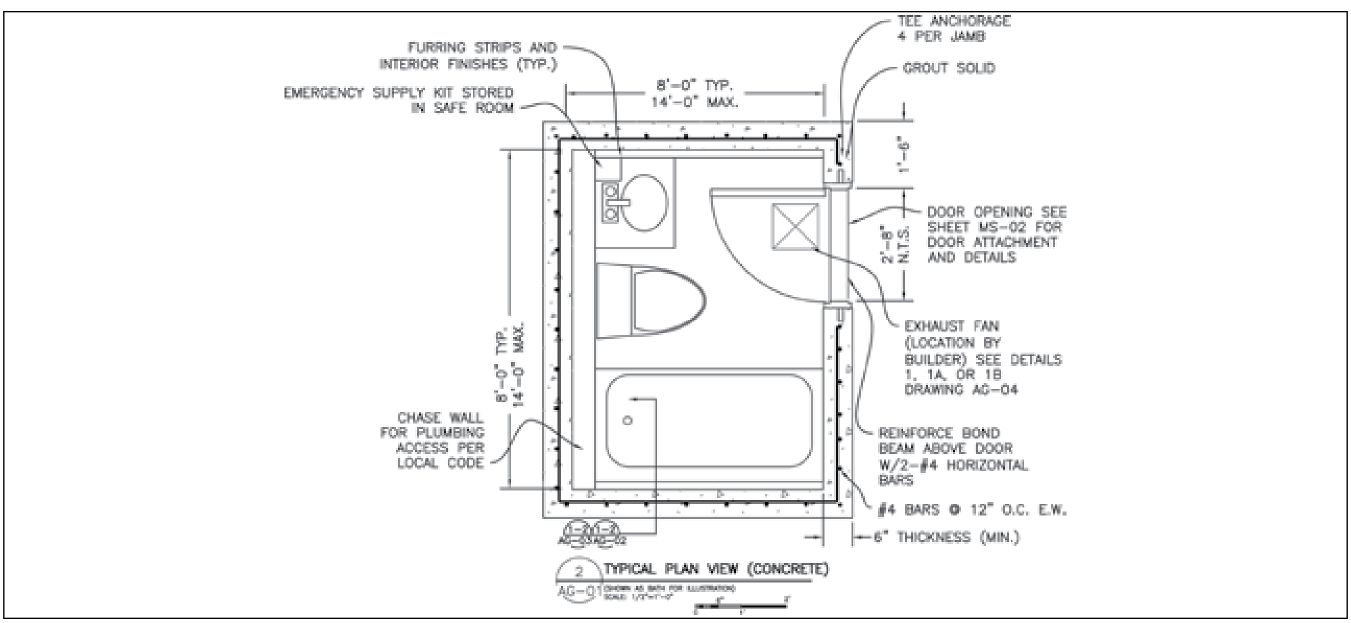

Figure 5. A cast-in-place concrete safe room from FEMA 320.

Lite-Form International worked together to develop safe room plans specifically for insulating concrete forms (ICFs).

Like the forms used for cast-in-place concrete, ICFs are forms that hold the concrete during placement. The difference is that the ICF forms stay in place as a permanent part of the wall assembly. Made of foam insulation or other insulating material, the forms typically have one of two basic configurations:

- Pre-formed interlocking blocks into which the concrete is placed; or
- Individual panels with plastic connectors that form cavities into which the concrete is placed.

Thanks to the efforts of these industry partners, FEMA 320 provides prescriptive solutions using ICF. Drawing Numbers AG-08 and AG-09 include details for waffle grid and flat wall ICF systems **(FIGURE 6)**. The sections provided in the FEMA 320 plans have all been tested and shown to resist the 15 lb, 2x4 projectile traveling at 100 mph (160 km per hour). It is important to note there are some ICF products, called screen grid forms, shaped similar to waffle grid forms. These ICF products create a discontinuous concrete infill (voids) and should not be used in safe room construction.

Concrete masonry units

The inherent physical characteristics of properly constructed reinforced masonry make it ideal to withstand wind-induced pressures and windborne-debris impacts. With the addition of an exterior finish capable of preventing water infiltration during events with wind-driven rain, these systems can provide exceptional protection under design events. It is for these reasons that masonry is one of the most preferred construction materials for a safe room. Many safe rooms are typically constructed with CMUs.

Examples of how concrete masonry can be used in the construction of residential and small community safe rooms are provided in FEMA 320 **(FIGURE 7)**. When designing safe rooms, the prescriptive designs in FEMA 320 may be used or the design criteria in FEMA 361 should be followed. FEMA 361 criteria provide all the necessary information to design a safe room to provide near-absolute protection using reinforced concrete masonry.

