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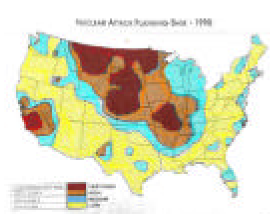
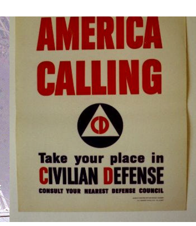
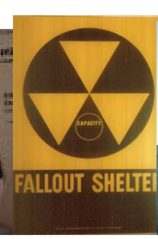


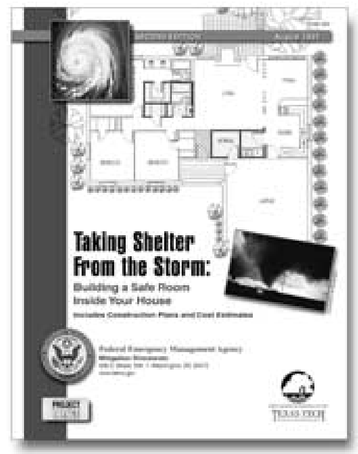


1 Introduction

1.1 Purpose

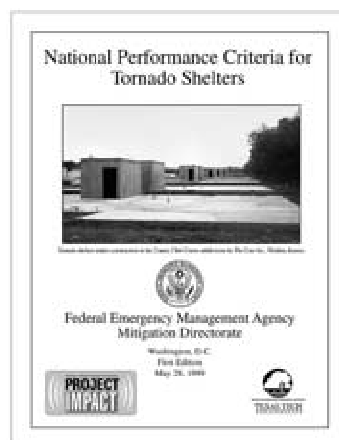
This document is a guidance manual for engineers, architects, building officials, and prospective shelter owners. It presents important information about the design and construction of community shelters that will provide protection during tornado and hurricane events. For the purpose of this manual, a *community shelter* is defined as a shelter that is designed and constructed to protect a large number of people from a natural hazard event. The number of persons taking refuge in the shelter will typically be more than 12 and could be up to several hundred or more. These numbers exceed the maximum occupancy of small, in-residence shelters recommended in FEMA 320, *Taking Shelter From the Storm: Building a Safe Room Inside Your House*.



This manual covers two types of community shelters:

- stand-alone shelter – a separate building (i.e., not within or attached to any other building) that is designed and constructed to withstand high winds and the impact of windborne debris (missiles) during tornadoes, hurricanes, or other extreme-wind events
- internal shelter – a specially designed and constructed room or area within or attached to a larger building; the shelter (room or area) is designed and constructed to be structurally independent of the larger building and to provide the same wind and missile protection as a stand-alone shelter

These shelters are intended to provide protection during a short-term high-wind event (i.e., an event that lasts no more than 36 hours) such as a tornado or hurricane. They are **not** recovery shelters intended to provide services and housing for people whose homes have been damaged or destroyed by fires, disasters, or catastrophes.



Both stand-alone and internal community shelters may be constructed near or within school buildings, hospitals and other critical facilities, nursing homes, commercial buildings, disaster recovery shelters, and other buildings or facilities occupied by large numbers of people. Stand-alone community shelters may be constructed in neighborhoods where existing homes lack shelters. Community shelters may be intended for use by the occupants of buildings they are constructed within or near, or they may be intended for use by the residents of surrounding or nearby neighborhoods or designated areas.

This manual provides detailed guidance concerning the design and construction of both stand-alone and internal community shelters for extreme-wind events—guidance that is currently not available in other design guides or in building codes or standards. This manual is a compilation of the best information available at the time of publication.

Shelters designed and constructed in accordance with the guidance presented in this manual provide "near-absolute protection" from extreme-wind events. Near-absolute protection means that, based on our knowledge of tornadoes and hurricanes, the occupants of a shelter built according to this guidance will be protected from injury or death. Our knowledge of hurricanes and tornadoes is based on substantial meteorological records as well as extensive investigations of damage from extreme winds. However, more extreme wind events may hypothetically exist, although they have not been observed. For this reason, the protection provided by these shelters is called near-absolute rather than absolute.

This manual discusses shelter location, design loads, performance criteria, and human factor criteria that should be considered for the design and construction of such shelters. Case studies—one for a stand-alone shelter and one for an internal shelter—are presented that illustrate how to evaluate existing shelter areas, make shelter selections, and provide construction drawings, emergency operation plans, and cost estimates.

