Background

Tornadoes and hurricanes are among the most destructive forces of nature, causing injury and death to people who are unable to safely evacuate or find shelter from these events. As of January 2015, FEMA grant programs have provided approximately $984 million in Federal funds toward the design and construction of nearly 25,000 residential and 2,000 community safe rooms in 25 states and territories. The release of the FEMA Building Science publications on design and construction guidance for safe rooms served as a catalyst for these grant programs to help fund safe rooms that can provide near-absolute life safety protection for their occupants.

Tornado Events

On average, more than 1,275 tornadoes have been reported nationwide each year since 1997. From 1950 through 2011, tornadoes caused about 5,600 fatalities in the United States,[1] as well as devastating personal property losses. The most violent tornadoes are capable of tremendous destruction with wind speeds of up to 250 miles per hour (mph) near ground level. Damage paths over 50 miles long and over 1 mile wide have been reported. During the Great Plains Tornado Outbreak of May 3, 1999, 67 tornadoes struck Oklahoma and Kansas, including numerous EF4 and EF5 tornadoes (EF4 and EF5 are classifications based on the Enhanced Fujita [EF] Tornado Scale; see Figure A2-1 in FEMA P-361). This tornado outbreak resulted in 49 deaths and leveled neighborhoods[2]. Additional information about the Oklahoma and Kansas tornadoes is available in the FEMA Building Performance Assessment Team (BPAT) report, *Midwest Tornadoes of May 3, 1999*, FEMA 342.

Figure 1 shows Kelley Elementary School in Moore, Oklahoma, and the central corridor of the school, which was the designated tornado refuge area. Fortunately, classes were over for the day when the tornado hit; however, had this tornado occurred earlier in the day, the effect on individuals taking shelter would have been disastrous.

[1] NIST (National Institute of Standards and Technology). 2013. *Technical Investigation of the May 22, 2011 Tornado in Joplin, Missouri*. March. Available at http://www.nist.gov/manuscript-publication-search.cfm?pub_id=915628.

Figure 1. Destroyed tornado refuge area at Kelley Elementary School, Moore, Oklahoma (1999)

Similar deadly storm outbreaks have occurred since that time, and these events have heavily influenced FEMA's decision to develop the first edition of FEMA 361 in June 2000. Almost 4 years to the day after the May 3, 1999 tornadoes, 80 tornadoes were reported across eight states, the hardest hit included Kansas, Oklahoma, and Missouri. The tornadoes struck on May 8, 2003, causing 37 deaths and destroying hundreds of homes and businesses.

On May 4, 2007, 12 tornadoes were spawned by an intense supercell. One of these tornadoes was rated an EF5 with wind speeds estimated to be greater than 205 mph (3-second gust). The tornado had a reported swath of 1.7 miles and destroyed approximately 95 percent of Greensburg, Kansas, causing 11 deaths in the town.

Prior to the Greensburg tornado, Florida was hit by a tornado outbreak in February 2007. A small but deadly outbreak of three tornadoes struck northeast Florida from the Lady Lake area to New Smyrna Beach. These three tornadoes killed 21 people and injured dozens of others. Of the three tornadoes, two were rated EF3 and one was rated EF1. Because these tornadoes struck in the middle of the night, almost all of the people who perished were in their homes. The unfortunate events of February 2007 remind us that, even when homes are built to the more hazard-resistant codes of Florida, they cannot be relied upon to provide life-safety protection. Furthermore, the two EF3 tornadoes were not the large EF4 and EF5 tornadoes typically associated with major storm fatalities. The destruction wrought by these lower intensity, more common tornadoes proves the tornado hazard exists in hurricane-prone regions and calls attention to the threat posed to homeowners because residential construction is typically not designed to provide near-absolute protection for occupants.

