Critical Facilities Located in Tornado-Prone Regions: Recommendations for Architects and Engineers

FEMA

TORNADO RECOVERY ADVISORY *RA6, August 2011*

Purpose and Intended Audience

Critical facilities are emergency operations centers (EOCs), fire and police stations, hospitals, nursing homes, schools, and other buildings that are essential for the delivery of vital services or protection of a community. Tornado damage investigations and other research have helped to identify techniques for protecting occupants of critical facilities struck by tornadoes, as well as maintaining continuity of operations for those facilities. The 2011 tornadoes that struck the southeast United States specifically highlighted the importance of properly selecting the best available refuge areas in existing facilities as well as the importance of minimizing collapse hazards, such as tall trees and other nearby objects.

The purpose of this advisory is to inform architects and engineers of design enhancements that can be made to both existing facilities and facilities in the planning stage. With this awareness, desired enhancements can be incorporated into construction documents.

The interim information in this Recovery Advisory is intended to assist during the recovery and redevelopment of tornado-damaged areas and to minimize future tornado damage and interruption of operations. This information was developed because of the lack of design guidance on this topic.

This Recovery Advisory Addresses:

- Existing Buildings
  - Best available refuge areas
  - Tree fall and other collapse hazards
- New Buildings and Additions to Existing Buildings
  - Safe rooms
  - Strengthening new facilities to minimize damage from tornadoes
  - Enhancements to avoid interrupted operations

Standard of Care

Critical facilities have facility and operational requirements that should be met in addition to building code requirements. Building codes do not stipulate expected building performance for tornadoes. The designer should discuss expectations for acceptable building damage, operational requirements, and occupant safety with the facility owner to ensure the full range of solutions for any special requirements is considered.

Multi-hazard Design

This Recovery Advisory addresses the tornado hazard. However, critical facilities may be damaged—and continuity of operations may be impaired—by other natural hazards such as flooding, seismic events, and wildfire. When performing vulnerability assessments and design work on critical facilities, all natural hazards that can affect the facility should be considered and accounted for.

Terminology: Safe Rooms and Shelters

"Safe rooms" are defined as buildings or portions thereof that comply with FEMA 361, *Design and Construction Guidance for Community Safe Rooms* (2008).

"Shelters" are defined as buildings or portions thereof that comply with International Code Council (ICC), ICC 500, *ICC/NSSA Standard on the Design and Construction of Storm Shelters* (2008).

FEMA 361 and the ICC 500 criteria are quite similar. All safe room criteria in FEMA 361 meet the shelter requirements of the ICC 500. However, a few design and performance criteria in FEMA 361 are more restrictive than those in the ICC 500.

A summary of the primary differences between FEMA 361 and ICC 500 is presented in Recovery Advisory No. 2, *Safe Rooms: Selecting Design Criteria* (June 2011). The 2009 edition of the International Building Code (IBC) references ICC 500 for the design and construction of hurricane and tornado shelters. However, although ICC 500 specifies shelter criteria, it does not require shelters.

FEMA's MRR-2-09-1, *Hazard Mitigation Assistance for Safe Rooms*, dated April 30, 2009, sets forth eligibility requirements for Pre-Disaster Mitigation Program and Hazard Mitigation Grant Program safe room projects and requires adherence to FEMA 361. Also refer to the appropriate State Hazard Mitigation Officer for additional information (http://www.fema.gov/about/contact/shmo.shtm).

Existing Buildings

Although safe rooms specifically designed and constructed to resist wind-induced forces and the impact of wind-borne debris provide the best protection, buildings can have rooms or areas that afford some degree of protection from all but the most extreme tornadoes (i.e., an EF4 or EF5 tornado on the Enhanced Fujita scale). In buildings that do not have areas designed and constructed to serve as safe rooms, the goal of the architect or engineer should be to select the ***best available refuge areas***. Giving building occupants a best available refuge area in a building greatly reduces the risk of injury or death. Best available refuge areas do not *guarantee* safety; they are, however, the safest areas available for building occupants. Interior areas with short-span roof systems, such as corridors and small rooms (e.g., restrooms), are often best available refuge areas. However, as shown in Figures 1 and 2, this is not always the case. It is therefore recommended that qualified architects or engineers familiar with tornado risk analysis follow the guidance in FEMA P-431, *Tornado Protection: Selecting Refuge Areas in Buildings* (2009), and the checklists in Appendix B of FEMA 361, to identify best available refuge areas. It is recommended that the best available refuge area(s) have a permanent sign installed that states "Tornado Refuge Area."

