TORNADO OUTBREAK *of* 2011

IN ALABAMA, GEORGIA, MISSISSIPPI, TENNESSEE, AND MISSOURI

9 Observations on Tornado Refuge Areas, Hardened Areas, and Safe Rooms

Although hurricanes in the Southeast have received most of the attention in recent years, the threat and risk from tornadoes in the central and eastern portions of the United States is real.

A total of 11,629 tornadoes were recorded by NOAA's SPC for the 60-year study period from 1950 through 2010 (NOAA 2011). Between 2000 and 2011, Alabama alone experienced 636 tornadoes with an associated 296 fatalities, and Missouri experienced 668 tornadoes with an associated 234 fatalities. For occupants of buildings not hardened to meet FEMA or ICC criteria to provide life-safety protection from tornadoes, it is critical to adequately plan how to minimize loss of operations and loss of life.

During severe weather, building occupants should be moved to a location in the building that is best protected from potential wind-borne debris and least susceptible to collapse. While these areas do not provide near-absolute protection (unless designed as safe rooms), they may reduce the number of occupants injured or killed. Appropriate tornado refuge areas should be identified by architects, engineers, or design professionals familiar with FEMA 361 and FEMA P-431, *Tornado Protection: Selecting Refuge Areas in Buildings* (2009b) (refer also to Section 1.2). These tornado refuge areas are usually interior locations with short-span roof systems, reinforced masonry or concrete walls, and no glazed (glass) openings. The tornado refuge areas that typically perform the best during tornadoes are corridors, small interior rooms, and restrooms. Although homeowners and building owners may have identified such areas for use during severe weather and implemented construction measures to improve their performance, these areas have not generally been designed specifically to provide occupant protection. In the absence of access to a safe room, tornado refuge areas are typically a "last choice" or "only option" for those seeking protection. It is important to note that tornado refuge areas do not guarantee safety and offer only limited protection from wind and wind-borne debris; however, if they are identified correctly, they offer the most protection for building occupants seeking refuge during tornadoes and are better than no protection at all. Additional information identifying refuge areas during tornadoes is provided in this chapter.

This chapter describes the differences between tornado refuge areas, hardened areas, storm shelters, and safe rooms (Section 9.1). It includes the MAT's field observations made after the April 25–28, 2011 tornado outbreak and the May 22, 2011 Joplin, MO tornado event regarding each of these types of protection areas (Sections 9.2 to 9.4). Section 9.5 presents observations related to travel time to places where individuals sought shelter during the tornadoes, and Section 9.6 presents observations related to compliance issues of both residential and community shelter areas not constructed to the stated criteria of the FEMA guidelines or ICC 500 standard.

9.1 Terminology and Examples

Buildings and portions of buildings that protect people during a tornado can be classified into four levels; in order of increasing level of protection, these levels of protection range from "minimal protection afforded" to "designed to provide near-absolute life-safety protection."

- ***Tornado refuge areas*** are constructed to regular building code requirements, but may also have continuous load paths, bracing, or other features that increase resistance to wind loads. It is important for people to know that such an area may not be a safe place to be when a tornado strikes and they still may be injured or killed during a tornado event.

- ***Best available refuge areas*** are areas in an existing building that have been deemed by a qualified architect or engineer to likely offer the greatest safety for building occupants during a tornado (defined in accordance with FEMA P-431). It is important to note that occupants of such areas may be injured or killed during a tornado since these areas are not specifically designed as tornado safe rooms. However, people in

> The MAT uses the terms "***safe room***" and "***storm shelter***" to describe only those hardened structures that meet the FEMA or ICC criteria for life-safety protection (see Section 1.2). Other structures, buildings, or portions thereof that have been described by their users as "shelters" but are not designed to accepted criteria for life-safety protection are identified here as ***hardened rooms***, hardened structures, or tornado refuge areas.

the best available refuge areas are less likely to be injured or killed than people in other areas of a building.

- ***Hardened areas or rooms*** are constructed for protection, but not specifically to set criteria. The difference between a hardened area and a best available refuge area is that specific portions of the area are designed to carry or resist higher loads from wind or wind-borne debris.

- ***Storm shelters/safe rooms*** are constructed to meet criteria set forth in FEMA 320, FEMA 361, or ICC 500[1]

The MAT's observations for the types of structures described above are presented in Sections 9.2 to 9.5. However, it is important that the public and possible users of storm shelters and safe rooms understand that the levels of protection provided by structures designed according to ICC 500 and FEMA guidance documents is notably more complete and safer than the level of protection provided by a building or structure in which part of the criteria set for the in those documents is implemented. Sections 9.1.1 and 9.1.2 provide observations from the field assessments to further define how these types of structures are different.

9.1.1 Hardened Areas: Areas Designed to Provide Some Protection

Some structures or portions of buildings observed by the MAT were designed and constructed to provide some level of protection, but did not meet the FEMA or ICC criteria; in some cases, this is because they were constructed prior to publication of the safe room guidance. These types of areas are often referred to as ***shelters*** by those who seek refuge in them. These ***hardened areas*** typically provide an improved level of protection for occupants from building or structural failure, but often do not follow FEMA or ICC design criteria. It is important to note that, beyond the basic ability to provide life-safety protection, hardened areas typically do not account for many of the other human factors addressed by ICC and FEMA criteria for storm shelters and safe rooms. Such factors include adequate space for occupants, ventilation, water, toilets, and other design elements to meet occupant needs.

Figure 9-1 shows a hardened room or "shelter" constructed in a residence in Tuscaloosa, AL, just weeks before the April 27, 2011 tornado. The home was directly in the path of the tornado as it moved through the Forrest Lake neighborhood of Tuscaloosa. This hardened room in the home did not collapse during the event, but the wooden door to its interior provided minimal protection from wind forces and wind-borne debris impacts. (The hardened room was not used during the tornado because the owners were not at home when the tornado struck Tuscaloosa.) Because the door did not meet the criteria from FEMA or ICC, the room should not be called a safe room or storm shelter because this component is not designed or tested to provide the same level of life-safety protection as the rest of the structure.

1 The 2008 versions of FEMA 320, FEMA 361, and ICC 500 are intended in this chapter unless another date is specified.

Figure 9-1:
A hardened room in a residential building in Tuscaloosa, AL

9.1.2 Storm Shelters and Safe Rooms: Areas Designed for Life-Safety Protection

Storm shelters are structures, buildings, or portions of buildings that have been designed and constructed to meet ICC 500 criteria and offer protection from extreme weather events, such as tornadoes and hurricanes. Storm shelters provide life-safety protection for their occupants. By contrast, a ***safe room*** is a hardened structure or area of a building that has been designed and constructed to provide near-absolute protection against both wind forces and the impacts from wind-borne debris, as defined in the FEMA safe room publications. In addition to providing life-safety protection from wind and wind-borne debris, structures built to the FEMA safe room criteria meet and exceed all of the design criteria in the ICC 500 and also consider other emergency management related performance criteria. Because of this, FEMA states that a safe room offers “near-absolute protection” in severe weather events, an even higher level of protection than that provided by storm shelters. Examples of a FEMA residential and community safe room are presented in Figures 9-2 and 9-3, respectively.

> *“**Near-absolute protection** means that, based on our [FEMA’s] current knowledge of tornadoes and hurricanes, the occupants of a safe room built according to this guidance [FEMA 361] will have a very high probability of being protected from injury or death.”*
>
> SOURCE: FEMA 361, PG. 1-2 (2008 EDITION)

While safe rooms and storm shelters can provide the same or different levels of protection, the FEMA criteria for near-absolute protection can provide a different (and higher) level of protection depending on the design criteria used. The level of occupant protection provided by a space specifically designed as a safe room is intended to be much greater than the protection provided by buildings that comply with the minimum requirements of building codes. With respect to the storm shelter criteria from the ICC, the FEMA safe room criteria provide the same or slightly higher level

Figure 9-2:
Above-ground residential safe room installed in a garage of a home in Joplin, MO, directly impacted by the tornado (rated EF4 based on the MAT's observations)

Figure 9-3:
These above-ground community safe rooms in Brookwood, AL, were used during the April 27 tornado outbreak, but were not directly impacted by a tornado

of protection than the criteria set forth in the ICC 500 and consequently, the FEMA criteria can be said to meet or exceed the design requirements of ICC 500 in all instances. The level of protection provided by a safe room or storm shelter is a function of the design wind speed, resulting wind pressure used in designing it, and wind-borne debris impact criteria.

- ***Storm shelters*** are designed and constructed in accordance with ICC 500 and offer greater protection than traditional buildings and homes because they have been designed to provide life-safety protection. However, they do not meet all the criteria of FEMA 320 and FEMA 361 and are not considered safe rooms.

> To date, NWS has not recorded any wind event exceeding the maximum design criteria provided in FEMA 320 and FEMA 361 (250 mph, 3-second gust, 33 feet above grade).

- ***Safe rooms*** are hardened structures that are specially designed and constructed in accordance with FEMA 320 and FEMA 361 guidelines. Safe rooms provide "near-absolute protection" in extreme weather events, including tornadoes and hurricanes. "Near-absolute protection" means that, based on our current knowledge of tornadoes and hurricanes, the occupants of a safe room will have a very high probability of being protected from injury or death per FEMA 320.

Safe rooms and storm shelters are typically interior rooms or spaces within a building, but they may also be entirely separate buildings or structures designed and constructed to protect their occupants from tornadoes or hurricanes. Safe rooms may be constructed above or below ground. Safe rooms and storm shelters can be used as dual-function rooms within a building or home, where the room may normally be used as a training room, hallway, or closet.

The fact that an engineering design standard (ICC 500) is referenced and heavily used as part of a much larger emergency management program shows FEMA's commitment to use voluntary consensus standards to the maximum extent possible in carrying out its programs. FEMA continues to educate designers, emergency management officials, property owners, and people in the community seeking to find protection from tornados on the benefits of FEMA 320, FEMA 361, and ICC 500 and how they complement one another.

When compared, the technical guidance for tornado hazards is essentially the same between ICC 500 and FEMA 361 for community storm shelters and safe rooms, but there are some differences when comparing criteria for hurricane hazards for wind, wind-borne debris, and flood design criteria. For residential applications, ICC 500 provides performance design criteria to be met. This allows for residential tornado and hurricane storm shelters to be designed for different wind speeds. In contrast, FEMA 320 guidance provides a prescriptive solution designed for the highest wind speed and wind-borne debris criteria shown on the tornado and hurricane hazard maps included in the ICC and FEMA documents. Further, the FEMA 320 criteria also specify the use of more stringent criteria than ICC 500. As a result, the prescriptive FEMA 320 safe room designs can be used for small community safe rooms, thereby expanding their applicability and usefulness.

In all cases, where differences exist, FEMA criteria are more stringent than the ICC 500 storm shelter criteria. Further, both the FEMA 320 and 361 documents provide important information about the planning, operation, and maintenance of a safe room while ICC 500 (an engineering standard) does not address those issues. Unfortunately, this does not diminish the reality that when the engineering design standard (ICC 500) and the FEMA technical guidance (FEMA 320 and FEMA 361) provide different levels of protection it may lead to some confusion for designers, emergency management officials, property owners, and people in the community seeking to find or provide life-safety protection from tornadoes.