Also in 2007, a tornado hit Enterprise, Alabama on March 1. The tornado was categorized as a lower-end EF4 and damaged a significant portion of the town where Enterprise High School was located (see Figure 2). Eight students perished at the high school as they were sheltering in the area the school had identified a best-available area for refuge during a tornado. No portion of the building had been hardened for tornado resistance to provide the level of protection consistent with a FEMA P-361 safe room. After the event, the following statement was released by the investigators from the National Oceanic and Atmospheric Administration (NOAA, *Tornadoes in Southern Alabama and Georgia on March 1, 2007*; NOAA tornado assessment):

> *"The high school in Enterprise followed proper protocol in terms of maximizing student safety. The eight fatalities at the high school appear to have been due to structural failure of the roof and walls, which collapsed on the students. Previous events have shown that hardened safe rooms provide better shelter from tornadoes than other permanent structures, especially during EF3 or greater tornadoes, and may be a critical component of adequate tornado safety plans, especially in mobile home parks, homes with standard grade construction, and non-residential buildings in which many people normally gather (schools, office buildings, etc.)."*

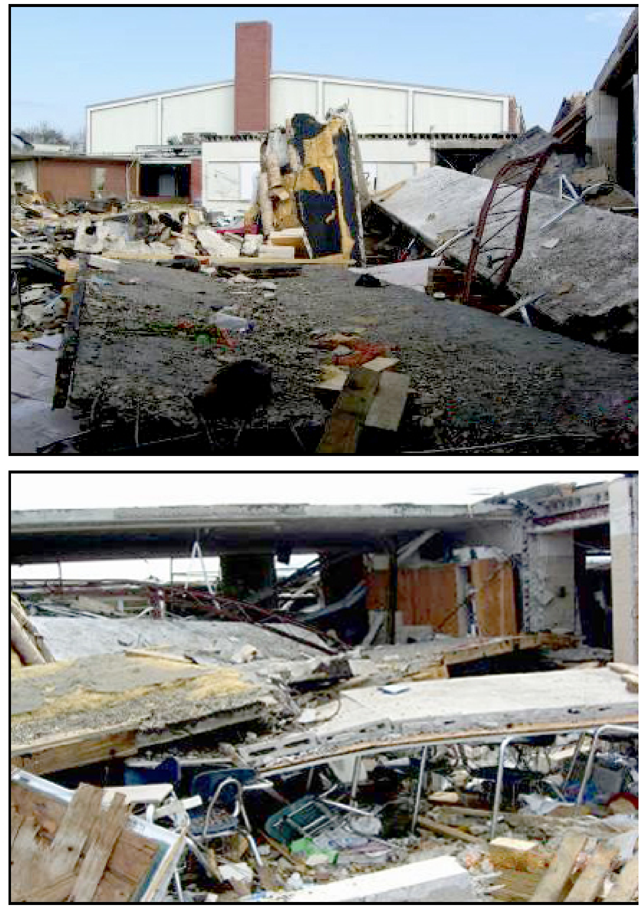


Figure 2. Destroyed tornado refuge area at Enterprise High School, Enterprise, Alabama (2007)

In the spring of 2011, the Southeastern and Midwestern portions of the United States experienced a historic number of tornadoes. From April 25 to 28, 2011, hundreds of tornadoes ranging from EF0 to EF5 touched down from Texas to New York, with some of the strongest and most devastating on April 27 in Alabama, Mississippi, Georgia, and Tennessee. According to the National Weather Service (NWS), there were 364 tornado-caused deaths in April of 2011, with 321 of those from the April 25-28 outbreak.

Less than a month later, on May 22, more than 50 tornadoes touched down across eight states, the most powerful of which was a 0.75-mile-wide EF5 tornado that cut a 6-mile path through Joplin, Missouri. The tornado destroyed thousands of homes and caused widespread damage in the city. This historic tornado resulted in 161 fatalities, the most fatalities ever recorded from a single tornado since 1950.

FEMA deployed a Mitigation Assessment Team (MAT) to assess the damage in Alabama; Mississippi; Georgia; Tennessee; and Joplin, Missouri. The MAT investigated the performance of residential buildings, commercial and industrial buildings, critical and essential facilities, and infrastructure, as well as safe rooms, storm shelters, hardened areas, and tornado refuge areas. FEMA P-908, *Mitigation Assessment Team Report – Spring 2011 Tornadoes: April 25-28 and*

May 22, presents the MAT's field observations, as well as subsequent conclusions and recommendations, which have been incorporated into FEMA guidance such as FEMA P-320 and P-361. More information can be found on this outbreak in the FEMA MAT report, FEMA P-908.