An architect's or engineer's systematic review of a building may reveal some problems (such as doors with glass vision panels as shown in Figure 3) within the best available refuge area that can be economically mitigated to improve the refuge area.

Vulnerability Assessment of Existing Facilities

Most existing critical facilities are vulnerable to damage if struck by tornadoes. The damage may result in minor inconvenience or it may necessitate shutting down the facility. Facilities struck by a violent (EF4 and EF5) tornado will normally not be operational unless the facility was designed to remain operational if struck.

A vulnerability assessment can be conducted by a team of architects and engineers. Findings from such an assessment can lay the groundwork for planning and budgeting capital improvements or developing contingency plans that address facility disruption.

Figure 1: Debris in a school corridor in Joplin, MO (2011 Tornado)

Figure 2: Collapsed concrete masonry unit (CMU) walls at a Joplin, MO, school restroom (2011 Tornado)

Figure 3: Broken vision panel at an elementary school corridor in Tuscaloosa, AL (2011 Tornado)

Areas that include such doors or other problems could still be considered the best available refuge areas despite the vulnerability of the glass. However, known problems should be addressed to the extent possible. An example of a corrective action would be to replace doors that have vision panels with new door/vision panel assemblies that resist the test Missile E load specified in ASTM E 1996, when tested in accordance with ASTM E 1886. For more information on the test Missile E, see Section 6.3.3.3 of FEMA P-424, *Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds* (2010).

Collapse Hazards

Position poles, towers, and trees with trunks larger than 6 inches in diameter away from new buildings, additions to existing buildings, and primary site access roads so that they do not hit or block access to the facility if they topple.

When evaluating critical facilities to determine the best available refuge areas, architects and engineers should identify ***potential collapse hazards*** using the checklists in Appendix B of FEMA 361. Collapse hazards can include parts of the building, communication towers and equipment, chimneys, poles, and trees that can damage buildings with light-frame construction, break windows, and rupture roof coverings (Figures 4 and 5). Refer also to Recovery Advisory No. 5, *Critical Facilities in Tornado-Prone Regions: Recommendations for Facility Owners* (2011).

Figure 4: Collapse of a large communications tower onto a building in Joplin, MO (2011 Tornado)

Figure 5: Tree-fall damage at a critical facility in Tuscaloosa, AL (2011 Tornado)

New Buildings and Additions to Existing Buildings

Architects and engineers designing new critical facilities or additions to existing facilities should consider including a safe room to protect occupants, making enhancements that will minimize building damage, and designing the facility to remain operational even if it is struck by a violent tornado.

Safe Rooms

For all new critical facilities, the facility design should incorporate one or more safe rooms (depending on facility size) to provide occupant protection. When adding on to an existing facility that does not have a safe room, incorporate safe rooms within the addition. Size the safe room to accommodate the number of occupants in the existing building and the addition. Note that if temporary buildings will be used to accommodate increases in occupancy (for example, schools with portable classrooms), space should be designed in the safe room to account for these potential changes in safe room occupancy.

FEMA 361 provides comprehensive guidance for the design of safe rooms, as well as for quality assurance and quality control for their design and construction. FEMA 320, *Taking Shelter from the Storm: Building a Safe Room for Your Home or Small Business* (2008), provides prescriptive solutions for safe rooms that will shelter 16 or fewer occupants. If a safe room is not incorporated, it is recommended that the architect or engineer identify the best available refuge area(s) and that a permanent sign be installed that states "Tornado Refuge Area."

Flood Hazards

See FEMA 361 Sections 3.2.1, 3.6, and 4.4.3 for information regarding flood hazards.

Minimizing Building Damage by Enhancing Building Resistance

By using design strategies and building materials that are used in hurricane-prone regions, critical facilities can be built to be more resistant to most tornadoes (i.e., EF0–EF3). FEMA's design guide series (see textbox) provides recommendations for facilities located outside of hurricane-prone regions; these recommendations should be considered minimum baseline recommendations for all critical facilities. The design guides also provide above-baseline recommendations for facilities located within hurricane- and tornado-prone regions.

New buildings and building additions can be strengthened to minimize building damage and disruption from weak (EF0–EF1) and strong (EF2–EF3) tornadoes that pass directly over the facility, and from violent (EF4–EF5) tornadoes on the periphery of the facility. With appropriate strengthening and selection of building materials and systems, the cost of tornado repairs and the potential for disruption of operations will likely be reduced. When strengthening buildings, it is recommended that a safe room(s) also be included in the critical facility to protect occupants in case a violent tornado (i.e., EF4 or EF5) passes over or near the facility.