9.2 Tornado Refuge Areas

The MAT was able to find only a few safe rooms and storm shelters along the more than 300 tornado tracks (or damage swaths) of the April 25–28, 2011 tornado events in the mid-south of the United States or in the May 22, 2011 Joplin, MO, tornado. This was surprising because it had been more than 10 years since FEMA began publishing technical guidance for the design and construction of safe rooms and storm shelters. Many people were forced to find any protection they could wherever they found themselves when the tornadoes struck.

> The NWS and local meteorologists should be credited for their ***forecasting success*** in providing important and useful storm information that allowed many people to take appropriate action to either find a safe room or move out of the path of the tornadoes before the event struck in their community.

Although some people taking refuge in areas of their homes in Alabama, Georgia, and Mississippi perished, the MAT believes the number of fatalities would have been significantly higher if these tornado refuge areas were occupied when the storms struck. The MAT observed many tornado refuge areas that had collapsed or filled with broken glass from windows shattered by wind-borne debris that would have been unsafe had they been occupied. However, for the tornado events of April 25–28, 2011 the NWS was able to provide long warning times and notifications. As a result, many people who would have taken refuge in an inappropriate place either found safer refuge or moved out of the path of the tornado.

The tornado that struck Joplin, MO on May 22, however, formed rapidly and descended on the city with little advanced warning. Numerous critical facilities, many commercial buildings, and thousands of homes were damaged by the tornado. There were fatalities in tornado refuge areas used during this event.

This section discusses the MAT's observations of buildings (or the areas of buildings) where people took refuge when no safe rooms, storm shelters, or hardened areas were available. The performance of the buildings in the direct path, or near the path, of strong or violent tornadoes was poor, as expected. Residential buildings are not designed to provide resistance to wind loads or consider only minimal wind loads in their design. Non-residential structures, while designed to consider some level of wind resistance, generally do not provide resistance to extreme wind loads. For more detailed discussions and observations related to building performance, see Chapters 4, 5, 6, and 7 of this report for residential buildings, commercial and industrial buildings, schools, and critical facilities, respectively.

9.2.1 Tornado Refuge Areas in Residences

The MAT was informed that many residents took refuge in their homes. This occurred for a number of reasons, including minimal warning time and the perception of their home being the safest location. In most cases, the homes did not have a safe room and there was no nearby community safe room or storm shelter. When such a place is not available within or near a home, homeowners are forced to take refuge in the best available spaces they can identify.

If homeowners cannot find shelter in a specifically designed safe room or storm shelter during a tornado, building occupants should take refuge either in the central areas of their homes or in the basements (if available). If no basement is available, the central area of the home is typically the portion most likely to survive tornado impacts and provides the best tornado refuge area in a home. This is evidenced by core remnants of residential buildings that survive tornado events. The performance of core remnants observed by the MAT is described in Section 9.2.1.1. The performance of basements is discussed in Section 9.2.1.2.

9.2.1.1 Core Remnants

In general, the basement is often the least vulnerable area during a tornado. However, if a house has no basement, the MAT's observations indicate that the best place for an individual to go in their home is the central or core areas of the home. Although the location of the core varies from home to home, areas with multiple wall intersections, stairways, or near bathrooms or kitchens are most often the building core. These portions of homes typically perform better than other areas when exposed to extreme winds from tornadoes; areas with multiple wall intersections provide additional strength to resist wind loads if the walls (and sometimes ceiling systems) are connected together.

Site-Built Housing: Based on the MAT's observations in all the impacted States, the cores of site-built homes provided the most redundant portions of the structure (see Chapter 4 for detailed discussions on residential building performance). Figures 9-4 and 9-5 illustrate this concept. Some residents in site-built homes in Crescent Ridge, AL, took refuge in the core areas of their homes and survived the tornado event, even when their homes were largely destroyed. Unfortunately, many of the core remnants observed by the MAT could not protect the occupants in this hard-hit community, which was one of the first areas to be impacted by the Macon County Supercell Thunderstorm (see Figure 2-2 in Chapter 2). This single tornado was associated with 61 reported fatalities across these two cities, 43 of which were in the Tuscaloosa area.[2] According to the FEMA JFO approximately one-third of the 43 people killed by this tornado were in Crescent Ridge. The NWS rated the center of the tornado circulation as EF4 in this portion of its track. The approximate centerline of the tornado damage swath is shown in Figure 9-4. This tornado struck both site-built and manufactured homes in the Cresent Ridge neighborhood, resulting in a significant loss of life.

Figure 9-6 shows another example of how a portion of a building may remain standing even after most of the building is destroyed by a violent tornado. No individuals took refuge in this home, but this core remnant survived the impact of the May 22, 2011 Joplin, MO, tornado. The NWS rated the center of the tornado circulation as EF4 in the vicinity of this building.

Manufactured Housing: Manufactured housing in Crescent Ridge, AL, did not withstand the tornado that struck the neighborhood. Damage in this neighborhood was ranked as EF4 by the MAT (see Appendix E for additional detail). Although the design and construction of manufactured housing improved greatly after HUD requirements were changed in 1994, manufactured housing is not constructed to survive a tornado event. The long, narrow dimension of the units and different means and methods of securing the units to foundations are a few of the factors that have contributed to overturning and other failures of manufactured home units. Figure 9-7 shows several manufactured homes in the Crescent Ridge, AL, area after the tornado. These homes were displaced off their foundations and also experienced significant damage to the units themselves. No core remnants remained.

2 NOAA's NWS SPC, Annual U.S. Killer Tornado Statistics, http://www.spc.noaa.gov/climo/torn/fataltorn.html.

Figure 9-4: Aerial view of tornado damage swath in Crescent Ridge, AL (approximate centerline of swath is indicated by red line).[3] Core remnants of homes shown in Figures 9-5 are identified with red arrows. The damaged manufactured homes in Figure 9-7 are identified with a yellow arrow.

SOURCE: ALL AERIAL PHOTOGRAPHS ARE FROM NOAA IMAGERY (HTTP://NGS.WOC.NOAA.GOV/STORMS) UNLESS OTHERWISE NOTED

Figure 9-5: Core remnants of homes sometimes survive a tornado as shown in this photograph of site-built homes where a closet (red arrow in left photograph) and a bathroom behind a kitchen (red arrow in right photograph) remained standing after the tornado (Crescent Ridge, AL)

3 The red line in this and all similar figures is intended to represent the center of the damage swath. The track location is approximated by the MAT based on post-event aerial photographs. The actual centerline of circulation is offset from the centerline of the damage.

Figure 9-6:
The core remnant of a home in Joplin, MO

Figure 9-7:
Manufactured homes destroyed in Crescent Ridge, AL (location shown in Figure 9-4)

9.2.1.2 Basement Areas

Basement areas typically provide better protection than above-ground areas because one or more walls (or a room within the basement) are below ground and will not be affected by wind forces or wind-borne debris. However, basements are vulnerable to damage from the collapse of the structure above unless the ceiling of the basement (or the floor above) is designed to provide protection if the house above collapses.

Figure 9-8 shows an interior basement storage room in a Tuscaloosa, AL, home. This unique home was re-constructed in the 1940s from two old cabins that had been re-located to the site. Placed atop a hillside, the masonry foundation supporting the cabins created a walkout basement. When the family constructed the basement, they set aside the storage room to be used during tornadoes. With heavy timber construction and one wall built into the hillside, this space offered some level of protection. Damage in the neighborhood of this home was ranked as EF2 by the MAT (see Appendix E for additional detail). Although not specifically designed for protection, the family

Figure 9-8:
Tornado refuge area in a Tuscaloosa, AL, basement

occupied the basement during the tornado, and the storage room provided the family a place to take cover when a tornado passed over their neighborhood.

The Pleasant Grove neighborhood outside Birmingham, AL, was directly struck by a tornado (Figure 9-9). The NWS rated the center of the tornado circulation as EF4 in this portion of its track. Many homes in this neighborhood were destroyed, resulting in several fatalities.[4] In several of the destroyed homes, residents sought refuge in their basements, but they were not always safe.

Figure 9-10 shows a home that had a heavily reinforced porch slab over a storage area in their basement; the slab was voluntarily constructed with reinforcing steel and with a slab depth thickness of 9 inches to provide protection during a tornado. The family sought refuge in the storage area under the front porch. The home was completely destroyed by the tornado, but the family survived in the portion of the walk-out basement where the reinforced concrete roof deck was placed.

4 NOAA's NWS SPC, Annual U.S. Killer Tornado Statistics, http://www.spc.noaa.gov/climo/torn/fataltorn.html.

Figure 9-9: Aerial view of the Pleasant Grove, AL, neighborhood.
NOTE: TRACK DAMAGE CENTERLINE IS NOT IN THE FRAME SHOWN HERE.

Figure 9-10:
A hardened porch slab over this basement helped to create a tornado refuge area that allowed this family to survive the tornado; location shown in Figure 9-9 (Birmingham, AL)

It is important to note, however, that not all basement areas should be considered "safe" during a tornado just because they are below ground. According to local residents, a few doors down from the home shown in Figure 9-10, a fatality occurred when people sought shelter in the basement and the concrete floor above collapsed into the basement space.

9.2.1.3 Tornado Refuge Areas in Multi-Family Buildings or Complexes

In multi-family residential situations, it is important to understand the limitations for potential tornado refuge areas. Figure 9-11 shows a new, multi-unit residential complex in Tuscaloosa, AL, after it was struck directly by a tornado as it tracked through the city. The NWS rated the center of the tornado circulation as EF4 in this portion of its track; its track is shown as tornado #46 on Figure 2-2. Most of the complex was destroyed. The inset photograph shows an interior bathroom in a first floor unit of the complex. Although areas like this are often used as tornado refuge areas, the damage to the space and the debris inside it illustrate the limitations of such refuge areas. Though the bathroom may have provided a place of refuge in this portion of the building that was badly damaged, but did not collapse, the space was not safe. The ceiling (floor structure for the upper floor) blew off, a piece of framed lumber was thrown into the bathroom, and an asphalt shingle (red arrow) penetrated the wall. It is important to note that other similarly constructed areas were completely destroyed by the tornado.

> ***Taking refuge does not guarantee safety or survival.*** While some refuge areas may survive a direct hit by a tornado, thereby protecting the occupants, other identical refuge areas may collapse and result in fatalities.

