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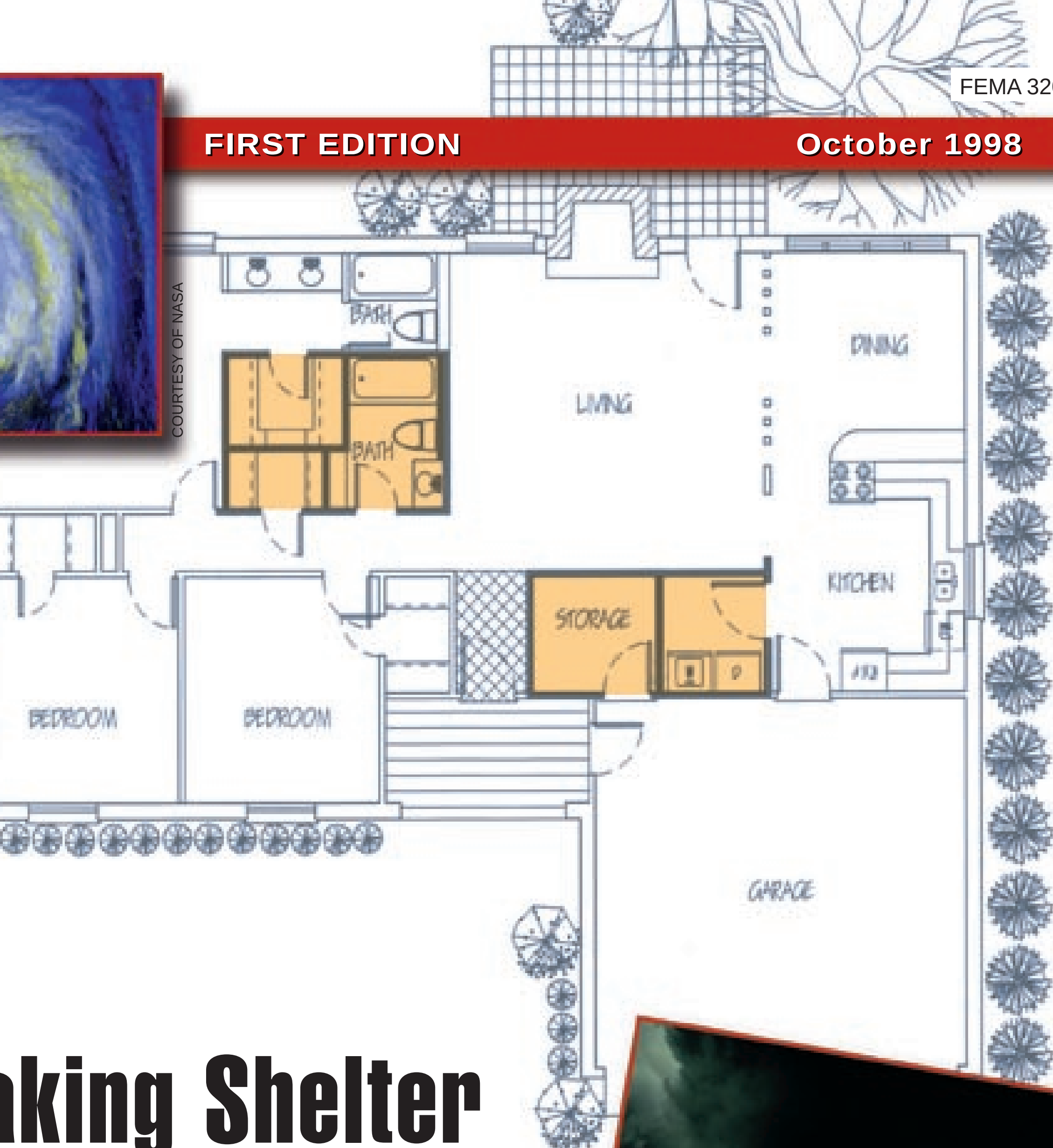

Taking Shelter From the Storm:

Building a Safe Room Inside Your House

COURTESY OF NOAA/NSSL

Includes Construction Plans and Cost Estimates

Federal Emergency Management Agency
Mitigation Directorate
500 C Street, SW. • Washington, DC 20472
www.fema.gov

WIND ENGINEERING RESEARCH CENTER
TEXAS TECH UNIVERSITY

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Taking Shelter from the Storm:
Building a Safe Room Inside Your House

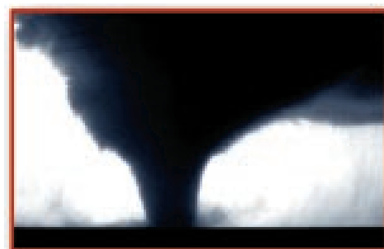
Table of Contents

Introduction

Every year, tornadoes, hurricanes, and other extreme windstorms injure and kill people, and damage millions of dollars worth of property in the United States. Even so, more and more people build houses in tornado- and hurricane-prone areas each year, possibly putting themselves into the path of such storms.