FEMA Design Guides

Wind design recommendations for critical facilities located both inside and outside of hurricane- and tornado-prone regions can be found in the following FEMA publications:

- FEMA P-424, *Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds* (2010)
- FEMA 543, *Design Guide for Improving Critical Facility Safety from Flooding and High Winds* (2007)
- FEMA 577, *Design Guide for Improving Hospital Safety in Earthquakes, Floods, and High Winds* (2007)

Enhancement Levels

FEMA recommends three enhancement levels. As the enhancement level increases, so does the level of protection from damage, disruption, and cost. Note that none of the enhancement levels ensure continuity of services such as electrical power or communications (see *Continuity of Operations* below). Table 1 provides a summary of the provisions to minimize building damage by enhancement level.

Level 1 Enhancements

Weak tornadoes (EF0 and EF1) have wind speeds that are below or somewhat above the 90-mph basic wind speed,[1] which is the design wind speed throughout most of the continental United States. Hence, buildings that comply with the International Building Code should exhibit good structural, door, and wall performance when struck by weak tornadoes. However, weak tornadoes can generate wind-borne debris that can break unprotected glazing and puncture many types of door, wall, and roof assemblies, which can result in significant interior damage and disruption. When the Level 1 enhancement recommendations are followed, the potential for debris and water to enter the building, if struck by weak tornadoes, is low.

Level 1 Enhancement Recommendations: In addition to the baseline recommendations in the FEMA P-424, 543, and 577 chapters that discuss high winds, design the roof deck, exterior doors, exterior glazing, and exterior walls to resist complete penetration by the test Missile E specified in ASTM E 1996. In addition, follow the roof system recommendations in P-424 (Section 6.3.3.7), 543 (Section 3.4.3.4), or 577 (Section 4.3.3.8) for hurricane-prone regions to reduce the potential for wind-borne debris-induced roof leakage. Figure 6 shows one of the recommended roof systems: sprayed polyurethane foam (SPF) over structural concrete. The strong tornado that struck this building did not debond the SPF from the concrete. Although wind-borne debris caused numerous gouges in the foam, the building did not leak because gouged SPF is not susceptible to leakage unless the foam is completely penetrated.

For fire stations, it is additionally recommended that apparatus bay doors and their connections to the structure be designed for a basic wind speed of 150 mph (plus an importance factor of 1.15).[2]

Brick veneer, aggregate roof surfacing, roof pavers, slate, and tile cannot be effectively anchored to prevent them from becoming missiles if a strong or violent tornado passes near a building with these components. To reduce the potential number of missiles, and hence reduce the potential for building damage and injury to people, it is recommended that these materials not be specified for critical facilities in tornado-prone regions.

Table 1: Summary of Provisions to Minimize Building Damage by Enhancement Level

Enhancement Levels	Recommendations
Level 1	• Resist test Missile E • Special roof system • Avoid listed roof and wall coverings • Design fire station apparatus bay doors for a basic wind speed of 150 mph
Level 2	• Level 1 enhancement recommendations • Design for basic wind speed of 150 mph
Level 3	• Level 2 enhancement recommendations • Special roof deck and exterior walls

Figure 6: Although struck by a strong tornado, the SPF roof system of this Plainfield, IL, building did not blow off (1990 Tornado)

Brick Veneer

If brick veneer is selected, the veneer should not be depended on to resist debris because of the high potential for collapse of the veneer.

Level 2 Enhancements

Strong tornadoes (EF2 and EF3) have wind speeds that are below or near the Level 2 enhancements design wind speed. Hence, when Level 2 recommendations are followed, buildings should not experience structural failure or door or wall collapse when struck by strong tornadoes. However, debris from an EF3 tornado may penetrate the building and result in extensive interior water and perhaps wind damage.

1 The 90-mph basic wind speed is based on the 2005 edition of American Society of Civil Engineers ASCE 7, *Minimum Design Loads for Buildings and Other Structures*. If ASCE 7-10 is used, the equivalent basic wind speed for Risk Category III and IV buildings is 120 mph.

2 The 150-mph basic wind speed is based on ASCE 7-05. If ASCE 7-10 is used, the equivalent basic wind speed for Risk Category III and IV buildings is 200 mph. (Note: The importance factor is built into the ASCE 7-10 maps; hence, the 1.15 importance factor is not used in the ASCE 7-10 pressure calculation equation.)