It is relatively straight-forward to construct a safe room from reinforced masonry. Advances in the industry include the addition of water repellant in the block mix, additional sealers and flashing applied on-site and foam installation used as moisture repellant. Concrete masonry can be used in new construction, existing homes and in stand-alone safe rooms. The most critical aspect of constructing a safe room using reinforced masonry is that all cells must be filled with concrete or grout. This provides resistance to glazing, shutter or other products that have been tested per requirements set forth in the building code and standards.

After the initial FEMA 320 publications were developed in 1998 and 2000, the National Concrete Masonry Association (NCMA) continued to investigate the use of reinforced masonry in safe room construction. Through their own research, development and testing, NCMA refined the safe room designs

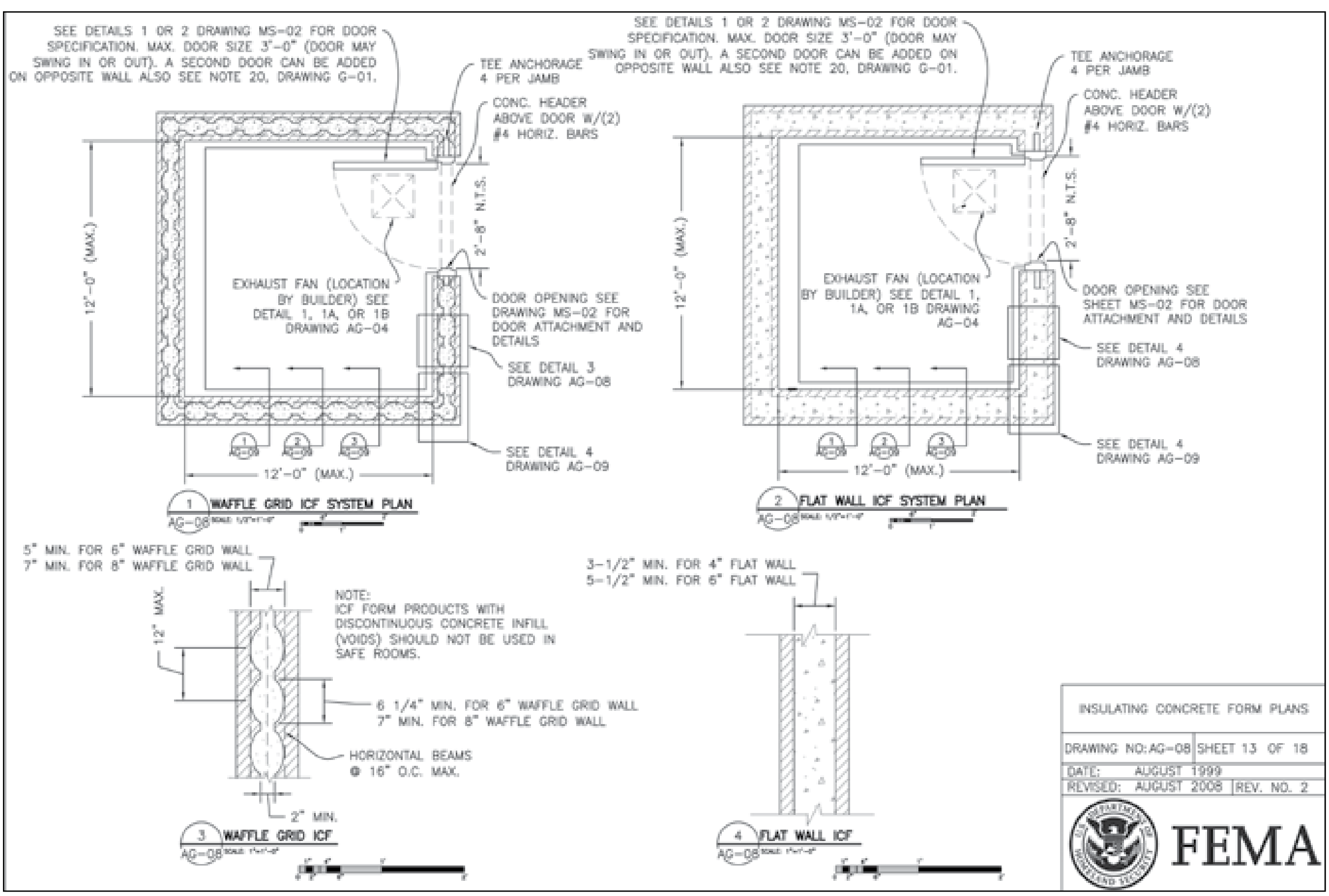

Figure 6. ICF safe rooms from FEMA 320.

to better utilize materials. As a result, NCMA was able to provide new design details to FEMA when the publications were updated in 2008. These new details now allow masonry wall designs that will not require vertical reinforcing steel in every vertical "stack" of cells.