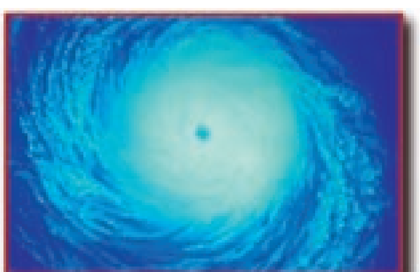
Having a shelter, or a safe room, built into your house can help you protect yourself and your family from injury or death caused by the dangerous forces of extreme winds. It can also relieve some of the anxiety created by the threat of an oncoming tornado or hurricane.

Should you consider building a shelter in your house to protect yourself and your family during a tornado or hurricane? The answer depends on your answers to many questions, including:



- Do you live in a high-risk area?
- How quickly can you reach safe shelter during extreme winds?
- What level of safety do you want to provide?
- What is the cost of a shelter?

This booklet will help you answer these and other questions so you can decide how best to protect yourself and your family. It includes the results of research that has been underway for more than 20 years, by Texas Tech University's Wind Engineering Research Center (WERC) and other wind engineering research facilities, on the effects of extreme winds on buildings.



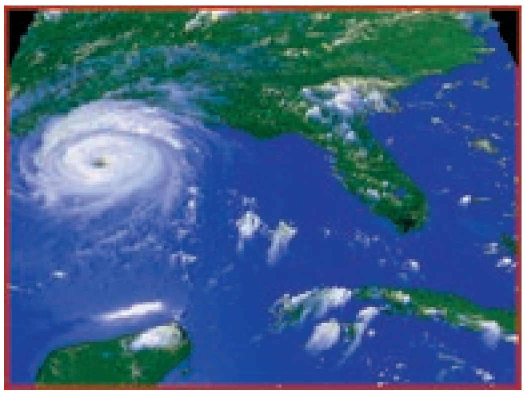
IMAGES COURTESY OF NOAA/
DEPARTMENT OF COMMERCE

This booklet also provides shelter designs that will show you and your builder/contractor how to construct a shelter underneath a new house, in the basement of a new house, or in an interior room of a new house, or how to modify an existing house to add a shelter in one of these areas. These shelters are designed to protect you and your family from the high winds expected during tornadoes and hurricanes and from flying debris, such as wood studs, that tornadoes and hurricanes usually create.

The National Association of Home Builders (NAHB) Research Center has evaluated these designs for construction methods, materials, and costs. Engineers at Texas Tech University have confirmed the design requirements for the expected forces from wind pressure and the impact of typical flying debris. The shelters are designed with life safety as the primary consideration.

Section I: Understanding the Hazards

Satellite picture of Hurricane Andrew taken August 25, 1992

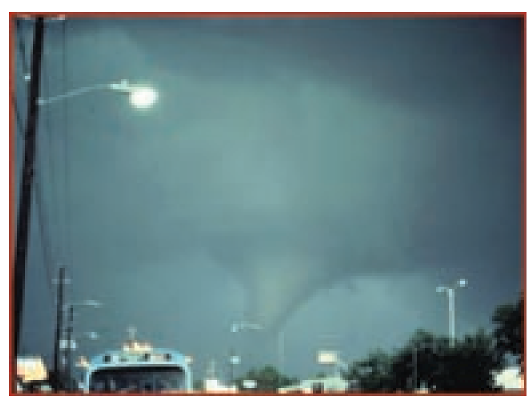


COURTESY OF NASA

Almost every state in the United States has been affected by extreme windstorms such as tornadoes and hurricanes. Virtually every state has been affected by a “considerable” tornado (see the terms in Table I.1). All Atlantic and Gulf of Mexico coastal areas in the United States – including coastal areas of Puerto Rico and the U.S. Virgin Islands – and coastal areas of Hawaii have been affected by hurricanes. Even in states not normally considered to be susceptible to extreme windstorms there are areas that experience dangerous high winds. These areas are typically near mountain ranges, and include the Pacific Northwest coast.

What Is a Tornado?

Tornadoes are categorized by the Fujita scale (see Table I.1). They typically occur in the spring and summer months, but can occur at any time in any part of the country. Tornadoes are sometimes spawned by hurricanes.



COURTESY OF NOAA, NATIONAL SEVERE STORMS LABORATORY (NSSL)

On May 26, 1981, a tornado moved through Dallas, Texas

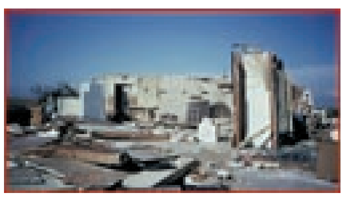
Table I.1
Typical tornado damage

Category / Typical Damage

F0 Light: Chimneys are damaged, tree branches are broken, shallow-rooted trees are toppled.