Level 2 Enhancement Recommendations: The facility should be designed to incorporate Level 1 enhancements and to a basic wind speed of 150 mph (plus an importance factor of 1.15) for the main wind-force resisting system (MWFRS), the building envelope, and rooftop equipment.

Note: The basic wind speed in south Florida is nearly 150 mph, and as a result, numerous products and systems are available that have been tested for pressures associated with this wind speed.

Level 3 Enhancements

With incorporation of Level 3 enhancements, penetration of the roof deck or walls by EF3 debris is unlikely, but debris may penetrate doors or glazing. Designing with Level 3 enhancements also minimizes the potential for interior water and wind damage from strong tornadoes. However, significant interior damage could occur (though not within the safe room) if the core of a violent tornado (EF4 or EF5) passes over or near the building.

Level 3 Enhancement Recommendations: Facility design should incorporate Levels 1 and 2 enhancements as well as the following:

- Roof deck – A minimum 4-inch-thick, cast-in-place, reinforced concrete deck is the preferred deck. Other recommended decks include minimum 4-inch-thick structural concrete topping over steel decking and precast concrete with an additional minimum 4-inch-thick structural concrete topping.
- Exterior walls – A minimum 6-inch-thick, cast-in-place concrete wall reinforced with #4 rebar at 12 inches on center each way is the preferred wall. Other recommended walls are a minimum 8-inch-thick, fully grouted CMU reinforced vertically with #5 rebar at 40 inches on center and minimum 6-inch-thick precast concrete that is reinforced equivalent to the recommendations for cast-in-place walls.

  Note that the above reinforcing recommendations are based on wind-borne debris resistance. More reinforcing steel may be required in the wall to carry wind loads, depending on the design and geometry of the wall.

The benefit of the Level 3 enhancement deck recommendation is illustrated by the fire station shown in Figure 7, which was struck by a strong tornado. The apparatus bay doors collapsed (red arrow), and all of the unprotected glazing was broken. However, the walls and cast-in-place concrete roof deck remained in place. Interior damage was substantial as a result of the glazing failures. If the Level 3 enhancement door, glazing, and rooftop equipment recommendations had been followed, this station would likely have had little, if any, interior damage. The adjacent unreinforced CMU apartment building (red circle) experienced blow off of the wood roof structure and collapse of some exterior CMU walls.

Hospitals and Nursing Homes

Designing to at least the Level 1 enhancement recommendations is particularly important for hospitals and nursing homes. Designing these facilities to the Level 3 enhancement recommendations is preferable. Sometimes tornado warning time is ample for occupants to reach a safe room; however, at times an approaching tornado is not noticed until a few minutes before it strikes. In those instances with little or no warning of an impending tornado strike, maintaining building envelope integrity is crucial to providing protection to patients, residents, and staff, and to minimizing disruption of services.

Figure 7: Fire station with a cast-in-place concrete roof deck in Tuscaloosa, AL. The apparatus bay doors (red arrow) collapsed and the adjacent building (red circle) was damaged (2011 Tornado).

Figure 8: Collapse of the second-floor roof structure, interior walls, and exterior walls of a school in Tuscaloosa, AL (2011 Tornado)

The performance of the fire station in Figure 7 is in stark contrast to the school shown in Figure 8, which did not have any of the Level 1, 2, or 3 enhancements. The school was struck by the same strong tornado as the fire station, but the school's steel deck/steel joist roof structure blew away, and the exterior CMU/brick veneer walls and interior walls on the second floor collapsed.

Continuity of Operations

Designing a facility to ensure it will remain operational if struck by a violent tornado is expensive. Therefore, when considering the costs and benefits of designing for continuity of operations, designing to minimize building damage and/or provide safe rooms may be more cost effective. Facilities such as EOCs that are determined to be critical in providing effective emergency response should be designed to avoid interrupted operations even if struck by violent tornadoes. The following practices will reduce the chances of interrupted operations related to building damage or loss of municipal utilities (i.e., water, sewer, and electrical power).

> **Vulnerability Assessments**
>
> As part of the planning process for new facilities, other natural hazards (flood, seismic, and wildfire) should be considered in addition to the tornado hazard. FEMA P-424, 543, and 577 provide guidance on conducting vulnerability assessments. If the building design does not ensure continuity of operations, contingency plans should be developed that address facility disruption.

Follow Recommendations in FEMA 361

If the entire facility must remain operational, FEMA 361 recommendations should be applied to the entire building. However, if only a portion of the building must remain operational, the recommendations can be applied only to that portion.