Many factors may influence the decision to construct a community shelter. They include the following:

- the likelihood of an area being threatened by an extreme-wind event
- the consequences (deaths and injuries) of an extreme-wind event
- the cost of constructing a shelter

Therefore, this manual also provides decision-making tools that include shelter hazard evaluation checklists and economic analysis software. These tools provide an effective means of addressing all or many considerations that can affect the decision to either build or not build a community shelter.

1.2 Background

Sections 1.2.1 and 1.2.2 provide background information about tornadoes and hurricanes and about post-disaster assessments, research activities, and wind shelter design development carried out by the Federal Emergency Management Agency (FEMA) and other organizations.

1.2.1 Tornadoes and Hurricanes

Tornadoes and hurricanes are among the most destructive forces of nature. On average, more than 1,200 tornadoes have been reported nationwide each year since 1995. Since 1950, tornadoes have caused an average of 89 deaths and 1,521 injuries annually, as well as devastating personal and property losses. A tornado is defined as a violently rotating column of air extending from a thunderstorm to the ground. The most violent tornadoes are capable of tremendous destruction with wind speeds of 250 mph near ground level. Damage paths over 50 miles long and over 1 mile wide have been reported. Sixty-seven tornadoes struck Oklahoma and Kansas on May 3, 1999, including numerous F4 and F5 tornadoes. (F4 and F5 are classifications based on the Fujita Tornado Scale—see Table 3.1 in Chapter 3.) This tornado outbreak resulted in 49 deaths and leveled entire neighborhoods. (Additional information about the Oklahoma and Kansas tornadoes is available in the FEMA Building Performance Assessment Team report *Midwest Tornadoes of May 3, 1999*, FEMA 342.)

A hurricane is a type of tropical cyclone (the general term for all weather systems that circulate counterclockwise in the Northern Hemisphere over tropical waters) originating in the Atlantic Ocean, Caribbean Sea, or Gulf of Mexico. Around its core, winds can grow with great velocity, generating violent seas. As the storm moves ashore, it can push ocean waters inland while spawning tornadoes and producing torrential rains and floods. On average, 10 tropical storms (6 of which become hurricanes) develop each year in the Atlantic Ocean. 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 3.2 in Chapter 3). The loss of life and property from hurricane-generated winds and floodwaters can be staggering. Tornadoes of weak to moderate intensity occasionally accompany tropical storms and hurricanes that move over land. These tornadoes are usually to the right and ahead of the path of the storm center as it comes onshore.

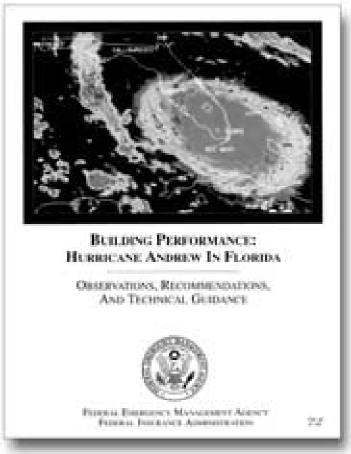
CROSS-REFERENCE

The **Saffir-Simpson Hurricane Scale** is discussed in Chapter 3.

In the western Pacific, hurricanes are called "typhoons" and affect the Pacific Islands, including Hawaii, Guam, and American Samoa; in the Indian Ocean, similar storms are called "cyclones." Like hurricanes and tornadoes, typhoons and cyclones can generate high winds, flooding, high-velocity flows, damaging waves, significant erosion, and heavy rainfall. Historically, typhoons have been classified by strength as either typhoons (storms with less than 150 mph winds) or super typhoons (storms with wind speeds of 150 mph or greater), rather than by the Saffir-Simpson Hurricane Scale.

An example of a hurricane that caused severe wind damage is Hurricane Andrew, which made landfall in southeastern Florida on August 24, 1992, generating strong winds and heavy rain over a vast portion of southern Dade

County. This Category 4 storm (which is defined as having a range of sustained wind speeds from 131 mph to 155 mph) produced high winds and high storm surge, but the most extensive damage was caused by wind. The storm caused unprecedented economic devastation; damage in the United States was in the tens of billions, making Andrew the most expensive natural disaster in U.S. history. In Dade County, the storm forces caused 15 deaths and left almost one-quarter million people temporarily homeless. (Additional information about Hurricane Andrew is provided in *Building Performance: Hurricane Andrew in Florida*, FIA-22.)