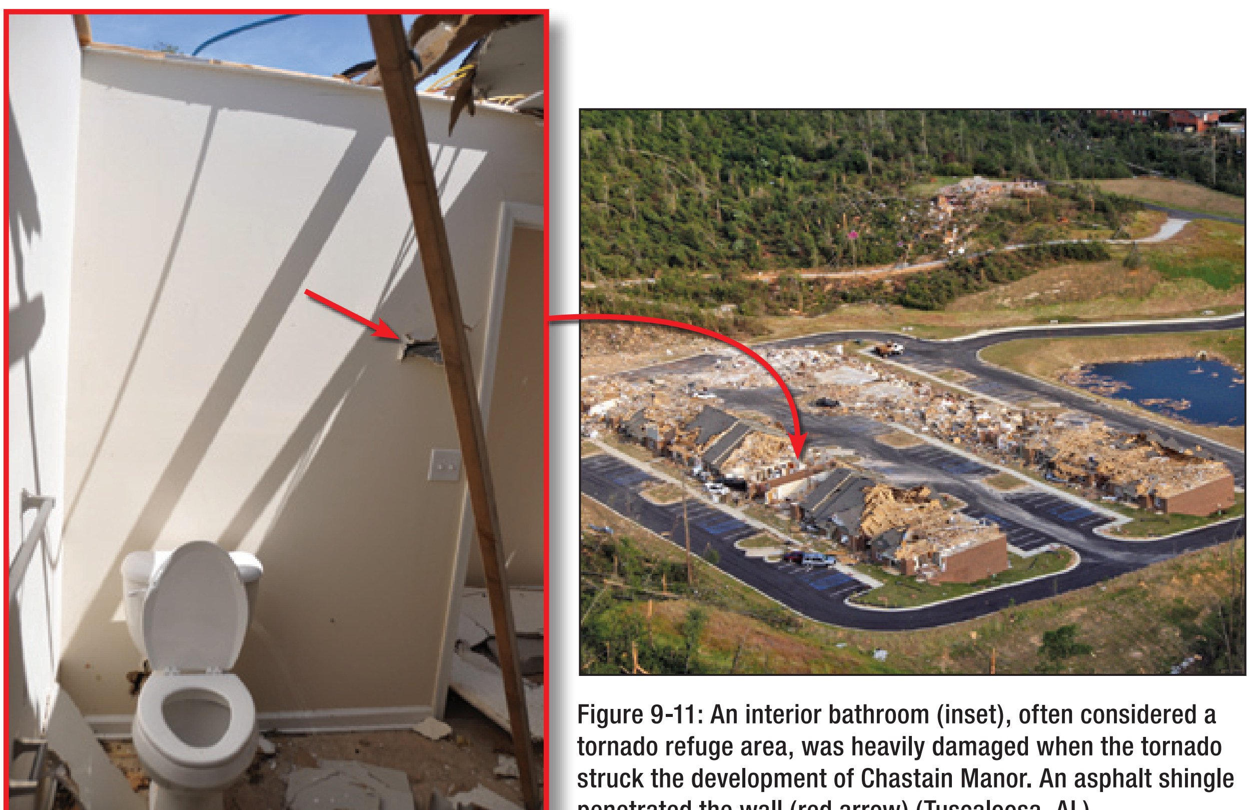

Figure 9-11: An interior bathroom (inset), often considered a tornado refuge area, was heavily damaged when the tornado struck the development of Chastain Manor. An asphalt shingle penetrated the wall (red arrow) (Tuscaloosa, AL).

9.2.2 Tornado Refuge in Commercial and Industrial Buildings: Planned Tornado Refuge Areas

The MAT visited a number of sites that had formally designed areas within their building for use during tornadoes. These areas performed no better than the typical commercial and industrial construction described in Chapter 5 of this report because they were not constructed to resist high wind loads. In all cases, the designated areas had been identified and were part of a formal plan, but the buildings (and designated areas for use during tornadoes) weren't designed or constructed to provide additional protection. Further, the MAT did not find any indication that these designated areas had been evaluated to understand and document their vulnerability to high winds and wind-borne debris impact.

In commercial and industrial buildings, post-disaster assessments by the MAT and NSF team following the April 25–28, 2011 and May 22, 2011 tornado events suggested that administrative officials or others involved in local planning often identified designated areas or tornado refuge areas without the guidance of a qualified architect or engineer. While it was clear that an effort was made to protect the occupants, many of these designated areas were not evaluated for their ability to provide resistance to or protection from wind and wind-borne debris and were vulnerable. These designated areas were located in:

- Large spaces, such as gymnasiums or auditoriums
- Areas near exterior windows and doors
- Areas surrounded by wall systems subject to collapse in high-wind events

Additionally, in some cases the designated areas had insufficient space for all of the building occupants or were in locations where it would be difficult to move occupants in a reasonable period of time.

> In the tornado-prone region of the United States, ***many schools have designated refuge for students and faculty during tornadoes***. Several of the schools visited by the MAT had designated refuge areas. The observations on the performance of tornado refuge areas in schools are presented in Chapter 6. An example of a school with a community safe room meeting the FEMA criteria is presented in Section 9.4.4.3.
>
> In addition to schools, other critical facilities often have designated areas for use during tornadoes. The observations on the performance of tornado refuge areas in other critical facilities are presented in Chapter 7.
>
> See also Recovery Advisories 5, 6, and 8 in Appendix F for additional information regarding refuge areas in schools and critical facilities.

9.2.2.1 Walmart (Joplin, MO)

Although not a public shelter or designated community tornado refuge area, a Walmart store in Joplin, MO, had a disaster plan that provided guidance on where to take refuge during a tornado. Over 200 people sought refuge inside the store during the May 22, 2011 tornado. The damage swath centerline of the tornado that devastated Joplin was located just a few hundred feet from the building (Figures 9-12 and 9-13). The NWS rated the center of the tornado circulation as EF4 in this portion of its track. Employees gathered everyone inside the store in break rooms, rest rooms, and

Figure 9-12: Walmart store in Joplin, MO

Figure 9-13:
Close-up view of the damage at the Walmart store in Joplin, MO

in the customer service desk area near the back of the store. Part of the store's tornado refuge area was constructed of reinforced CMU walls. Once the tornado struck, the front doors and roof were torn away from the building and part of the roof structure collapsed (see Section 5.2.5 for further discussion of the building). According to a local Walmart representative, there were three fatalities inside the store. The fatalities occurred near the center of the store, away from the reinforced exterior walls of the store.

9.2.2.2 Lowe's Home Improvement Store (Tuscaloosa, AL)

The Lowe's Home Improvement store in Tuscaloosa, AL (Figure 9-14), was a site where individuals who heard the tornado warning gathered to seek refuge. Although it was not impacted by a tornado, the MAT visited the site. The Lowe's store had an emergency response flipchart that clearly described the action to be taken by store employees during an emergency, including tornadoes (Figure 9-15). The tornado procedure included what to do for a tornado watch, tornado warning, response procedure, and post-tornado procedures.

Figure 9-14:
Lowe's Home Improvement building (Tuscaloosa, AL)

Figure 9-15:
Lowe's Emergency Response Flipchart (Tuscaloosa, AL)

The store manager had been advised of an updated procedure recently issued by Lowe's corporate officials after a tornado struck a Lowe's store in North Carolina just weeks before. The response plan originally called for customers inside the store to be moved to the center aisles of the building, away from exterior walls and windows. In the updated plan, employees were instructed to move everyone to the front of the store into areas with multiple walls defining the space. At this store location, the front of the store was identified in the updated response plan as the designated area for use during tornado events. These smaller rooms were identified in the hopes they would provide better protection for employees and patrons based on similar areas of the North Carolina store performing better during a tornado. This part of the store was primarily unreinforced CMU construction and drop ceiling. The MAT could not determine if this portion of the building had been assessed for use as a tornado refuge area or evaluated to be a best available refuge area.

Many existing buildings, both publicly and privately owned, do not have a safe room or storm shelter. Occupants in these buildings must either leave the building or take refuge in the best available tornado refuge area. The technical guidance in FEMA 361 recommends that ***all tornado refuge areas be evaluated by a design professional*** to identify the vulnerability of the refuge areas to high winds and wind-borne debris and to evaluate the residual risk associated with using these areas for tornado refuge. Additional information on this topic is presented in FEMA Recovery Advisories 2, 5, and 6 issued for this event (see Appendix F).

During the April 27, 2011 tornado event, the Lowe's store housed around 50 customers and residents from the surrounding area who came to the store seeking refuge, as well as employees at work at the time. The store manager moved everyone to the front area of the building and had the occupants congregate in the break rooms and meeting rooms. Power was lost for a short time during the storms, but auxiliary (generator) power turned on. Employees also had battery-powered flash lights to ensure they had enough light to see, as the storage rooms had no windows.

The Lowe's emergency response plan for responding to a tornado event appeared to have been well executed at this store, although the building was not struck or impacted directly by a tornado. The store manager put the response plan into action quickly and followed it to eliminate confusion among the work staff.

9.2.2.3 Home Depot (Joplin, MO)

The Home Depot in Joplin, MO, was struck by a direct hit from a very intense tornado on May 22, 2011 (Figure 9-16). The NWS rated the center of the tornado circulation as EF4 to EF5 in the vicinity of this building. Individuals in the area who heard the tornado warning attempted to seek refuge at this store. As discussed in Section 5.1.3 of this report, the roof of the store was torn off and the building's massive concrete tilt-up panels collapsed, resulting in seven fatalities in different locations in the store.

Employees listened to the weather radio and followed the standard emergency plan put in place by the company. As part of the emergency plan, all doors in the store were locked in an attempt to secure the building and reduce the risk of inflow of air, which could compromise the roof system of the building by causing uplift. There were two fatalities at the front of the store. People from the

Figure 9-16: Home Depot after the May 22, 2011 tornado (Joplin, MO)

surrounding area were trying to take refuge inside the building right up to the time the tornado struck it.

In accordance with the emergency plan, all shoppers and employees in the store were gathered in the employee lounge and training area at the back of the store. The MAT was unable to determine if this area was designated as a best available refuge area for use during tornadoes by a design professional or if a formal assessment of the tornado refuge area was conducted. The 28 people who took refuge in the training room survived the storm.

The area of the store where employees and shoppers congregated was constructed of metal stud framing and dry wall. This area was not a hardened structure and could have potentially been crushed had the tilt-up panels fallen on top of the room. Figure 9-17 shows a picture of the remaining structure around the training area. The wall composed of metal studs and drywall can be seen leaning inward (yellow arrow). The photograph also shows the tilt-up panels that collapsed outward beside this area (red arrow).

9.3 Hardened Structures, Rooms, and Areas Not Designed to Defined Criteria

This section discusses the MAT's observations of buildings where people took refuge in hardened structures or portions of buildings. In all cases, the buildings were designed to provide some level of hardening, but the MAT was unable to obtain details of the design wind speed used, the debris impact criteria used, or if any operational or emergency management plans were included

Figure 9-17:
Tornado refuge area (training room) of the Home Depot. Note the collapsed tilt-up wall (red arrow) and the wall leaning into the refuge area (yellow arrow) (Joplin, MO).

in the design process. Further, the MAT noted one or more deficiencies in all of the hardened areas described in this section that prevented them from being categorized as safe rooms or storm shelters. The most common deficiency observed was with door assemblies; specifically, the doors were not capable of withstanding wind forces and wind-borne debris associated with tornadoes. When such doors fail (as occurred in several cases), the occupants are exposed to the tornado and are not as protected as originally intended.

The Wind Science and Engineering Research Center at TTU is one entity that performs ***testing on doors*** for use in tornado safe rooms and storm shelters. For more information on doors and door hardware that has passed the debris impact test, see http://www.depts.ttu.edu/weweb.