On May 20, 2013, yet another destructive tornado touched down in Moore, Oklahoma. An EF5 tornado with a diameter of 1.1 miles was reported to have lasted for 39 minutes on the ground, traveling for 14 miles according to NOAA. There were 24 fatalities, 7 of which were children at Plaza Towers Elementary School. Another school was in the path of the tornado, Briarwood Elementary, but no fatalities occurred there. FEMA deployed a team of engineers to assess the safe rooms that were hit by the tornado. FEMA's formal observation report, *Tornado: Moore, Oklahoma, May 20, 2013*, FEMA P-1020, has more information on this.

These events show the deadly and destructive potential of tornadoes. Such events continue to illustrate the compelling need for shelters and safe rooms capable of protecting human lives from tornadoes. FEMA P-361 provides design criteria for the design and construction of residential and community safe rooms that will provide the level of protection needed to save lives during tornadic events.

NOTE

Two MAT recommendations from FEMA P-908 were successfully submitted as code change proposals for the 2015 International Building Code (IBC). As a result, the 2015 IBC requires storm shelters to be incorporated when any of the following are constructed: K-12 schools with capacity for more than 50 occupants; 911 call stations; fire, rescue, ambulance, and police stations; and emergency operation centers. The requirement only applies in Wind Zone IV (areas with a design wind speed of 250 mph per ICC 500-2014 and FEMA P-361) for communities that adopt the 2015 IBC.

Hurricane Events

A hurricane, as defined by NOAA, is a tropical cyclone in which the maximum sustained surface wind (using the U.S. 1-minute average) is 74 mph. The term “hurricane” is used for northern hemisphere tropical cyclones east of the International Dateline to the Greenwich Meridian. Around its core, winds can gain great velocity, generating violent seas. As the storm moves ashore, it can push ocean water inland (this effect is known as “storm surge”) while spawning tornadoes and producing torrential rains and floods.

> **NOTE**
>
> FEMA P-320, *Taking Shelter from the Storm: Building a Safe Room for Your Home or Small Business*, also has guidance on building safe rooms for tornado and hurricane protection. FEMA P-320 presents a summary of storm hazards, guidance on planning for a safe room in a home or small business, and prescriptive designs of above-ground safe rooms that meet the design criteria of FEMA P-361 and the ICC 500 for residential and small community shelters.

The term “storm surge,” as used in FEMA P-320 and P-361, means an abnormal rise in sea level accompanying a hurricane or other intense storm, with a height that is the difference between the observed level of the sea surface and the level that would have occurred in the absence of the tropical cyclone. Storm surge is usually estimated by subtracting the normal or astronomic high tide from the observed storm tide (see Section B4.2.2.2 of FEMA P-361). The storm surge measurement does not include wave height unless specifically noted, which can add 3 feet or more.

On average, 10 tropical storms (6 of which become hurricanes) develop each year in the Atlantic Ocean.[2] Approximately five hurricanes strike the United States mainland every 3 years; two of those storms will be major hurricanes (Category 3 or greater on the Saffir-Simpson Hurricane Scale; see Table A2-1 in FEMA P-361). The loss of life and property from hurricane-generated winds and floodwaters can be staggering. Although these storms do not make landfall in the U.S. every year, 289 recorded hurricanes have made landfall between 1851 and 2011. Over one-third of these hurricanes (97) were classified as major hurricanes. And hurricanes between 1950 and 2011 resulted in 3,102 deaths[3] and a substantial number of injuries (as well as extensive personal property losses). Tornadoes of weak to moderate intensity (typically EF0 to EF2) occasionally accompany tropical storms and hurricanes that move over land. These tornadoes are usually to the east and ahead of the path of the storm center as it makes landfall.

> **CROSS-REFERENCE**
>
> The Saffir-Simpson Hurricane Scale is discussed in Section A2.1.1.2 of FEMA P-361.