Figure 9 shows an example of an EOC (red oval) located in a portion of the first floor of a large building.[3] The collapsed second floor of this facility did not need to remain operational; hence, if a similar facility were being constructed, designing the second floor in accordance with FEMA 361 would not be necessary.

Figure 9: An EOC in Tuscaloosa, AL, that remained intact even though the story above it collapsed (Tornado 2011)

Avoid Water Leakage

Critical facilities can be housed either on a top floor, with a roof overhead, or a bottom or intermediate floor with another story overhead. Avoiding water leakage is important for both scenarios. For critical facilities with a roof overhead, either of the following options is recommended:

- A modified bitumen roof membrane that is torch-applied to a primed concrete roof deck. Over this membrane, apply roof insulation, gypsum roof board, and another roof membrane as recommended in FEMA P-424 (Section 6.3.3.7), 543 (Section 3.4.3.4), or 577 (Section 4.3.3.8).
- A minimum 4-inch-thick SPF roof system over a concrete roof deck. The SPF should be coated rather than protected with an aggregate surfacing.

  For critical facilities with a floor slab overhead, as shown in Figure 9, collapse of an upper level could allow water to leak into the critical facility. If water-sensitive equipment or operations are within the critical facility, the following is recommended.

- Design a false ceiling between the equipment or operations and the floor slab above. Design a waterproof membrane over the top of the false ceiling to prevent leakage into the water-sensitive area below.

3 The building shown in Figure 9 was not FEMA 361 compliant.

Design to Protect the Heating, Ventilation, and Air Conditioning

FEMA 361 provides recommendations pertaining to protecting heating, ventilation, and air conditioning (HVAC) equipment for safe rooms. Safe rooms, however, are normally occupied for relatively short durations, whereas critical facilities are normally needed for continuous long-term operation after a tornado. Therefore, additional provisions for ventilation and/or cooling may be required depending on facility operational requirements.

Maintaining functioning HVAC equipment in facilities that must either remain operational during an event or be able to be made operational shortly after an event can be challenging. Portions of commercial HVAC systems are typically inside the building, but portions that transfer heat to the environment are located outside and are, therefore, vulnerable to damage from wind and wind-borne debris (Figures 10 and 11).

Figure 10: ACC units vulnerable to wind and wind-borne debris

Figure 11: Cooling tower vulnerable to wind and wind-borne debris

To protect HVAC components outside buildings from horizontal wind-borne debris, wind- and debris-resistant walls can be designed around the equipment. Vertical debris protection is more difficult to achieve. Baffling, as shown in FEMA 361 (Section 3.3.2.e and Figure 7-12) to protect doors from direct debris impact, can be used to prevent damage to exterior equipment. However, baffling can restrict air flow and thereby reduce the cooling capacity of HVAC equipment. The effects of baffling should be considered in the system design.

Geothermal loops transfer heat to the earth and are, therefore, protected from wind and wind-borne debris. Although retrofitting existing systems to use geothermal loops is often not practical, installing geothermal systems during original construction can produce HVAC systems that meet the wind pressure and wind-borne debris criteria in FEMA 361.

An alternative to protecting equipment from debris is to rely on a temporary system, especially in situations when cooling is not needed immediately after an event. In this scenario, portable chiller units, cooling towers, or DX units could be brought to the site if a tornado damages the equipment. If temporary systems will be used, facility owners should source the equipment in advance, and design professionals should specify preinstallation for the power and control connections, as well as the associated piping and duct connections.

Ensure Water Supply

Depending on facility operational requirements, drinking water or other water needs (such as for hand washing and fire protection) may be satisfied by stored water bottles, a water storage tank within the facility, or a well that is protected by an enclosure that meets the wind pressure and wind-borne debris criteria in FEMA 361.

Ensure Sewer Service

FEMA 361 recommends self-contained, chemical-type receptacles/toilets to provide sewer service for safe rooms. However, the recommendations in FEMA 361 may be inadequate for critical facilities that do not have to access to functional municipal sewer service for days or weeks after a tornado. For these facilities, a temporary storage tank that can be pumped out by a local contractor should be designed.

FEMA has observed critical facilities that were flooded by backflow from surcharged sewer systems as a result of loss of electrical power to sewage lift stations or storm-damaged sewage treatment plants. Sewer backflow valves can be installed in the sewage discharge line to avoid this problem. However, because sewage will also not be able to leave the building from the primary discharge line, provisions should be made for diversion to a temporary storage tank.