Many people interviewed by the MAT had the perception that the only safe place to be during a tornado was in a below-ground structure. Although below-ground shelters have afforded their occupants reasonable protection from violent storms for centuries, this is not accurate, and above-ground safe rooms and storm shelters can also provide life-safety protection when designed and constructed properly. However, for either type of structure or room to protect occupants, all exposed portions must resist debris impacts, and the structures or rooms must have robust doors and locking systems that are easily operated in a high-wind environment. This means any door system used must be tested for wind and debris impact-resistance, or prescriptive solutions that have been shown to pass the FEMA and ICC 500 criteria must be used. The specifications for a prescriptive solution to constructing debris impact-resistant doors are presented in FEMA 320. The solution specifies using three hinges and three points of latching, though variations on the number of hinges attaching doors is becoming more common as more products are tested to the ICC criteria.

The advantage of above-ground hardened structures and rooms is that they are more accessible to young, old, and handicapped people than below-ground structures. The complete exterior of the safe room or storm shelter (including the door assembly) must be designed to resist the violent wind pressures as well as the debris impacts associated with high-wind events. Doors on above-ground structures used for occupant protection are particularly vulnerable and must resist debris with minimal damage after impact (see Chapter 8 of ICC 500). The MAT observed dozens of below-ground and above-ground "shelters" and hardened structures in Alabama and Mississippi. In Joplin, MO, only above-ground structures and rooms were observed. The MAT speculates that this is because of the existence of old mining tunnels under portions of the City of Joplin, but there may be other reasons below-ground structures were not observed. Research into why a certain type of structure was selected for protection is beyond the scope of the MAT.

There are several sources for ***information on securing safe room and storm shelter doors.*** FEMA 320 provides a prescriptive design for door construction (with hinges and latching systems) that can resist wind and wind-borne debris associated with tornadoes. This solution meets the testing requirement of the ICC 500 for residential safe rooms.

Although three hinges and three latching mechanisms are no longer required per the ICC 500, most doors and systems that have passed the debris impact and wind pressure tests have multiple (or continuous) hinges and multiple latches. As of this publication, no single dead bolt acting as the lone closure mechanism has passed the ICC 500 tests for wind and wind-borne debris resistance.

9.3.1 Hardened Structures for Residential Use

The structures presented in the following sections did not meet the FEMA or ICC criteria for safe rooms or storm shelters. Although these structures provided some protection, the occupants were at risk due to the poor construction of the door assemblies or door latching systems.

9.3.1.1 Below-Ground Applications

Although constructed of a hardened concrete shell, the "shelter" shown in Figure 9-18 was protected by plywood doors clad with light steel, a single point locking system, and a vent system that was vulnerable to impacts. It is unknown how many occupants using this structure survived, but the adjacent home was destroyed when the tornado passed over Smithville, MS. Although the Smithville tornado was rated higher at different locations along its track (see Section 2.5.1.7 of this report), the MAT derived the tornado rating as EF2 at this location based on damage to this building.

The Hackleburg, AL, below-ground structure shown in Figure 9-19 seemed to be relatively new. The MAT was unable to determine how many sought refuge here, but there was evidence in the shelter that it was used. Damage in the neighborhood of this home was ranked as EF3 by the MAT (see Appendix E for additional detail). Though the structure was mostly underground and had a reinforced concrete roof structure, the door was constructed of wood planks and locked with a chain held by bent nails. This type of door and method of connection is inadequate to resist wind loads and wind-borne debris; occupants who took refuge here were still at risk because of the low quality and characteristics of this door assembly.

Figure 9-18: Underground shelter that survived a tornado (rated EF2 based on the MAT's observations). Inset shows the location of shelter (Smithville, MS).

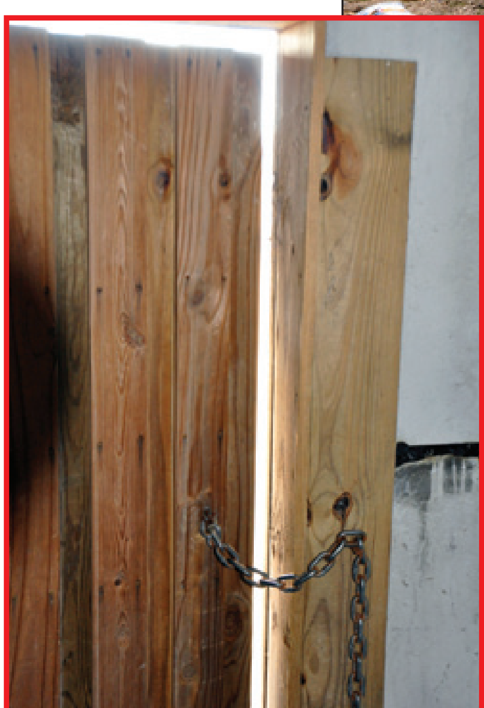

Figure 9-19: Below-ground hardened structure used for tornado refuge; door and closure system are shown in the inset (rated an EF3 based on the MAT's observations) (Hackleburg, AL)

9.3.1.2 Above-Ground Applications

A husband and wife took shelter is their above-ground concrete shelter in Smithville, MS, shown in Figure 9-20. Although the small town of Smithville was devastated by a tornado that reached EF4 intensity in places along its track, this home was on the periphery of the vortex and suffered little damage. The clam-shell concrete structure was anchored to the ground with steel bands and earth anchors. Although the concrete walls were sufficiently thick at 6½ inches, the door system was untested, and the locking system could open when impacted by debris or subjected to high wind pressures. The door locking mechanism used three points of connection on the non-hinge side of the door (as suggested in FEMA 320), but the three individual mechanisms used to keep the door in the closed position were not identified as having been tested to the FEMA or ICC debris impact resistance criteria. Because these latching mechanism were light weight and the door did not appear to be reinforced around the latch points, the door was vulnerable to being forced open from wind or wind-borne debris. Further, this structure did not appear to be anchored to resist wind loads (other than the grounding force resulting from its dead weight).

The MAT observed another example of an above-ground "shelter" in Athens, AL (Figure 9-21). A family survived the tornado in a hardened room they had constructed within a shop building east of their home. The hardened room (approximately 8 feet tall, and 6 feet by 9 feet in plan) was constructed with a reinforced CMU wall structure and concrete roof deck. The shop building was totally destroyed by the tornado, as was most of their home. The NWS rated the center of the

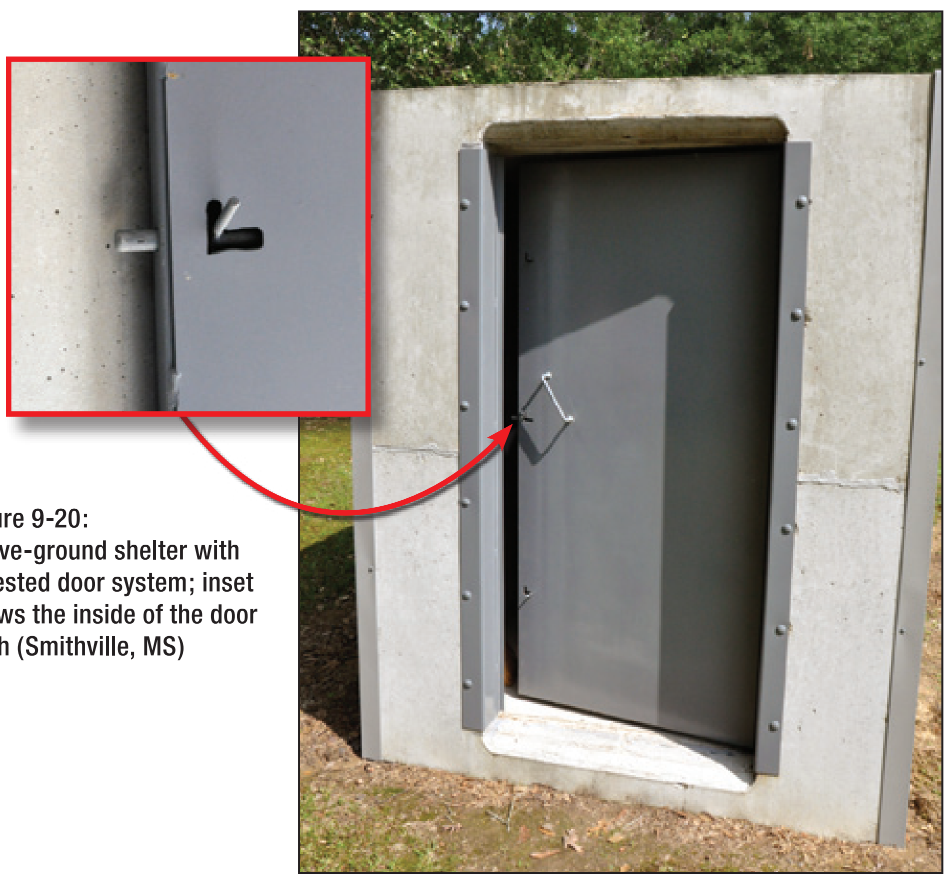

Figure 9-20:
Above-ground shelter with untested door system; inset shows the inside of the door latch (Smithville, MS)

Figure 9-21:
A family shelter with a single deadbolt (Athens, AL)

tornado circulation in the vicinity of this building as EF3. The design of the structure was consistent with the FEMA 320 guidelines with the exception of the door assembly. The door and latching mechanism was not a tested assembly and had only one deadbolt; at the time of this publication, no door latch configuration with one bolt has passed the ICC 500 or the FEMA 361 debris impacting testing criteria.

Although this room successfully provided safe refuge for the family, they were still at risk from high winds and wind-borne debris because of the door system used. The performance of this structure may not have been successful if the door had been impacted by wind-borne debris that caused the door system to fail. Occupants are often unaware of residual risks that remain in these otherwise robustly constructed structures and rooms when structures intended to provide protection from tornadoes are not constructed to the FEMA or ICC criteria.

9.3.2 Hardened Structures Used as Community Tornado Refuge Areas

The MAT observed several hardened structures used by communities as tornado refuge areas. The hardened structures presented in this section did not meet the FEMA or ICC criteria for safe rooms or storm shelters. Although these structures provided some protection, the occupants were at risk because of the poor construction of the door assemblies or door latching systems. Unless otherwise noted, the MAT was not able to verify if these hardened structures had been evaluated by design professionals for vulnerabilities to high winds or use as tornado refuge areas.

9.3.2.1 Above-Ground Applications

The Town of Amory, MS, was directly struck by the tornadoes of April 25–28, 2011, but its sirens were sounded by their 911 facility and many took refuge in the concrete above-ground structures shown in Figure 9-22. These structures were not in the damage swath of the tornado that struck Amory. It is unknown how many residents occupied these structures during the several days when tornado watches were in effect. Each unit is 13 feet x 13 feet wide and 7.5 feet tall. Although conduit and switch receptacles for lighting were present in the concrete structures when the MAT visited, no wiring or fixtures had been installed. The doors were hollow metal commercial grade with three deadbolts, but it is unknown if they were FEMA-compliant and tested door assemblies. Although the intended use of these structures was clear, the MAT could not verify the design criteria used for these structures and if they were evaluated to any standards or guidelines for tornado protection.