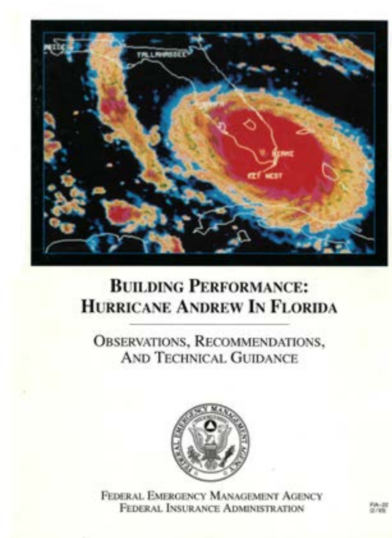
The term “typhoon” is used for Pacific tropical cyclones north of the equator and west of the International Dateline ([i.e., the Pacific Islands, including Guam and American Samoa]). In the Indian Ocean, similar storms are called “cyclones.” Like hurricanes and tornadoes, typhoons and cyclones can generate extreme winds, flooding, high-velocity flows, damaging waves, significant

[2] Hurricane occurrence data obtained from NOAA historical records. Note: Although the statistical set goes back to 1851, data records older than 1900 may underreport occurrences because many coastal communities had not yet been established.

[3] Source: http://www.ncdc.noaa.gov/stormevents/.

erosion, and heavy rainfall. Typhoons are classified by strength rather than by the Saffir-Simpson Hurricane Scale; typical typhoons have wind speeds less than 150 mph, while “super typhoons” have wind speeds of 150 mph or greater).

In recent years, several hurricanes have caused severe damage to coastal areas in the southern Atlantic and Gulf Coast regions of the United States. One hurricane that significantly affected not only the people and the community impacted, but also on design and construction requirements for all building types (residential, non-residential, and essential facilities), was Hurricane Andrew. The storm made landfall in southeastern Florida on August 24, 1992 and generated strong winds and heavy rains over a vast portion of southern Dade County. This Category 4/5 hurricane (which is defined as having sustained wind speeds of approximately 155 mph) produced extreme winds and high storm surge, but the most extensive damage was caused by winds and not the storm surge.



The storm caused unprecedented economic devastation; damage in the United States was estimated to be $21 billion in insured losses (adjusted for inflation to 2006 dollars). In Dade County, the storm forces caused 15 deaths and left almost one-quarter-million people temporarily homeless. Additional information about Hurricane Andrew was documented in the FEMA report *Building Performance: Hurricane Andrew in Florida*, FIA-22.

Facilities that have not been designed to any standard or criteria, but are designated as “shelters” are still perceived as areas intended to protect the lives of those taking refuge within them. When these “shelters” are damaged or fail, it undermines public confidence in the general idea of taking shelter. Often, there is a lack of understanding of what is required to provide life-safety protection from extreme-wind events. A variety of “shelter” types used before, during, and after storm events provide different levels of protection. If the building or structure selected for use as a shelter cannot withstand the effects of hurricane winds, the results can be devastating.

In 2004, Hurricane Charley hit Florida as a Category 4 hurricane. In an inland county, a facility had recently been constructed to design wind speeds above the 110 to 120 mph (3-second gust) wind speeds that were actually experienced. The building met minimum requirements established by the State for shelter facilities. The building was sheltering approximately 1,200 people when roof panels began lifting off and one end wall of the facility partially collapsed (see Figure 3). Shelter performance such as this prompts scrutiny of the different protection levels that have been developed over the years. It reinforces the need for better shelter design and construction guidance such as FEMA P-361 and the ICC 500, which address the entire design and construction life-cycle from planning through design and construction of the facility, and promote a life-safety level of protection for shelter occupants.

Figure 3. Severely damaged hurricane shelter at Turner Agri-Civic Center, Arcadia, Florida (2004)

One of the most devastating hurricanes in recent years was Hurricane Katrina, the third strongest hurricane to make landfall in the history of the United States. Though crossing Florida as only a moderate Category 1 hurricane, it moved into the Gulf of Mexico where it rapidly increased to a Category 5 hurricane. After weakening 24 hours prior to landfall, Katrina came ashore as a Category 3 storm in Louisiana and Mississippi. Hurricane Katrina went on to cause over 1,800 deaths and $81.2 billion in insured losses (making it the largest natural disaster in U.S. history). The storm caused the levees to break in New Orleans, pushing floodwaters throughout much of the city, and caused tremendous damage to many cities and towns all along the Mississippi coast.