FEMA 320 provides options for constructing an 8 x 8 ft (2 x 2 m) and 14 x 14 ft (4 by 4 m) safe room **(FIGURE 8)** of reinforced masonry (in addition to designs using reinforced concrete and wood systems). New for the 2008 designs, the reinforcing details have been modified and reinforcing steel is no longer required in every vertical cell. In the new designs for the 8 x 8 ft (2 x 2 m) CMU safe room, the vertical reinforcing steel is now #5 bars at every corner and 48 inches (121 cm) on the center. As mentioned previously, it is very important to remember that each cell is still fully grouted.

Reinforced CMU safe room designs are now provided for rooms that are 14 x 14 ft (4 by 4 m). Vertical reinforcing steel used for these larger safe rooms is now #6 bars at every corner and 40 inches (101 cm) at the center. Another addition provides better details on the CMU roof design and connections to other materials used for safe room roof construction. See Drawing AG-01 in FEMA 320 (2008 edition) for more CMU safe room design details and a reinforcement schedule. **FIGURE 6** presents the CMU reinforcement schedule for the safe rooms presented in the FEMA drawings.

With a constantly-evolving industry, new technologies and adaptations are on the horizon. In addition to modified mix designs, the market is already seeing advances in the use of Kevlar, in conjunction with concrete, to resist debris impact. As the industry advances, new materials and construction methods