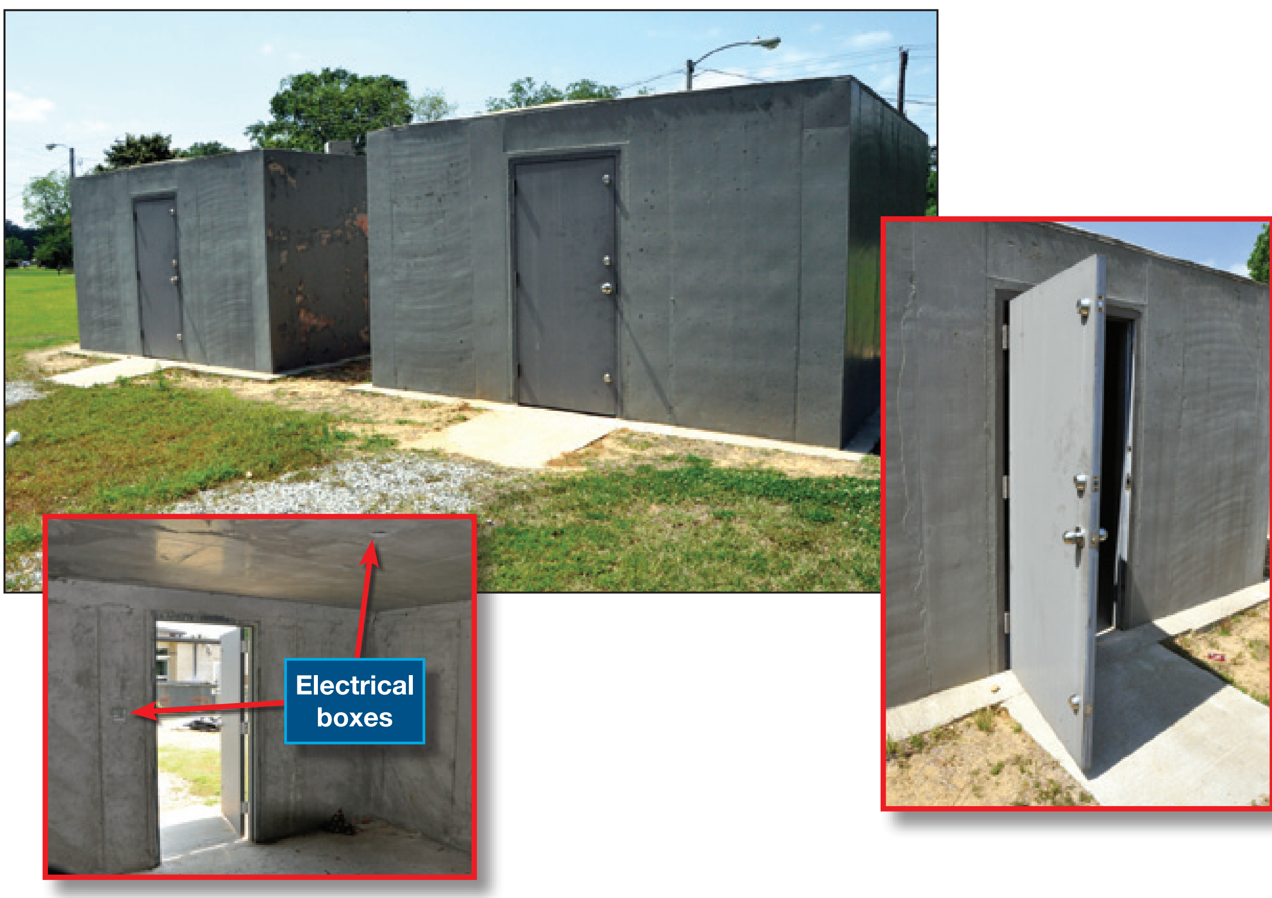

Figure 9-22: Above-ground hardened structures used as community tornado refuge areas. Insets show electrical boxes ready for wiring and fixtures (left) and door assemblies (right) (Amory, MS).

9.3.2.2 Below-Ground Applications

In Smithville, MS, a hardened, underground structure (Figure 9-23) was designated as the "community shelter" to be used during tornadoes. The structure reportedly held 10 individuals during the April 27, 2011 tornado event, rated EF3 by the NWS. Although the structure was robust and constructed from reinforced concrete, the doors were inadequate and did not provide the appropriate level of protection. The doors were constructed of two layers of plywood with a thin sheet steel cladding and only one locking point. This structure also had only one vent for fresh air; the vent was damaged by debris during the storm.

Figure 9-23: Below-ground, hardened structure with poor door and locking system (inset on lower left) and damaged vent (upper inset) (Smithville, MS)

9.4 Safe Rooms and Storm Shelters

The MAT observed safe rooms that were compliant with FEMA 320 and FEMA 361 criteria and storm shelters that were compliant with ICC 500 criteria in Alabama and Joplin, MO. Refer to Section 1.2 for a detailed description of the differences between safe rooms and storm shelters.

Safe rooms and storm shelters can be above-ground or below-ground. They can also be site-built or prefabricated structures. The MAT observed all of these types of safe rooms during the field assessments after the April 25–28, 2011 and May 22, 2011 tornadoes.

9.4.1 Above- and Below-Ground Alternatives

There are two general types of safe rooms and storm shelters: above-ground and below-ground. Both types were observed during the field observations. Both above-ground and below-ground safe rooms and storm shelters can be stand-alone structures away from the home or building, or they can be rooms or areas in the home, such as a bedroom, a bathroom, or a closet. Wherever it is located, it is specially designed to provide life-safety protection for the people who live in the house or building. Above-ground safe rooms are particularly desirable for those who have a disability or difficulty climbing down into a below-ground area.

Figure 9-24 shows an above-ground safe room that was added to the exterior of an existing home in Tuscaloosa, AL. This home was not in the path of the tornado that struck Tuscaloosa, but the safe room was used by the resident during the storms. The safe room was placed at-grade on the back porch of the home and matched the existing siding and aesthetics of the home. This particular design was chosen because the homeowner's mother had limited mobility and would not be able to access a below-ground safe room in the event of an emergency. This safe room was constructed with FEMA funds.

Figure 9-25 shows an above-ground community storm shelter in Graysville, AL. The structure is adjacent to a church and available for residents of the surrounding area to use in the event of a tornado.

Figure 9-24: Above-ground safe room that matches the aesthetics of the home (outside Tuscaloosa, AL)

Figure 9-25:
Above-ground community storm shelter (Graysville, AL)

A common safe room design is a stand-alone residential safe room installed below the ground surface outside a house or building. Small stand-alone safe rooms can be constructed to accommodate the occupants of one house, a few houses, or a small apartment building. Building a stand-alone safe room underground can be desirable because it does not take up any additional space within the home or building, and the grade of the surrounding land may lend itself favorably to this design. Figure 9-26 is an example of a below-ground safe room built into the side slope of the back yard of a home in Tuscaloosa, AL. This safe room, constructed in 2008 and funded in part through FEMA grant programs, was placed about 20 feet away from the home and could be reached quickly during a storm. This particular model is large enough to accommodate 10 people comfortably. It is a prefabricated unit, and the door and portions of the safe room that are above ground were tested to show compliance with FEMA 320 criteria. This safe room was occupied during the April 25–28, 2011 tornado outbreak, but this site was not struck by a tornado.

Figure 9-26:
Below-ground FEMA-funded residential safe room (Tuscaloosa, AL)

9.4.2 Prefabricated versus Site-Built Alternatives

Safe rooms and storm shelters can be prefabricated or site-built, depending on the needs of the owner and the specific site limitations. If constructed correctly to FEMA or ICC criteria, both types can provide life-safety protection. Safe rooms built within existing homes or as part of new construction projects tend to be site-built because there is usually limited access to position a prefabricated safe room or storm shelter. Figure 9-27 is an example of a residential site-built safe room constructed in the master bedroom closet of an existing home in Tuscaloosa, AL, using one of the designs presented in FEMA 320. The above-ground, wood-frame safe room with steel sheathing was used (see Drawing No. AG-06, sheet 11 of 18 [FEMA 1999b]). This safe room was constructed in 2002, funded in part through FEMA grant programs. The safe room was completely contained by the existing structure and very well concealed. The residents of this home used the safe room during the April 25–28, 2011 tornado outbreak, but this site was not struck by a tornado.

The MAT observed many configurations of both above- and below-ground prefabricated safe rooms used during the April 25–28, 2011 and May 22, 2011 tornado outbreaks. Several examples of prefabricated safe rooms (with space for 3 to 12 occupants) are discussed in Sections 9.4.3 and 9.4.4.

Figure 9-27:
Site-built FEMA-funded residential safe room (Tuscaloosa, AL)

9.4.3 Residential Safe Rooms and Storm Shelters

Many residential safe rooms were successfully used during the April 25–28, 2011 and May 22, 2011 tornado outbreaks. All but one of the safe rooms observed were prefabricated units. Homeowners told the MAT they had chosen to install a prefabricated safe room because of the speed of installation and lower cost of the structure. When the safe rooms were constructed as in-home- and garage-installed safe rooms, these alternative locations provided the occupants the most protected access during the tornadoes as they were not required to go outdoors.

9.4.3.1 Below-Ground Applications

In Tuscaloosa, AL, four people survived an EF2 tornado (as rated by the NWS) in the below-ground FEMA-funded safe room shown in Figure 9-28. The grab bar to the right of the safe room was bent by a fallen tree that trapped the family in the safe room until a neighbor cut the tree away from the door. This safe room was installed in 2001 and complies with the FEMA 320 criteria for residential safe rooms in place at the time.

The concrete below-ground safe room shown in Figure 9-29 was in a rural area outside of Smithville, MS, and provided shelter for the occupants of a manufactured home. On April 27, 2011 the homeowner and nine other family members and neighbors, as well as one dog and two cats, took shelter in this FEMA-funded safe room. The shelter had a tested door assembly. Though the area was not struck by the storm, the occupants were comforted and protected by their safe room.

The MAT observed the below-ground garage storm shelter shown in Figure 9-30 in Huntsville, AL. This area of Huntsville was placed under two separate tornado warnings on April 27. The homeowner and his wife retreated to their storm shelter on both occasions. This house was not ultimately affected by the tornadoes, though it sustained damage when a tree fell on it as a result of the strong winds from the storm. Though not a FEMA-funded safe room, the shelter is ICC 500-compliant and

Figure 9-28: Below-ground FEMA-funded residential safe room (Tuscaloosa, AL)

Figure 9-29:
FEMA-funded residential safe room (Smithville, MS)

Figure 9-30:
Below-ground garage shelter (Huntsville, AL)

manufactured by a member of the NSSA. The homeowner, not being an Alabama native, said that he feared “the infamous tornadoes of the southeast” and was intent on having a shelter. He reported that he felt very safe in his new storm shelter.

9.4.3.2 Above-Ground Applications

In the Village of Providence in Huntsville, AL, the MAT found the small and unique above-ground storm shelter shown in Figure 9-31. The shelter was not funded by FEMA, but was ICC 500-compliant and was constructed and installed by an NSSA member company. A husband and wife sought shelter here during both tornado warnings issued on April 27, 2011 for the Huntsville area.