After the storm, FEMA dispatched a MAT to assess the performance of buildings impacted by the storm (see FEMA 549, *Hurricane Katrina in the Gulf Coast* [2006]). Among the many findings and conclusions made by the MAT, it was determined that buildings functioning as critical and essential facilities (which were often used as shelters during the storm) did not perform better than their commercial counterparts. The same construction issues that affected residential and commercial buildings were observed in critical and essential facilities, the very facilities that the public regularly assumes have to been hardened to resist hurricane winds and floodwaters.

Hurricane Sandy made landfall on October 29, 2012 on the East Coast of the United States. This was the third-costliest hurricane in U.S. history and affected 24 states across the northeastern and mid-Atlantic areas, with New York and New Jersey being the most severely damaged. Total economic losses were estimated to be $50 billion. FEMA deployed a MAT composed of national and regional experts to assess the performance of buildings in New Jersey and New York. It was observed that the wind speeds of Hurricane Sandy were below the design wind event; however, flooding caused significant damage to structures, critical facilities, and infrastructure. Most damage was from inundation. Additional information can be found in the MAT report, *Hurricane Sandy in New Jersey and New York*, FEMA P-942 (2013).

The events discussed represent just a small sampling of the deadly and destructive potential of hurricanes, and continue to illustrate the compelling need for shelters and safe rooms capable of protecting human lives. FEMA P-361 contains design criteria for the design and construction of community safe rooms for facilities that can resist such wind forces.

Post-Disaster Assessments, Research, and Design Development

When a hurricane, tornado, earthquake, or terrorist attack results in a catastrophic natural or manmade disaster in the United States or one of its territories, FEMA frequently deploys a technical building sciences team or MAT to document the performance of the built environment during the event. The objectives of a MAT are to inspect damage to buildings, assess the performance of the buildings, evaluate design and construction practices, and evaluate building code requirements and enforcement. The MAT then makes recommendations for improving building performance in future storm events. The MAT consists of representatives from FEMA Headquarters, the FEMA Regional offices, State and local governments, and public and private sector experts in design, construction, and building code development and enforcement.

> **NOTE**
>
> **The MAT Process:** In response to catastrophic hurricanes, floods, tornadoes, earthquakes, and other disasters, FEMA often deploys Mitigation Assessment Teams (MATs) to conduct field investigations at disaster sites. More information about the MAT program can be found at https://www.fema.gov/mitigation-assessment-team-program.

The findings from MATs have uncovered building science issues of national significance that warrant further study. Since Hurricane Opal in 1989, MATs (and building science teams from preceding programs, such as the Building Performance Assessment Team [BPAT] program) have studied and reported on more than 10 major hurricane or tornado events. In addition, FEMA uses smaller technical field assessment teams to support the MAT and other post-disaster activities to further document the performance of buildings and shelters during these events. For example, in 2007, in response to numerous tornado outbreaks, FEMA ordered several teams into the field to assess building performance, damage, and associated issues. These teams produced a series of technical safe room and building improvement documents: five February 2007 Tornado Recovery Advisories (RAs) (FEMA DR-1679, http://www.fema.gov/library/viewRecord.do?id=2631) and three May 2007 Tornado RAs (FEMA DR-1699, https://www.fema.gov/media-library/assets/documents/11953). These were prepared for public release to aid in post-disaster reconstruction. The RAs contain facts about tornadoes, their effects on various types of construction from manufactured housing to community safe rooms, the risk of tornado events in different regions of the country, and potential mitigation actions that can be taken to reduce damage to both older and new manufactured homes.

Additionally, studies have been conducted since the early 1970s to determine design parameters for safe rooms intended to protect people from tornadoes, hurricanes, and other extreme-wind events. In 1998, using the results of research conducted by Texas Tech University's (TTU's)

National Wind Institute (NWI) (formerly the Wind Science and Engineering [WISE] Research Center and before that the Wind Engineering Research Center [WERC]), FEMA developed design guidance and construction plans for in-home safe rooms and released the publication *Taking Shelter from the Storm: Building a Safe Room Inside Your House* (FEMA 320). This was the first predecessor of the current publication FEMA P-320, *Taking Shelter from the Storm: Building a Safe Room for Your Home or Small Business*, Fourth Edition (2014).