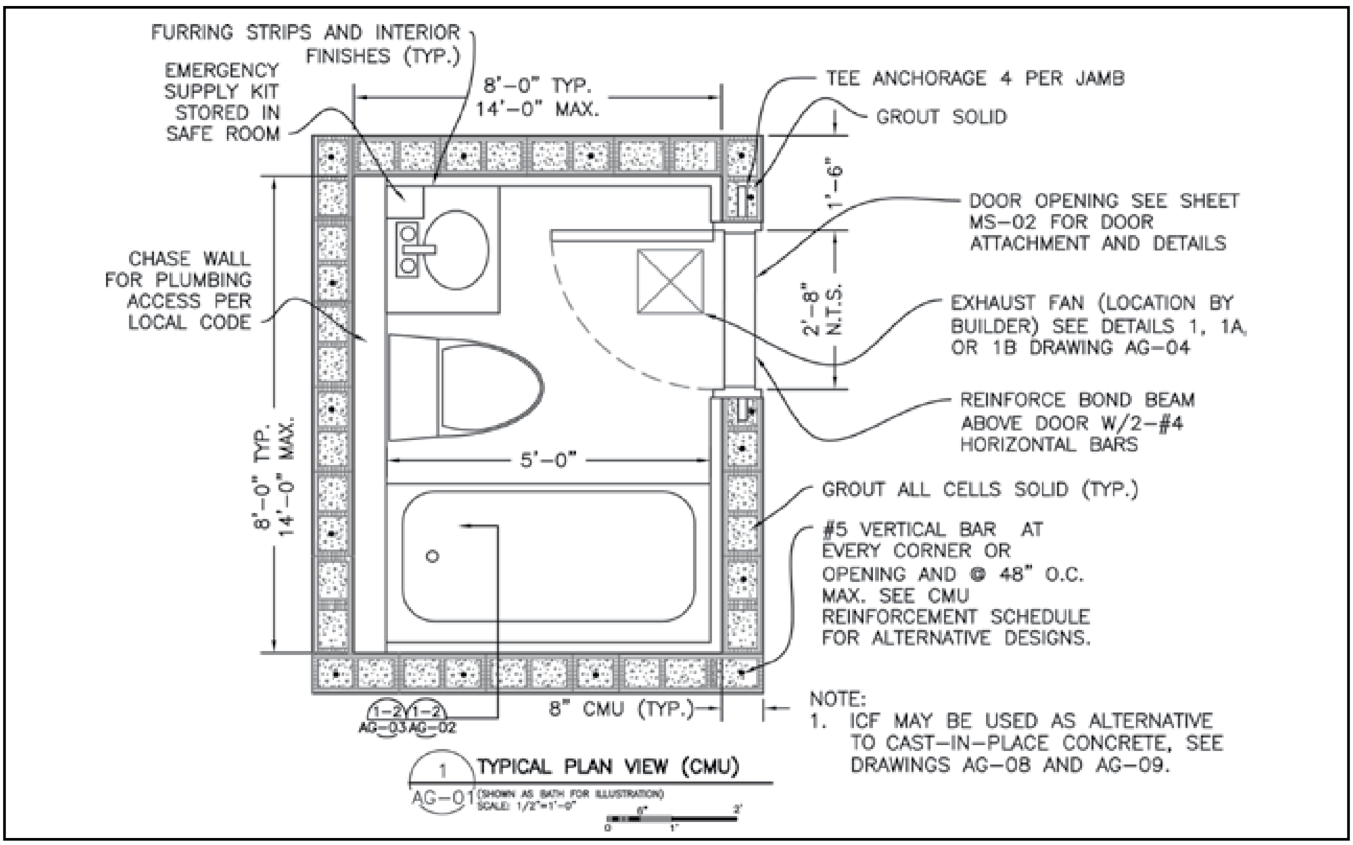

Figure 7. A CMU safe room from FEMA 320.

CMU REINFORCEMENT SCHEDULE			
DIMENSIONS	CMU THICKNESS	WALL GROUTING AND REINFORCEMENT	CONCRETE ROOF OPTIONS SLAB THICKNESS AND REINFORCEMENT
8'X8'X8'	6"	FULLY GROUTED CELLS WITH #4 VERTICAL REINFORCEMENT @ 16" O.C. AND AT EVERY OPENING AND EACH CORNER	4" THICK CONCRETE ROOF SLAB REINFORCED WITH #4 BARS EACH WAY @ 12" O.C.
8'X8'X8'	8"	FULLY GROUTED CELLS WITH #5 VERTICAL REINFORCEMENT @ 48" O.C. AND AT EVERY OPENING AND EACH CORNER	4" THICK CONCRETE ROOF SLAB REINFORCED WITH #4 BARS EACH WAY @ 12" O.C.
14'X14'X8'	8"	FULLY GROUTED CELLS WITH #6 VERTICAL REINFORCEMENT @ 40" O.C. AND AT EVERY OPENING AND EACH CORNER ALTERNATIVE REINFORCEMENT : FULLY GROUTED CELLS WITH #5 VERTICAL REINFORCEMENT @ 32" O.C. AND AT EVERY OPENING AND EACH CORNER	6" THICK CONCRETE ROOF SLAB REINFORCED WITH #4 BARS EACH WAY @ 18" O.C.

TABLE NOTE:
VERTICAL REINFORCEMENT SHALL TERMINATE IN BOND BEAM WITH A STANDARD HOOK. IF CEILING SYSTEM IS A REINFORCED CONCRETE SLAB, A SEPARATE BOND BEAM IS NOT REQUIRED. GROUT WALLS SOLID AS PER NOTES.

Figure 8. A CMU reinforcement schedule from FEMA 320.

will be developed to enhance the durability, feasibility and robustness of FEMA safe rooms.

CONCLUSION

The August 2008 release of the FEMA 320 and 361 safe room guidance documents and the ICC 500 storm shelter standard were significant milestones in the standardization of criteria for structures to be used to provide life safety protection from tornadoes and hurricanes. With the incorporation of the ICC 500 into the 2009 IBC and IRC, the majority of the FEMA safe room criteria that have been used since the 1990s is now codified.

It is now the challenge of designers, emergency managers, owners/operators and industry groups and participants to strive towards producing quality safe rooms that meet the new criteria.

While it is true that few, if any, shelters constructed to the criteria and standards presented in this paper have experienced a design event, in time this will occur. Tornadoes and hurricanes will happen and will inevitably impact a safe room. When this happens, investigations of the effect of the event on the safe room will take place and these criteria and standards will be reviewed and improved.

There is debate in the architectural and engineering communities about some of the design values chosen for safe rooms and shelters, particularly the internal pressure coefficients, exposure categories and debris impact criteria. The criteria set forth in FEMA 361/320 and ICC 500 are based on the best available research, from both the field and laboratory, at the time these documents were produced. As opportunities arise to further investigate and research these criteria, both FEMA and ICC should work together to investigate and update the design guidance and requirements of the standard, respectively. ■

For more information on FEMA safe rooms, see www.fema.gov/plan/prevent/saferoom, contact the FEMA Safe Room Help Line at saferoom@dhs.gov, or call (866) 222-3580 and select "2" from the help menu.

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