Amidst the massive destruction of the violent tornado that struck Joplin, MO, on May 22, 2011 the MAT discovered the safe room shown in Figure 9-32; its location is shown in Figure 9-33. A family of two walked out of their safe room, only to find their home and their neighborhood totally destroyed. The safe room was anchored to the concrete slab where the garage once stood. The safe room door was locked with multiple locking points and used four hinges. This shelter design was tested at TTU. Installed with no FEMA or Federal funding assistance, the safe room effectively protected the occupants during the historic May 22, 2011 Joplin, MO, EF4 tornado event.

Figure 9-31:
ICC 500-compliant storm shelter (Huntsville, AL)

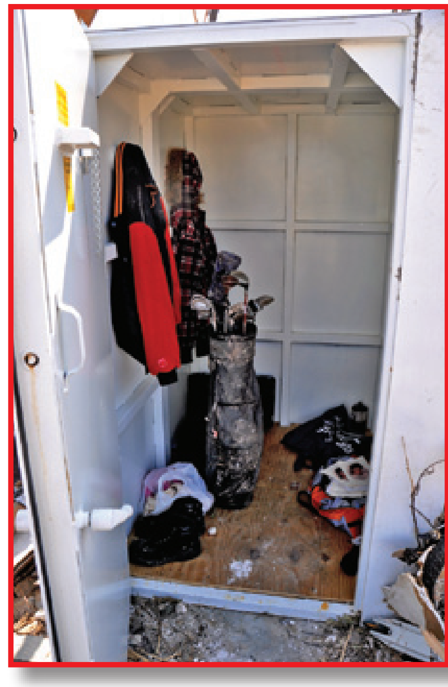

Figure 9-32:
Residential safe room that survived the May 22, 2011 Joplin, MO, tornado (rated EF4 based on the MAT's observations). The upper inset shows the inside of the safe room.

Figure 9-33: Proximity of the residential safe room shown in Figure 9-32 (circled in yellow in the inset) to the approximate centerline of the Joplin, MO, tornado damage swath (red line). The safe room was located 0.5 mile west of the heavily damaged St. John's Medical Center (shown by yellow box and described in Section 7.1.4.)

TTU assisted the manufacturer of the in-residence safe room shown in Figure 9-34 in researching and developing its design and performed all the debris impact testing to meet the residential safe room criteria set forth in FEMA 320 and FEMA 361. The home and its safe room were on the periphery of the violent May 22, 2011 Joplin, MO, tornado. The NWS rated the center of the tornado circulation in the vicinity of this home as EF2. The roof structure of the home was lifted up and glazing damage occurred.

9.4.4 Non-Residential and Community Safe Rooms

Similar to residential safe rooms, the MAT observed both site-built and prefabricated non-residential safe rooms. However, for community safe rooms, the prefabricated safe rooms observed all had a maximum occupancy of 100 to 150 people (but often fewer). Larger community safe rooms are typically site-built structures. Steel panels were the predominant materials used in the prefabricated community safe rooms observed by the MAT, while reinforced concrete and reinforced masonry were the predominant materials used in the site-built community safe rooms.

Figure 9-34:
Residential safe room
(Joplin, MO)

9.4.4.1 Brookwood and Phil Campbell Community Safe Rooms (AL)

The MAT visited three community safe rooms in Alabama. The two above-ground safe rooms were prefabricated structures, while the one below-ground safe room was site-built with reinforced concrete. Although none of these safe rooms was directly hit by a tornado, they each provided safety and comfort to their occupants during the April 25–28, 2011 tornado outbreak.

Brookwood, AL

In 2007, in response to past tornado activity in the town, the Town of Brookwood installed an above-ground safe room in its Town Park. Figure 9-35 shows the safe room, which is also promoted on the town Web site. The safe room was used by members of the community for most of the day on April 27, 2011. 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. Power in the town was lost several times during the day, but the safe room was supported by a generator (protected from wind-borne debris by a steel structure) that functioned properly and provided electricity to the safe room. The Brookwood safe room had a restroom for occupant comfort.

Figure 9-35:
Community safe room with exterior and interior locking mechanism; inset shows the three-point interior locking system (Brookwood, AL)

Phil Campbell, AL

The community of Phil Campbell, AL, was struck by a violent tornado on April 27, 2011. The NWS rated the center of the tornado circulation for this tornado as EF4. Hundreds of homes were damaged or destroyed, and 27 lives were lost according to a local representative. On top of a hill, away from most of the devastation, was Phil Campbell's FEMA-funded community safe room (Figure 9-36), which housed 60 residents on the day of the storm. The safe room door and panel system was tested in the Debris Impact Test Facility at TTU and meets FEMA 361 debris impact guidelines. The safe room and door is heavy gauge steel and the shelter is partially buried into the hill. An emergency generator (located in the box outside the door of the safe room) supplies electricity for lighting and the mechanical ventilation system. The generator is protected by an impact-resistant enclosure, and the ventilation system is protected from debris impacts with heavy steel shrouds. Figure 9-37 shows the inside of the safe room and the seating arrangement.

The temporary communications tower shown in Figure 9-36 was installed after the tornadoes struck the town. The tower should not be connected to the safe room because the structure was not designed to provide foundation support for guy wires for a communications tower.

Figure 9-36: FEMA-funded community safe room; guy wires for the temporary communications tower should not be attached to the structure (Phil Campbell, AL)

Figure 9-37: Interior of the community safe room shown in Figure 9-36 featuring seating, emergency lighting (green arrows), and ventilation (red arrows); inset is a close-up of the entrance door (Phil Campbell, AL)

9.4.4.2 Brookside Fire Station and Community Safe Room (Brookside, AL)

The MAT visited a below-ground community safe room constructed beneath the Brookside Fire Station in Brookside, AL (Figures 9-38 and 9-39). The safe room was known throughout the community to be at this location and was used by approximately 150 individuals during the April 25–28, 2011 tornado outbreak. Although the town was not struck by a tornado that day, many of the occupants reportedly drove over 5 miles to get to the safe room after watching the day's events unfold on television.

Figure 9-38:
A large site-built, below-grade community safe room is housed below this fire station; the red arrow indicates an unprotected generator (Brookside, AL)

Figure 9-39:
Interior view of the well-furnished community safe room shown in Figure 9-38 (Brookside, AL)

The safe room was constructed in 2008 and funded in part through FEMA grant programs. The fire station and other municipal functions were relocated to this site because of repetitive flooding of the town buildings. The safe room was designed during the fire station design process and is part of the building. It is constructed below grade from reinforced concrete walls with a pre-cast concrete roof deck. The roof deck is the floor system for the fire station offices and dispatch area located above in a non-hardened structure.

There are two entrances to the safe room, one of which has a lift so disabled occupants can access it. The structure can shelter over 300 occupants. The safe room has tools, equipment, bedding, and other support elements in adequate supply for the safe room occupants. Although an emergency generator is on site for backup power, it is not protected from wind-borne debris (red arrow in Figure 9-38). Figure 9-39 shows the interior of the safe room.

9.4.4.3 Seneca Intermediate School (Seneca, MO)

After suffering damage from a tornado in May of 2008, the City of Seneca, MO, built a new Intermediate School (Figure 9-40). Using FEMA HMGP funding, the school designed the cafetorium and gymnasium as a FEMA 361 community safe room (Figures 9-41 and 9-42). This safe room was also constructed to comply with the new ICC 500 storm shelter standard; it was the only safe room visited by the MAT designed to both criteria.

Figure 9-40:
Seneca Intermediate School (Seneca, MO)

Though the community of Seneca, MO, was not hit by a tornado on May 22, 2011 the MAT inspected this new community safe room as a case study of good community safe room construction:

- ■+ The walls are constructed from pre-cast, insulated concrete panels and the roof structure is constructed from precast concrete double tee's (Figure 9-42)
- ■+ All doors are tested FEMA 361 assemblies (Figure 9-43) and the louvers above doors are protected by alcove entries (Figure 9-44)

- Elevated ventilation units are protected on the outside wall with heavy steel shrouds (Figure 9-45)

- The generator building was similarly constructed with heavy wall and roof construction, tested doors, and steel shrouds over ventilation openings (Figure 9-46)

Figure 9-41: Seneca Intermediate School safe room in the cafetorium

Figure 9-42: Seneca Intermediate School gymnasium safe room

Figure 9-43:
Doors and ventilation louvers in Seneca Intermediate School community safe room

Figure 9-44:
Outside doors and louvers (red arrow) protected by alcoves at the Seneca Intermediate School community safe room

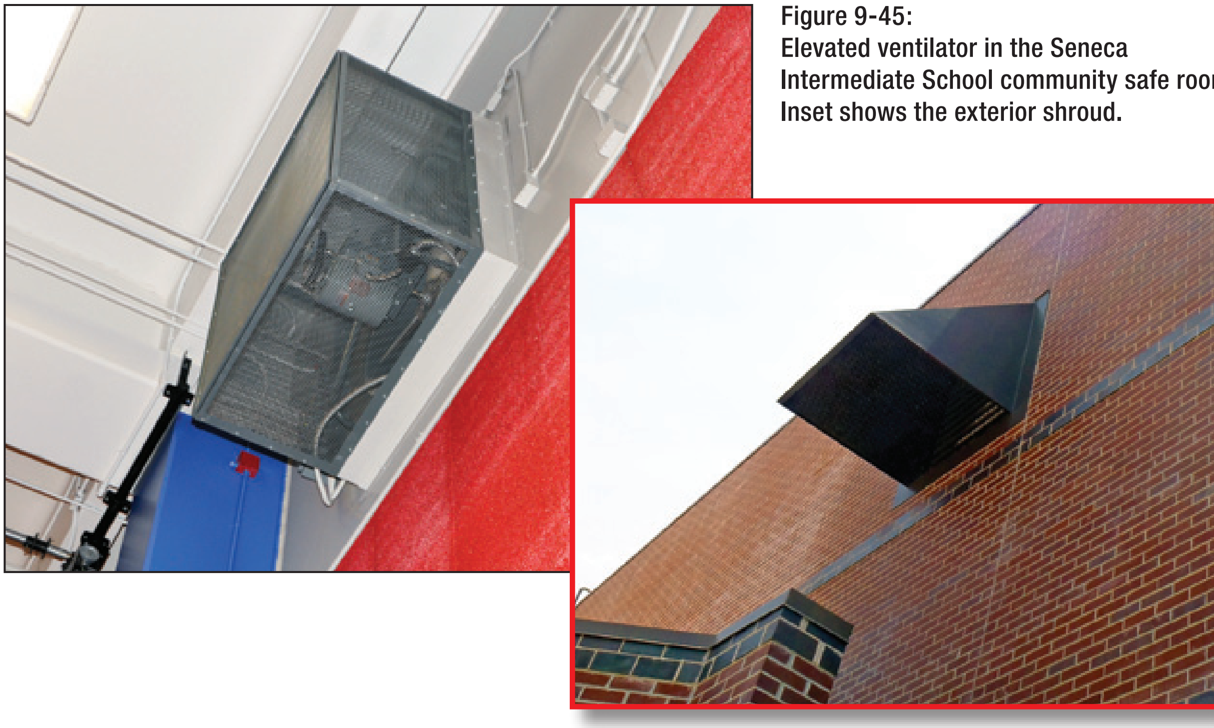

Figure 9-45:
Elevated ventilator in the Seneca Intermediate School community safe room. Inset shows the exterior shroud.

