Critical Facilities Located in Tornado-Prone Regions: Recommendations for Facility Owners

FEMA

TORNADO RECOVERY ADVISORY *RA5, July 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 shown us 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 area in existing facilities as well as the importance of minimizing collapse hazards, such as tree fall and other nearby objects. The purpose of this advisory is to inform critical facility owners of enhancements that can be made both to existing facilities and those still in the planning stage. With this awareness, facility owners can budget for desired enhancements and request that these enhancements be incorporated into the construction documents.

This Recovery Advisory Addresses:

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

Existing Buildings

Critical facility owners should hire the services of a qualified architect or engineer to evaluate their existing building. The evaluation should determine whether the facility adequately protects occupants, operations, and the facility itself from tornadoes and other appropriate hazards. The evaluation should identify the best available refuge areas in the existing facility. Any needed enhancements can be incorporated into capital improvement planning and budgeting. Lack of adequate planning can result in loss of operation and possible loss of life when buildings are inadequately hardened or lack a best available refuge area for occupants (Figure 1).

Best Available Refuge Areas

In regions of the United States subject to tornadoes, identifying the best available refuge areas within buildings is essential for the safety of building occupants. ***Safe rooms*** specifically designed

Figure 1: An EOC in Tuscaloosa, AL, that saw a loss of operations but remained intact even though the story above it collapsed (Tornado 2011)
PHOTO COURTESY OF THE TUSCALOOSA COUNTY SHERIFF'S OFFICE.

and constructed to resist wind-induced forces and the impact of wind-borne debris provide the best protection. However, findings from investigations of past tornadoes show that many critical facilities contain rooms or areas that may afford some degree of protection from all but the most extreme tornadoes (i.e., an EF4 and EF5 tornado). The ***best available refuge areas*** should be identified in buildings that do not have areas designed and constructed to serve as safe rooms. 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 the best available refuge areas. However, as shown in Figure 2, this is not always the case. It is therefore recommended that owners of critical facilities hire a qualified architect or structural engineer familiar with tornado risk analysis to assess existing buildings and identify the best available refuge areas.

The architect's or engineer's systematic review of a building may reveal some problems (such as doors with glass vision panels) within the best available refuge area that can be economically mitigated to improve the refuge area. 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. Examples of corrective actions include replacing any doors that contain windows or replacing the existing glazing with impact-resistant glazing.

Collapse Hazards

Collapse hazards can include parts of the building, communication towers and equipment, chimneys, poles, and trees. Collapses can break windows and rupture roof coverings of critical facilities, damage components such as emergency generators and HVAC equipment needed for the operation of a critical facility, and cause structural damage to buildings (Figure 3). Collapse hazards must be addressed in design and sheltering decisions to avoid injuries or death and to ensure operational requirements of a critical facility are met. Potential collapse hazards can be evaluated using the checklists in Appendix B of FEMA 361, *Design and Construction Guidance for Community Safe Rooms* (2008) and the results can be used to evaluate the best available refuge areas.

Guidance documents for identifying best available refuge areas are referenced in FEMA Recovery Advisory No. 6, *Critical Facilities in Tornado-Prone Regions: Recommendations for Architects and Engineers*.

Enhanced Fujita Scale	
EF0	65–85 mph winds
EF1	86–110 mph
EF2	111–135 mph
EF3	136–165 mph
EF4	166–200 mph
EF5	>200 mph

Figure 2: Debris in an elementary school restroom in Tuscaloosa, AL (Tornado 2011)

Figure 3: Collapse of a large communications tower onto a building in Joplin, MO (Tornado 2011)

Proper maintenance and placement of trees will minimize damage to critical facilities and surrounding buildings. Trees should be placed such that the distance between the critical facility and the tree is greater than the height the tree will reach when it is fully grown. Trees with wounds, decay, structural defects, known internal trunk voids, severed roots, and soil compaction are prime targets for storm damage. These defects are often a result of damage from a lawnmower or weed trimmer and can be avoided with proper, careful lawn maintenance.

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 an EF4 or 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.

New trees should be planted at the correct depth. Trees planted too deep can develop stem girdling, where the tree roots encircle the stem and weaken it just below the ground, making it more likely to snap off at the stem-girdled point in the event of a forceful wind. In addition, mature trees should be pruned to correct defects, such as multiple leaders and weak branch attachments. Prune trees as soon as the defect is detected because younger trees will heal faster from the pruning.