1.2.2 Post-Disaster Assessments, Research, and Design Development

When a catastrophic event such as a hurricane, tornado, or earthquake causes a natural disaster in the United States or one of its territories, FEMA frequently deploys a field investigation team consisting of representatives from FEMA Headquarters and the FEMA Regional Offices, state and local governments, and public and private sector organizations related to construction and building code development and enforcement. These teams are referred to as **Building Performance Assessment Teams** (BPATs). The objectives of a BPAT are to inspect damage to buildings, assess the performance of the buildings, evaluate design and construction practices, and evaluate building code requirements and enforcement in order to make recommendations for improving building performance in future storm events.

The BPAT Process: In response to catastrophic hurricanes, floods, tornadoes, earthquakes, and other disasters, FEMA often deploys BPATs to conduct field investigations at disaster sites. More information about the BPAT program can be found on the World Wide Web at www.fema.gov/mit/bpat.

During assessments conducted after extreme-wind events, BPATs have often found portions of otherwise destroyed buildings still standing. Frequently, these surviving portions are small rooms (e.g., a closet or bathroom) or a hallway located in the center of the building (see Figure 1-1). These observations suggest that an interior room within a house or other building could be designed and constructed to serve as a wind shelter.

Studies have been conducted since the early 1970s to determine design parameters for shelters intended to provide protection from tornadoes, hurricanes, and other extreme-wind events. In 1998, using the results of research conducted by Texas Tech University's Wind Engineering Research Center (WERC), FEMA developed design guidance and construction plans for in-home wind shelters and prepared the booklet *Taking Shelter From the Storm: Building a Safe Room Inside Your House,* FEMA 320. As the title suggests, the guidance presented in FEMA 320 is specific to small shelters built inside individual houses.

This manual builds on the information in FEMA 320 to provide design guidance for larger, community shelters for high-wind events.

Figure 1-1
Small interior room that survived a tornado.

1.3 Organization of the Manual

This manual consists of 11 chapters and 7 appendixes:

Chapter 2 describes the objectives of designing community shelters—the primary objective is the safety of the occupants within the shelters—and discusses risk assessment tools.

Chapter 3 describes the characteristics of tornadoes and hurricanes and their effects on structures.

Chapter 4 discusses shelter location concepts, including shelters accessed from the interior or exterior of a building, modifying and upgrading existing interior space, shelter location and accessibility, and types of shelters.

Chapter 5 details the wind load design criteria for shelter structures (e.g., determination of wind loads, protection against penetration by windborne missiles, and proper anchorage and connection).

Chapter 6 presents the performance criteria for windborne missile impacts, doors and door frames, windows, and roofs.

Chapter 7 discusses considerations regarding flood and seismic hazards, permitting, code compliance, and quality control.

Chapter 8 discusses the human factors criteria for shelters (e.g., proper ventilation, square footage per shelter occupant, accessibility, lighting, occupancy durations, emergency food and water, sanitary management, emergency supplies, and emergency power).

Chapter 9 discusses emergency management considerations, including parameters for developing a plan of action to respond to a high-wind event for both community shelters and shelters in commercial buildings, and preparation of a shelter maintenance plan.

Chapter 10 presents a commentary on the design and performance criteria.

Chapter 11 presents a list of references used in the preparation of this report.

Appendix A describes the FEMA shelter benefit/cost model, which is provided on a CD-ROM included in this appendix.

Appendix B contains checklists for use in assessing wind, flood, and seismic hazards at a potential shelter site.

Appendixes C and D present case studies in which community shelters were designed for two applications. Appendix C contains design plans for a community shelter intended to protect residents of manufactured housing provided by FEMA after Hurricane Floyd in North Carolina. Appendix D contains design plans for a shelter for a school building in Wichita, Kansas. The case studies include wind load analyses, detailed shelter design plans, and cost estimates.

Appendixes E and F present the results of missile impact tests on shelter wall sections, and shelter doors and door hardware, respectively.

Appendix G presents design guidance regarding impact protection for wood sheathing.