Figure 9-46:
Emergency generator building for the community safe room at the Seneca Intermediate School

9.5 Travel Time to Community Safe Rooms, Storm Shelters, and Tornado Refuge Areas

To better understand the time and distances that people traveled to these safe rooms, shelters and places of tornado refuge during the storms, the MAT interviewed the owners, operators, and some users of community safe rooms, storm shelters, and other areas used to take refuge from tornadoes (including both hardened structures and best available tornado refuge areas). The MAT interviewed staff at schools and commercial businesses, as well as community safe room operators. This effort was intended to collect data and possible gaps in knowledge that experts in social sciences or behavior analysis may find useful in researching travel time issues and people's considerations when deciding whether to seek shelter or remain in place.

At the time of publication of this report, FEMA technical and policy guidance on safe rooms states:[5] "The distance from the safe room for the at-risk population is based on a maximum walking travel time of 5 minutes or a maximum driving travel distance of approximately 0.5 mile… whether walking or driving, prospective safe room occupants must be able to safely reach the facility within 5 minutes of receiving a tornado warning or notice to seek shelter."

This guidance was observed to have been followed at most schools in Mississippi, Alabama, and Missouri visited by the MAT that had safe rooms and best available tornado refuge areas. For all schools discussed in Chapter 6, the tornado refuge areas could be reached by the facility, staff, and students within 5 minutes, and the distances to the safe rooms were ½ mile or less.

The MAT visited several commercial businesses in the tornado warning areas and along the paths of the April 25–28, 2011 tornadoes in Tuscaloosa and Birmingham, AL. Staff at the Hobby Lobby, Lowe's Home Improvement, and Home Depot stores in Tuscaloosa said that, to the best of their knowledge, the people who took refuge within their facility during the event were either inside or near the store when they decided to take refuge in the buildings. This finding is consistent with the MAT's discussions with Joplin, MO, business owners and employees after the May 22, 2011 tornado.

Unlike staff of schools and commercial businesses who reported receiving occupants from areas immediately adjacent to their facility, operators of community safe rooms, storm shelters, and tornado refuge areas outside the larger cities reported that many individuals traveled longer distances to seek refuge from the tornadoes. The operators of community safe rooms in Brookside, Brookwood, and Phil Campbell, AL, indicated that occupants reported travelling "miles" and that some had driven to the safe room seeking refuge; no log was kept to record where occupants came from. The operators of hardened structures used during the event in Smithville, MO, and Armory, AL, reported similar information.

While none of the MAT's findings are conclusive about the risk and vulnerability accepted by individuals that travel to a safe room, storm shelter, or best available tornado refuge area (hardened or not), the variation in the travel patterns and the behaviors reported were not unexpected. However, the MAT is concerned that not all of the observed behavior was the safest reaction to an impending tornado event; specifically, more study is needed to quantify (if possible) how many people drove to

5 HMA Unified Guidance, Part IX, Section C.4.1.2, page 111, http://www.fema.gov/library/viewRecord.do?id=4225.

a safe room or best available tornado refuge area. Further study is also needed to understand what risks people took, both knowingly and unknowingly, for themselves and their families when they decided to travel great distances within a warning area or along/across a tornado's path, instead of sheltering in place when they became aware of the tornado threat.

9.6 Compliance Issues with FEMA 320, FEMA 361, and the ICC 500

The MAT observed a number of well-constructed shelters and safe rooms constructed to FEMA criteria, but only one that was also stated to be constructed to the ICC 500 standard. They also observed a number of safe rooms with compliance issues. In some cases, the safe room was compliant except for a minor element; unfortunately, even a small deviation from the criteria can endanger occupant lives. Consequently, many of the shelters and hardened structures the MAT observed were selected for presentation in this chapter to demonstrate that these structures could be brought into compliance with the FEMA and ICC criteria with only slight modifications.

Note that all the hardened structures the MAT observed were constructed to either the FEMA 320 and FEMA 361 criteria or to unidentified or unknown criteria. The MAT identified only one storm shelter designed to be compliant with the ICC 500 standard; this was the Seneca Intermediate School community safe room in Missouri, which was designed specifically to meet both the FEMA and the ICC criteria (see Section 9.4.4.3). However, as the FEMA and ICC 500 criteria are very similar (and essentially identical for wind and wind-borne debris protection in tornado-prone areas), compliance issues identified in this section are evaluated based on both sets of criteria.

The following section describes ICC 500 and FEMA safe room and storm shelter design and construction elements that were not followed in at least one facility observed by the MAT. The description of each element is followed by a summary of the specific MAT observations related to that element. This information is provided because people may be at risk during a tornado event and unaware of their vulnerability.

9.6.1 Identifying Design Criteria Used for Safe Rooms and Storm Shelters

Compliance Criteria: Wind pressure design criteria are given by different guides, codes, and standards. The wind pressure criteria specify how strong the safe room must be. The design wind speed is the primary factor in determining the magnitude of wind pressure a building is designed to withstand. FEMA's safe room publications and ICC 500 use the same wind speed hazard maps to recommend design wind speeds ranging from 130 to 255 mph, depending on location. The only exception to this is for residential tornado safe rooms as described in FEMA 361, which requires that residential safe rooms be constructed to resist 250 mph wind speeds. The designs presented in FEMA 320 were designed for the most severe wind and debris condition, those associated with a 250-mph wind speed. Therefore, a safe room designed to the FEMA criteria would be designed to resist tornado (or hurricane) wind speeds in any of the different regions defined by the wind speed hazard maps. This approach was chosen by FEMA to provide a set of designs for home owners and small business that would meet and exceed the design criteria regardless of geographic location. FEMA performed an analysis of costs and materials for each of their prescriptive designs to arrive at this approach. The results did not support development of separate prescriptive designs for each wind speed. These safe room and storm shelter design wind speeds are in contrast to the minimum required design wind speed of 90 mph for most tornado-prone areas of the country, as stated in the 2009 IRC and the 2009 IBC (codes that establish the minimum requirements for residential and other building construction).

The FEMA 320 safe room designs reflect considerable feedback from stakeholders that pre-engineered prescriptive solutions are highly desirable and simplify the safe room design process. As such, safe room designs in FEMA 320 include easy-to-follow construction plans and specifications.

When designing a safe room, it is also critical to consider wind-borne debris load criteria. The "Tornado Missile Testing Requirements" in FEMA 361 are guidance for missile-resistance requirements for residential and community safe rooms that provide near-absolute protection.

In addition to the safe room's structural performance requirements, the following operational, maintenance, and human factors must be considered for a successful safe room: electric generator, lighting, emergency provisions, occupancy duration, and more described in FEMA 361 and ICC 500. Each of these items is further elaborated in FEMA 361 and ICC 500. Not all items must be considered for a residential safe room, but they are especially important when designing a community safe room.

MAT Observation: Although most community safe room operators and residential safe room owners the MAT visited provided documentation of the design criteria used, the MAT did not observe any posted signs or labels stating the criteria to which the safe rooms were designed in any of the community safe rooms. Only a few of the prefabricated residential safe rooms had a label stating the design criteria or NSSA member compliance.

9.6.2 Accessibility to Safe Rooms and Storm Shelters

Compliance Criteria: A safe room designer should consider the time needed for occupants of a building to reach the safe room or storm shelter. Safe rooms and storm shelters are only useful if users are able to make it inside safely before a tornado strikes. The following elements should be considered:

- Safe room users with disabilities may need assistance to access the safe room and may take longer to reach it. Wheel-chair users may require special accommodations along the route to the safe room to reduce the amount of time needed to reach it.
- Clearly posted signs and labels indicating the purpose of the safe room or storm shelter and its location will make it easier to find.
- It is essential that the path to the safe room remain clear to allow orderly access to it.
- Adequate interior dimensions of the safe room and shelter to house the number of users expected. FEMA and ICC both recommend a square foot area per occupant to ensure an appropriate minimum area. The area requirements vary depending on the number of standing and seated occupants and the number of wheel-chair-bound occupants a community safe room can safely hold.

MAT Observation: Accessibility requirements were considered in the larger community safe rooms visited by the MAT (Seneca Intermediate School in Missouri and the Brookside, AL, Fire Department community safe room). The Brookside, AL, safe room had a lift to assist disabled or impaired occupants with access to and from the safe room. However, the MAT could not determine whether the smaller Alabama community safe rooms in Phil Campbell, Brookwood, and Graysville had additional space for disabled occupants or whether access for them was considered.

9.6.3 Ventilation for Safe Rooms and Storm Shelters

Compliance Criteria: Tornado community and residential safe rooms should be ventilated by natural means or mechanical ventilation in accordance with FEMA 361 or ICC 500 for storm shelters. If mechanical ventilation is provided, it must be protected from the wind pressures and wind-borne debris criteria used for the protected space. Further, the ventilation system should be capable of providing the minimum mechanical ventilation rate required by local building code provisions and should also be connected to a backup power system in the event that primary power is lost.

MAT Observation: While all the community safe rooms the MAT observed had passive ventilation systems or mechanical ventilation systems, only the Seneca Intermediate School (in Missouri) and the Brookwood and Brookside community safe rooms (in Alabama) were observed to have mechanical systems protected and supported with backup power systems.

9.6.4 Toilet Facilities for Community Safe Rooms and Storm Shelters

Compliance Criteria: Safe rooms and storm shelters should contain toilets within the protected space. While this is not a design requirement for life-safety protection, this criterion is included to ensure the successful operation and management of safe rooms and storm shelters.

MAT Observation: The MAT observed that compliance with providing toilets in the safe rooms varied. The large safe rooms at the Seneca Intermediate School (in Missouri) and in the community safe room in Brookside, AL, had toilet facilities within the protected space. However, no toilets were observed in the smaller Alabama community safe rooms in Graysville.

9.6.5 Location and Labeling of Safe Rooms and Storm Shelters

Compliance Criteria: Safe rooms and storm shelters should be located such that those intending to seek refuge in the safe room or shelter are not exposed to additional hazards while traveling to or occupying the shelter. Users should be able to safely reach the safe rooms or storm shelter with minimal travel time. Therefore, community safe rooms should be located in a central area such that all designated users can access it quickly. Users should not have to cross obstructions such as creeks, fences, busy roads, or railroad tracks to reach the shelter. Safe rooms and storm shelters should be located outside of floodprone areas. When possible, safe rooms should be located away from structures and objects that could collapse onto it, such as communications towers, roof-mounted equipment, and immediately adjacent multi-story buildings. Similarly, safe rooms should be located such that they avoid nearby electrical transmission or distribution lines that can collapse onto, or very near, the structure. If it is not possible for a safe room to meet any of these criteria, a design and/or operational solution to adequately overcome the shortcoming should be provided.

The MAT recommends local emergency management agencies ***maintain a list of community and residential safe rooms*** to allow them to efficiently locate and check on the safety of the occupants after the storm.