Make Provisions for Emergency Power

FEMA 361 provides recommendations pertaining to emergency power. However, because critical facilities may have to rely on emergency generators for several days or weeks after a tornado, designers of critical facilities should also refer to the electrical power recommendations in FEMA P-424 (Section 6.3.5.1). Following these recommendations will minimize the loss of needed emergency power (see Figures 12 and 13). These recommendations also pertain to dual fuel generators.[4]

Figure 12: This Joplin, MO, building housing the switchgear (red arrow) and emergency generator (Figure 13) collapsed (2011 Tornado)

Figure 13: The steel deck/steel joist roof structure and unreinforced CMU walls of this Joplin, MO, building collapsed onto the emergency generator (2011 Tornado)

Minimizing Operational Disruption in Hospitals

Hospitals present special challenges because of the need for glazing in patient rooms. The following options should be considered to minimize disruption of operations in hospitals.

Adhere to FEMA 361: To ensure continuity of operations, designers could follow the recommendations provided in Continuity of Operations above, including specifying that the entire building, including all exterior glazing, meet the tornado wind-borne debris and wind pressure criteria in FEMA 361.

Note: The test missile used for safe room design has much greater momentum than test Missile E (68 versus 22 pounds force per second). Glazing assemblies that have passed the Missile E testing are readily available, and a few assemblies are available that meet the tornado test missile. Known assemblies that have passed the tornado test missile requirement employ polycarbonate glazing. In some assemblies, a pane of glass is on the exterior side of the polycarbonate. The glass protects the outer surface of the polycarbonate from scratches, but the inner surface is susceptible to scratching.

Note: Safe rooms that have a few small windows protected by a shutter on the inside of the room have been designed. However, expecting a shutter within each patient room to always be closed before a tornado event is impractical.

Implement Level 3 enhancement recommendations: To minimize operational disruption, the Level 3 enhancement recommendations could be implemented in patient rooms, lobbies, and other areas where exterior glazing is necessary. In other areas of the facility (such as the emergency room, lab, radiology department, surgery department, and the physical plant), the recommendations provided in Continuity of Operations above could be implemented. By taking this approach, some exterior glazing might be breached if a violent tornado passed over or near the hospital, but much of the facility would have a high potential of remaining operational.

4 After a tornado, main natural gas lines may need to be turned off to prevent fires. If a critical facility has a gas-fired generator, it may not be operational unless it has a secondary diesel fuel source.

Useful Links and Resources

Recovery Advisories from the Tornado MATs for Alabama, Mississippi, Tennessee, and Georgia. FEMA. 2011. Available from: http://www.fema.gov/library/viewRecord.do?id=4723.

- Tornado Recovery Advisory No. 1 – *Tornado Risks and Hazards in the Southeastern United States*
- Tornado Recovery Advisory No. 2 – *Safe Rooms: Selecting Design Criteria*
- Tornado Recovery Advisory No. 3 – *Residential Sheltering: In-Residence and Stand-Alone Safe Rooms*
- Tornado Recovery Advisory No. 4 – *Safe Rooms and Refuge Areas in the Home*
- Tornado Recovery Advisory No. 5 – C*ritical Facilities Located in Tornado-Prone Regions: Recommendations for Facility Owners*.

Taking Shelter from the Storm: Building a Safe Room for Your Home or Small Business (FEMA 320), August 2008, Third Edition. http://www.fema.gov/library/viewRecord.do?id=1536.

Design and Construction Guidance for Community Safe Rooms (FEMA 361), August 2008, Second Edition. http://www.fema.gov/library/viewRecord.do?id=1657.

Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds (FEMA P-424), December 2010, Second Edition. http://www.fema.gov/library/viewRecord.do?id=1986.

Tornado Protection: Selecting Refuge Areas in Buildings (FEMA P-431), October 2009, Second Edition. http://www.fema.gov/library/viewRecord.do?id=1563.

Design Guide for Improving Critical Facility Safety from Flooding and High Winds (FEMA 543), January 2007. http://www.fema.gov/library/viewRecord.do?id=2441.

Design Guide for Improving Hospital Safety in Earthquakes, Floods, and High Winds (FEMA 577), June 2007. http://www.fema.gov/library/viewRecord.do?id=2739.

ICC/NSSA Standard on the Design and Construction of Storm Shelters, International Code Council (ICC) and National Storm Shelter Association (NSSA) (ICC 500), June 2008, Country Club Hills, IL. http://www.iccsafe.org/Store/Pages/Product.aspx?id=8850P08_PD-X-SS-P-2008-000001#longdesc.