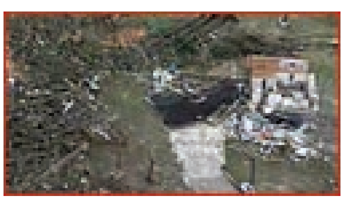
F1 Moderate: Roof surfaces are peeled off, windows are broken, some tree trunks are snapped, unanchored mobile homes are overturned, attached garages may be destroyed.

F2 Considerable: Roof structures are damaged, mobile homes are destroyed, debris becomes airborne (**missiles** are generated), large trees are snapped or uprooted.



F3 Severe: Roofs and some walls are torn from structures, some small buildings are destroyed, non-reinforced masonry buildings are destroyed, most trees in forest are uprooted.

F4 Devastating: Well-constructed houses are destroyed, some structures are lifted from foundations and blown some distance, cars are blown some distance, large debris becomes airborne.



F5 Incredible: Strong frame houses are lifted from foundations, reinforced concrete structures are damaged, automobile-sized missiles become airborne, trees are completely debarked.

F0, F1, AND F2 IMAGES COURTESY OF ANDREW DEVANAS, FLORIDA DIVISION OF EMERGENCY MANAGEMENT
F3, F4, AND F5 IMAGES COURTESY OF NOAA, NATIONAL SEVERE STORMS LAOBORATORY (NSSL)

DEFINITION

In this guide, the term **missiles** refers to debris and other objects picked up by the wind and moved with enough force to damage and even penetrate windows, doors, walls, and other parts of a building. In general, the stronger the wind, the larger and heavier the missiles it can carry and the greater the risk of severe damage. But even small stones, branches, and other lighter missiles can easily break glass doors and windows.

Not all parts of each state are at equal risk from tornadoes. For example, while Texas has the highest number of recorded tornadoes, the state's least tornado-prone area—along the Gulf Coast—has been hit by fewer tornadoes than northeastern Arkansas. Comparing the numbers of tornadoes recorded in different areas within a state can give you a better understanding of the potential tornado activity in those areas. Figure I.1 shows the numbers of tornadoes recorded per 1,000 square miles in the United States and its possessions and territories.