Preferably, every community should have GPS coordinates of the main entrances for all safe rooms in the community. This information will help locate and perform rescue operations after an event, if needed. The presence of debris can make it impossible for occupants to exit a safe room and difficult for rescue workers to locate. The MAT had difficulty finding some safe rooms located in and amongst the piles of debris on large properties because it did not have the exact coordinates of the main entrance.

Some cities have voluntary storm shelter / safe room registries so that emergency personnel can check on the shelter occupants without being notified.

Safe rooms and storm shelters should be accurately labeled and also identified on posted floor plans. This is especially important for visitors who may not know where the safe room is located or the extent of the protected space within a larger building. Operators of community safe rooms should register their safe rooms with their local emergency management agencies (sometimes it might be police or fire departments) with the exact coordinates of the location of the main entrance of their safe room.

MAT Observation: Following the April 25–28, 2011 tornado outbreak, the community of Madison, AL, created such a registry noting the locations of all of safe rooms and storm shelters.

9.6.6 Tools and Other Equipment within Safe Rooms and Storm Shelters

Compliance Criteria: FEMA guidance on safe rooms recommends that tools, communication devices, and other ancillary equipment be stored within the safe room. This equipment is not intended for life-safety protection, but to support the successful operation of the safe room during a hazard event. Every safe room and storm shelter, both residential and community, should have a supply of tools to help occupants exit the safe room after an event. Since the ICC 500 is an engineering standard, these operational items are not discussed or required for life-safety protection.

MAT Observation: Tools were not needed by any of the community safe room occupants to exit after the tornado events because none of the safe rooms observed by the MAT were in structures destroyed by the tornadoes. However, if safe rooms had been located within the numerous damaged businesses visited by the MAT, the occupants would likely have had difficulties exiting the safe rooms since many of the buildings had completely collapsed.

In Tuscaloosa, AL, a family was trapped in their below-ground safe room when a tree fell across the door (see Section 9.4.3.1). The family had to wait for assistance and for the tree to be removed before they could leave the safe room. In another residential safe room in Smithville, MS, the latching mechanism was damaged by debris during the tornado and not operational from inside the safe room. Tools for opening such a damaged locking mechanism were not present in the safe room; storing such tools in a safe room is, however, recommended by in FEMA's guidance documents.

9.7 Summary of Conclusions and Recommendations

Table 9-1 provides a summary of the conclusions and recommendations for Chapter 9 and provides section references for supporting observations. Additional commentary on the conclusions and recommendations is presented in Chapters 10 and 11.

Table 9-1: Summary of Conclusions and Recommendations for Tornado Refuge Area, Hardened Area, and Safe Room Performance

Observations	Conclusions	Recommendations
ICC 500 and FEMA technical guidance provide similar levels of protection (see Terminology and Examples, Section 9.1)	**Conclusion #27** **Design and construction guidance for storm shelters and safe rooms is consistent, though somewhat different in scope.** FEMA adds different requirements pertaining to using ICC 500 within the context of an emergency management program.	**Recommendation #12** **Continue to coordinate standards and guidance for storm shelters and safe room design.**
With the exception of the Seneca Intermediate School in Seneca, MO, all of the safe rooms and storm shelters inspected by the MAT, for both residential and community uses, were constructed prior to the publication of the ICC 500. Many of the observed safe rooms and storm shelters were deficient when measured against the ICC 500 standard. Refer to: • Hardened structures, rooms, and areas not designed to defined criteria (Section 9.3) • Identifying design criteria used for safe rooms and storm shelters (Section 9.6.1)	**Conclusion #7** **State of ICC 500 adoption and enforcement.** Many of the observed safe rooms and storm shelters were deficient when measured against the ICC 500 standard.	**Recommendation #13** **Improve performance of safe rooms and storm shelters through code adoption and enforcement.**
The MAT observed many existing buildings that did not have: • a FEMA 361-compliant safe room, • an ICC 500-compliant storm shelter, • a designated evaluated by a design professional to be a best available refuge area, or • a tornado refuge area Refer to: • Terminology and examples (Section 9.1) • Tornado refuge areas in commercial and industrial buildings: Planned tornado refuge areas (Section 9.2.2)	**Conclusion #7** **State of ICC 500 adoption and enforcement.** Many of the observed safe rooms and storm shelters were deficient when measured against the ICC 500 standard.	**Recommendation #13** **Improve performance of safe rooms and storm shelters through code adoption and enforcement.**

Table 9-1: Summary of Conclusions and Recommendations for Tornado Refuge Area, Hardened Area, and Safe Room Performance (continued)

Observations	Conclusions	Recommendations
Several schools visited by the MAT had designated refuge areas, however, aside from the Seneca Intermediate School, the MAT did not observe any schools with safe rooms constructed to the ICC 500 standard (refer to Section 9.4.4 and 9.2.2).	**Conclusion #22** **2010 Alabama State school tornado safe room requirement.** FEMA supports the State of Alabama Building Commission and Alabama House Bill 459 that requires new school buildings constructed after July 2010 to provide mandatory safe spaces for tornado protection in all K-12 public schools.	**Recommendation #10** **Propose IBC code change.** Refer to Chapter 11 for proposed language for submittal to IBC regarding shelters in schools.
People may travel great distances to get to a community safe room or storm shelter which exceed the ½-mile maximum travel distance advocated in FEMA publications (refer to Section 9.5, Travel time to community safe rooms, storm shelters, and tornado refuge areas)	**Conclusions #24 and #26** **(#24) People traveled excessive distances to community shelters and safe rooms.** **(#26) Guidance for identifying how to provide community-wide protection is lacking.** There is a lack of guidance as to how far people can and should travel safely to access a safe room or storm shelter.	**Recommendations #34 and #35** **(#34) Research travel time to, and use of, safe rooms and storm shelters.** **(#35) Locate safe rooms or storm shelters close to people who will use them.**
The MAT observed areas within exiting non-residential buildings labeled as "tornado shelters." However, these areas were not designed and constructed in compliance with FEMA 320/361 or ICC 500 to provide a clear level of protection from tornadoes. While it may result from a lack of understanding of the terminology used in safe room guidance such as FEMA 320/361 and ICC 500, such mislabeling may mislead and endanger potential occupants during a tornado event. Refer to: • Terminology and examples (Section 9.1) • Location and labeling of safe rooms and storm shelters (Section 9.6.5)	**Conclusions #8 and #28** **(#8 and #28) There is a lack of proper labeling and signage.** There is a lack of proper labeling and signage for the areas where people seek to take cover from tornadoes.	**Recommendation #14** **Submit proposed IBC code change**. Refer to Chapter 11 for proposed language for submittal to IBC regarding identification of best available refuge areas.

Table 9-1: Summary of Conclusions and Recommendations for Tornado Refuge Area, Hardened Area, and Safe Room Performance (continued)

Observations	Conclusions	Recommendations
The MAT observed lack of best available refuge areas sited in buildings: • Terminology and examples (Section 9.1) • Location and labeling of safe rooms and storm shelters (Section 9.6.5) • Tornado refuge areas (Section 9.2) • Identifying design criteria used for safe rooms and storm shelters (Section 9.6.1)	**Conclusions #25, #26, and#8 and #28** **(#25) There is a poor understanding of public actions/movement patterns during tornadoes.** Public actions/movement patterns during the April 27 tornadoes and the Joplin tornado are not understood. **(#26) Guidance for identifying how to provide community-wide protection is lacking.** Guidance is needed to help public to select a large, community safe room vs. one of the many smaller, dispersed safe rooms across a community **(#8) and (#28)** **There is a lack of proper labeling and signage.**	**Recommendations #36 and #34** **(#36) Identify best available refuge areas.** **(#34) Research travel time to, and use of, safe rooms and storm shelters.**
Tornado refuge areas in large, single-story commercial buildings and retail buildings did not perform well (see Section 9.2.2).	**Conclusion #37** **Tornado refuge areas located in large, single-story buildings performed poorly.** Tornado refuge areas located in large, single-story buildings did not perform well	**Recommendations #36 and #37** **(#36) Identify best available refuge areas.** **(#37) Perform vulnerability assessments.**
Almost none of the residential safe rooms and storm shelters observed by the MAT in the five affected States were registered or listed with local emergency management agencies or police/fire departments. Furthermore, the MAT had difficulty locating FEMA-funded safe room even when latitudes and longitudes were provided (see Section 9.6.5).	**Conclusions #29 and #31** **(#29) There were unregistered safe rooms.** **(#31) Some safe rooms were difficult to locate with given coordinates.**	**Recommendation #38** **Register safe rooms.**

Table 9-1: Summary of Conclusions and Recommendations for Tornado Refuge Area, Hardened Area, and Safe Room Performance (concluded)

Observations	Conclusions	Recommendations
Many safe room owners did not coordinate with their local government, so first responders did not necessarily know the locations of private and individual safe rooms and storm shelters. Also, few community safe rooms were equipped with alternate communication systems as recommended in FEMA 361 (see Sections 9.6.5 and 9.6.6).	**Conclusions #36, #39, and #30** **(#36) Safe room locations were not documented and occupants had no ability to communicate from within.** In many locations, first responders did not know the locations of private and individual safe rooms and storm shelters. This is a concern because safe rooms can be hidden beneath debris and difficult to locate after a storm, and occupants may have no means of communication with first responders. **(#39) There was a lack of alternate means of communication in community safe rooms.** **(#30) Safe rooms and storm shelters lacked tools to open or dismantle door if blocked.** Most safe rooms and storm shelters did not have tools available should the doors and egress routes become damaged, inoperable, or blocked by debris.	**Recommendations #39 and #40** **(#39) Equip safe rooms, storm shelters, and best available refuge areas with tools to assist occupants when doors and egress routes become damaged, inoperable, or blocked by debris.** **(#40) Equip safe rooms, storm shelters, and best available refuge areas with an alternate means of communication.**
Evidence of technical inadequacies and public misconceptions regarding tornado safe rooms and storm shelters. Refer to: • Above-ground applications (Sections 9.3.1.2, 9.3.2.1, 9.4.1, 9.4.3.2) • Ventilation for safe rooms and storm shelters (Section 9.6.3) • Terminology and examples (Section 9.1) • Location and labeling of safe rooms and storm shelters (Section 9.6.5) • Hardened areas: areas designed to provide some protection (Section 9.1.1) • Tornado refuge areas in residences (Section 9.2.1) • Hardened structures, rooms, and areas not designed to defined criteria (Section 9.3) • Safe rooms and storm shelters (Section 9.4)	**Conclusions #23, #8 and #28, #32, #33, #34, #35, and #38** **(#23) Above-ground safe rooms performed as well as those below ground.** The public has misconceptions that above-ground safe rooms are not as safe as below-ground safe rooms. **(#8) and (#28) There was a lack of proper labeling and signage.** **(#32) Safe room door quality observed was often inadequate.** **(#33) Safe room door hardware observed was often inadequate.** **(#34) There was a lack of adequate ventilation in shelters.** **(#35) Safe rooms were observed that had inadequate or no anchoring.** **(#38) There was inadequate doors and door hardware on safe rooms/ storm shelters.**	**Recommendation #41** **Provide training.**