Since the original guidance was published, several significant tornado and hurricane events have occurred. Moreover, considerable engineering and scientific research and investigations have been conducted that have resulted in important findings. Using the original FEMA 361 publication as guidance, the International Code Council (ICC) in partnership with FEMA and the National Storm Shelter Association (NSSA), formed a national committee that developed and released a consensus standard to codify the design and construction requirements of extreme-wind storm shelters. The latest version of this standard, the *ICC/NSSA Standard for the Design and Construction of Storm Shelters* (ICC 500), was released in December of 2014. ICC 500 is referenced by the 2009, 2012, and 2015 International Building Codes® (IBC®) and the International Residential Codes® (IRC®). The third edition of FEMA P-361 is the most up-to-date and is arranged to align with the ICC 500.

FEMA P-361 builds on the knowledge of field investigations, research, and technical reports and

NOTE

FEMA TR-83B, Tornado Protection: Selecting and Designing Safe Areas in Buildings, and FEMA TR-83A, Interim Guidelines for Building Occupant Protection from Tornadoes and Extreme Winds, were the two publications that led the movement towards FEMA's safe room publications.

publications prepared by FEMA and other national and State agencies that have studied the performance of the built environment during tornadoes and hurricanes. FEMA remains committed to the development of design and construction criteria and guidance for safe rooms capable of providing the highest quality life-safety protection from extreme-wind events. Table 1 lists safe room and shelter publications and guidance documents that FEMA has produced over the past 40 years.

Table 1. Past and Present FEMA Safe Room and Relevant Shelter Publications and Guidance

Date	Publication
July 1973	TR-79, *Schools in Kansas with Tornado Protection* (Defense Civil Preparedness Agency)
July 1975	Wind-Resistant Design Concepts for Residences (Defense Civil Preparedness Agency)
January 1980	TR-83A, *Interim Guidelines for Building Occupant Protection from Tornadoes and Extreme Winds* (Defense Civil Preparedness Agency)
October 1982	TR-83B, *Tornado Protection: Selecting and Designing Safe Areas in Buildings* (Defense Civil Preparedness Agency)
February 1993	FIA 22, *Mitigation Assessment Team Report: Hurricane Andrew in Florida*
September 1998	FEMA 320, *Taking Shelter from the Storm: Building a Safe Room Inside Your House* (First Edition)
May 1999	*National Performance Criteria for Tornado Shelters*
August 1999	FEMA 320, *Taking Shelter from the Storm: Building a Safe Room Inside Your House* (Second Edition)
October 1999	FEMA 342, *Building Performance Assessment Team Report – Midwest Tornadoes of May 3, 1999*
July 2000	FEMA 361, *Design and Construction Guidance for Community Shelters* (First Edition)
October 2001	FEMA 388, *Safe Room and Shelter Resource CD*
November 2003	FEMA 431, *Tornado Protection: Selecting Refuge Areas in Buildings* (in cooperation with the Florida Department of Community Affairs)
April 2005	FEMA 488, *Mitigation Assessment Team Report: Hurricane Charley in Florida*
August 2005	FEMA 489, *Mitigation Assessment Team Report: Hurricane Ivan in Alabama and Florida*
July 2006	FEMA 549, *Mitigation Assessment Team Report: Hurricane Katrina in the Gulf Coast*
February 2007	2007 *Tornadoes in Florida Recovery Advisories*

Date	Publication
May 2007	2007 *Tornadoes in Kansas Recovery Advisories*
August 2008	FEMA P-361, *Design and Construction Guidance for Community Safe Rooms* (Second Edition)
August 2008	FEMA P-320, *Taking Shelter from the Storm: Building a Safe Room for Your Home or Small Business* (Third Edition)
March 2009	FEMA 388, *Safe Room and Shelter Resource CD*
May 2012	FEMA P-908, *Spring 2011 Tornadoes: April 25-28 and May 22*
November 2013	FEMA P-942, *Hurricane Sandy in New Jersey and New York*
August 2014	FEMA P-1020, *Tornado: Moore, Oklahoma, May 20, 2013*
December 2014	FEMA P-320, *Taking Shelter from the Storm: Building a Safe Room for your Home or Small Business* (Fourth Edition)
March 2015	FEMA P-361, *Safe Rooms for Tornadoes and Hurricanes: Guidance for Community and Residential Safe Rooms* (Third Edition)
March 2015	FEMA 388, *Safe Room and Shelter Resource CD*