New Buildings and Additions to Existing Buildings

During planning and budgeting for a new facility or making additions to existing facilities, a designer or space planner normally helps the facility owner develop a program for types of spaces, size of space, equipment needed, parking, and many other elements. For critical facilities in areas prone to tornadoes, owners should consider building safe rooms, strengthening their facility to minimize damage, and enhancing their facility to avoid interruption of operations (see also Recovery Advisory No. 6 for the associated design and construction guidance).

Safe Rooms

All new critical facilities should include 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, facility owners should budget for a safe room within the addition (see Figure 4). If possible, the safe room should be sized to accommodate the number of occupants in the existing building and the addition.

Safe rooms are typically dual-function rooms. During normal times, the safe room may function as a training room, restroom, hallway, or other such purpose. When tornadoes threaten, the specially designed and

constructed safe room serves to protect the building occupants. The additional cost of making a room serve a dual function as a safe room varies. Excluding interior finishes and furnishings in the safe room area, a cost of $200 per square foot for budgeting is usually sufficient to cover design fees and construction.[1]

Safe rooms afford building occupants near absolute protection. However, facility operations that are housed outside of a safe room are normally susceptible to tornado damage and disruption. To minimize damage or to ensure continuity of operations, additional design and construction measures are needed as recommended below.

Figure 4: The addition to this school was designed to serve as a safe room (Wichita, KS)

If Federal funding for the design and construction of a safe room is sought, the technical information in FEMA 361 (2008) must be adhered to as part of the funding requirements of the FEMA safe room policy. FEMA policy on the eligibility of the design and construction of safe rooms for Federal funding is provided in FEMA Mitigation Interim Policy MRR-2-09-1, *Hazard Mitigation Assistance for Safe Rooms*, dated April 30, 2009.

Strengthening New Facilities to Minimize Damage from Tornadoes

By using design strategies and building materials that are used in hurricane-prone regions[2], facilities can be built to be more resistant to tornadoes. Therefore, facility owners should consider budgeting for strengthening new buildings or additions to minimize damage and disruption from nearby weak and strong tornadoes and from violent tornadoes that are 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 (see Figure 5) will likely be reduced. Even when constructing a facility using stronger systems, a safe room should be included in the facility to protect occupants during an EF4 or EF5 tornado that strikes the facility.

Enhancement to Avoid Interrupted 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, it may be more cost effective to design to minimize building damage and/or provide safe rooms. If, because of the additional expense, the owner determines that a critical facility does not need to be operational if struck by a violent tornado, then this reduced building performance should be clearly considered and addressed in emergency operations plans. Other critical facilities should be identified (that are not expected to be impacted by the same tornado) from which to continue critical operations. Appropriate planning, emergency plans, and agreements should be put in place. For facilities such as Emergency Operations Centers that are determined to be critical in providing effective emergency response, owners should budget facility enhancements to avoid interrupted operations even if struck by violent tornadoes.

Specific design recommendations pertaining to continuity of operations are provided in FEMA Recovery Advisory No. 6, *Critical Facilities in Tornado-Prone Regions: Recommendations for Architects and Engineers*.

1 Section 2.3 and Table 2-4 in FEMA 361 (2008), provides additional information on safe room costs.

2 For more information on constructing buildings hurricane-prone regions, refer to 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); and FEMA 577, *Design Guide for Improving Hospital Safety in Earthquakes, Floods, and High Winds* (2007).

Specific design recommendations for minimizing building damage are provided in FEMA Recovery Advisory No. 6, *Critical Facilities in Tornado-Prone Regions: Recommendations for Architects and Engineers.*

Figure 5: Most of the exterior glass in this Joplin, MO, hospital was broken (Tornado 2011)

Vulnerability assessment of new facilities: 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 (2010), 543 (2007), and 577 (2007) 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.

Useful Links and Resources

FEMA. 2007. *2007 Tornado Recovery Advisories*. FEMA. Washington, DC. http://www.fema.gov/library/viewRecord.do?id=2631

FEMA. 2009. Mitigation Interim Policy, MRR-2-09-1, *Hazard Mitigation Assistance for Safe Rooms,* FEMA, Wahington, DC, April. http://www.fema.gov/library/viewRecord.do?id=3634

FEMA. 2009. HMA Unified Guidance FY 10 http://www.fema.gov/library/viewRecord.do?id=3649

FEMA. 2010. HMA Unified Guidance FY 11 http://www.fema.gov/library/viewRecord.do?id=4225

FEMA. 2011, Recovery Advisory No. 6, *Critical Facilities in Tornado-Prone Regions: Recommendations for Architects and Engineers.*

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

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

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

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

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

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

International Code Council (ICC) and the National Storm Shelter Association (NSSA), 2008. *ICC/NSSA Standard on the Design and Construction of Storm Shelters*, ICC 500-2008, Country Club Hills, IL.