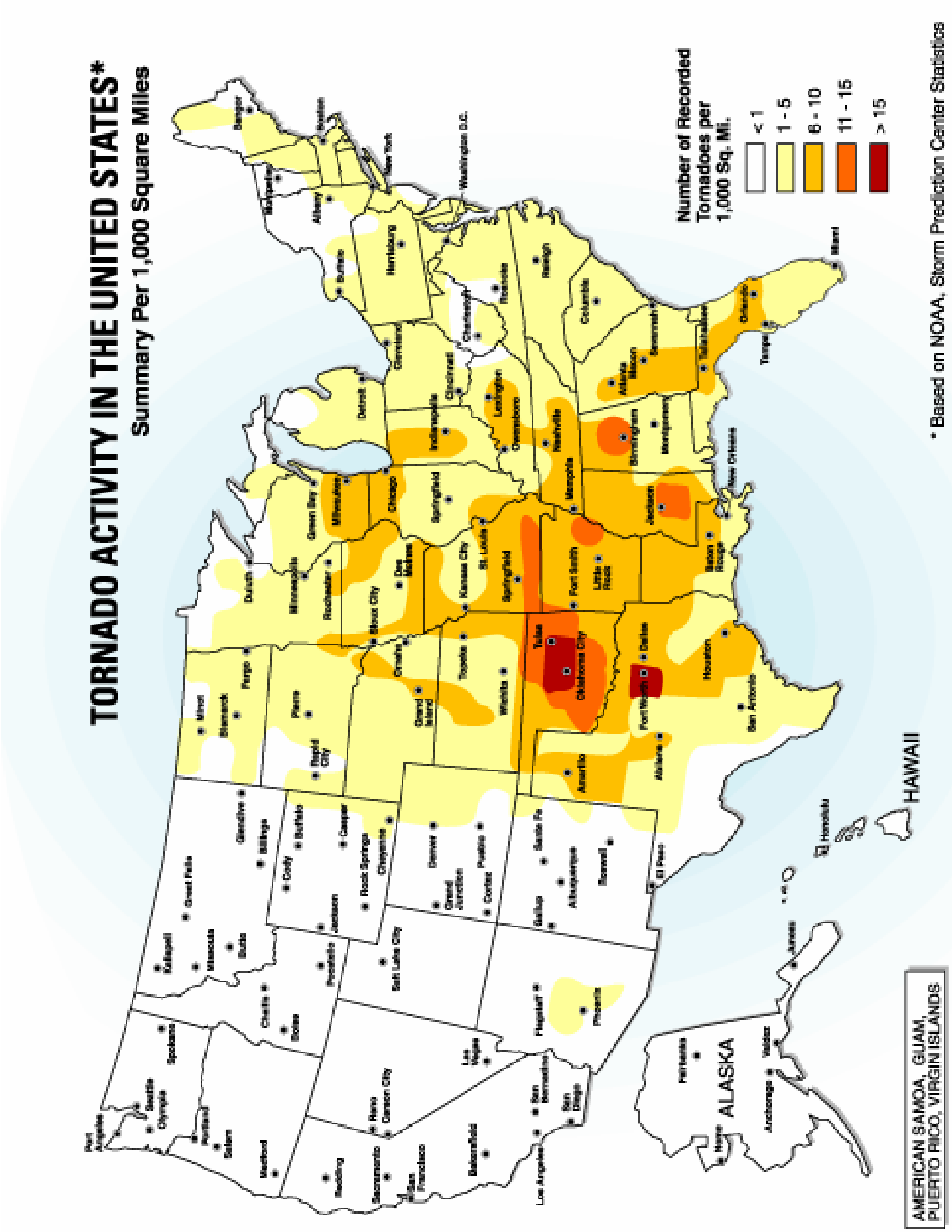


Figure I.1 The number of tornadoes recorded per 1,000 square miles

What Is a Hurricane?

Hurricanes are categorized by the Saffir-Simpson scale (see Table I.2).

Table I.2 Typical hurricane damage

Category / Typical Damage

C1 Minimal: Damage is done primarily to shrubbery and trees, unanchored mobile homes are damaged, some signs are damaged, no real damage is done to structures.

C2 Moderate: Some trees are toppled, some roof coverings are damaged, major damage is done to mobile homes.

C3 Extensive: Large trees are toppled, some structural damage is done to roofs, mobile homes are destroyed, structural damage is done to small homes and utility buildings.

C4 Extreme: Extensive damage is done to roofs, windows, and doors; roof systems on small buildings completely fail; some curtain walls fail.

C5 Catastrophic: Roof damage is considerable and widespread, window and door damage is severe, there are extensive glass failures, some complete buildings fail.

C1, C2, C3, C4 IMAGES: FEMA
C5 IMAGE COURTESY OF NOAA, HISTORICAL DATA COLLECTION

In the United States, 158 hurricanes were recorded to have made landfall between 1900 and1996. Hurricanes have made landfall in Florida more than in any other state. The second most hurricane-affected state is Texas, but every state on the Gulf Coast and bordering the Atlantic Ocean, as well as U.S. island possessions and territories, are susceptible to damage caused by hurricanes.

In recent years, the U.S. territories of American Samoa and Guam have been seriously affected by numerous tropical cyclones.

Do You Need a Shelter?

On the basis of 40 years of tornado history and more than 100 years of hurricane history, the United States has been divided into four zones that geographically reflect the number and strength of extreme windstorms. Figure I.2 shows these four zones. Zone IV has experienced the most and the strongest tornado activity. Zone III has experienced significant tornado activity and includes coastal areas that are susceptible to hurricanes.

To learn more about the wind history for the area where you live, check with your local building official, meteorologist, emergency management official, or television weather reporter.

Your house is probably built in accordance with local building codes that consider the effects of minimum, "code-approved" design winds in your area. Building codes require that buildings be able to withstand a "*design"* wind event. A tornado or extreme hurricane can cause winds much greater than those on which local code requirements are based. Having a house built to "code" does not mean that your house can withstand wind from any event, no matter how extreme. The shelter designs in this booklet provide a place to seek safe shelter during these extreme wind events.

The worksheet on pages 7 and 8 will help you determine your level of risk from these extreme events and will assist you in your consideration of a shelter. If you decide that you need a shelter, Section II will help you and your builder/contractor plan your shelter.

DEFINITION

In this guide, the term **storm surge** refers to the rise in the level of the ocean that results from the effects of wind and the drop in atmospheric pressure associated with hurricanes and other storms.

WARNING

A shelter designed to protect you and your family from a hurricane should not be built in an area expected to be flooded during a hurricane. Residents of these hazardous coastal areas should abide by the warnings of their local emergency services personnel and evacuate to safer ground. The protection from wind provided by safe rooms and shelters is quickly negated when stranded homeowners find themselves trapped by flood waters.

If you do not know whether your house is in a **storm surge** area or other area subject to flooding, check the community service section of your local phone book for storm surge evacuation information or ask your local emergency management or floodplain management official.

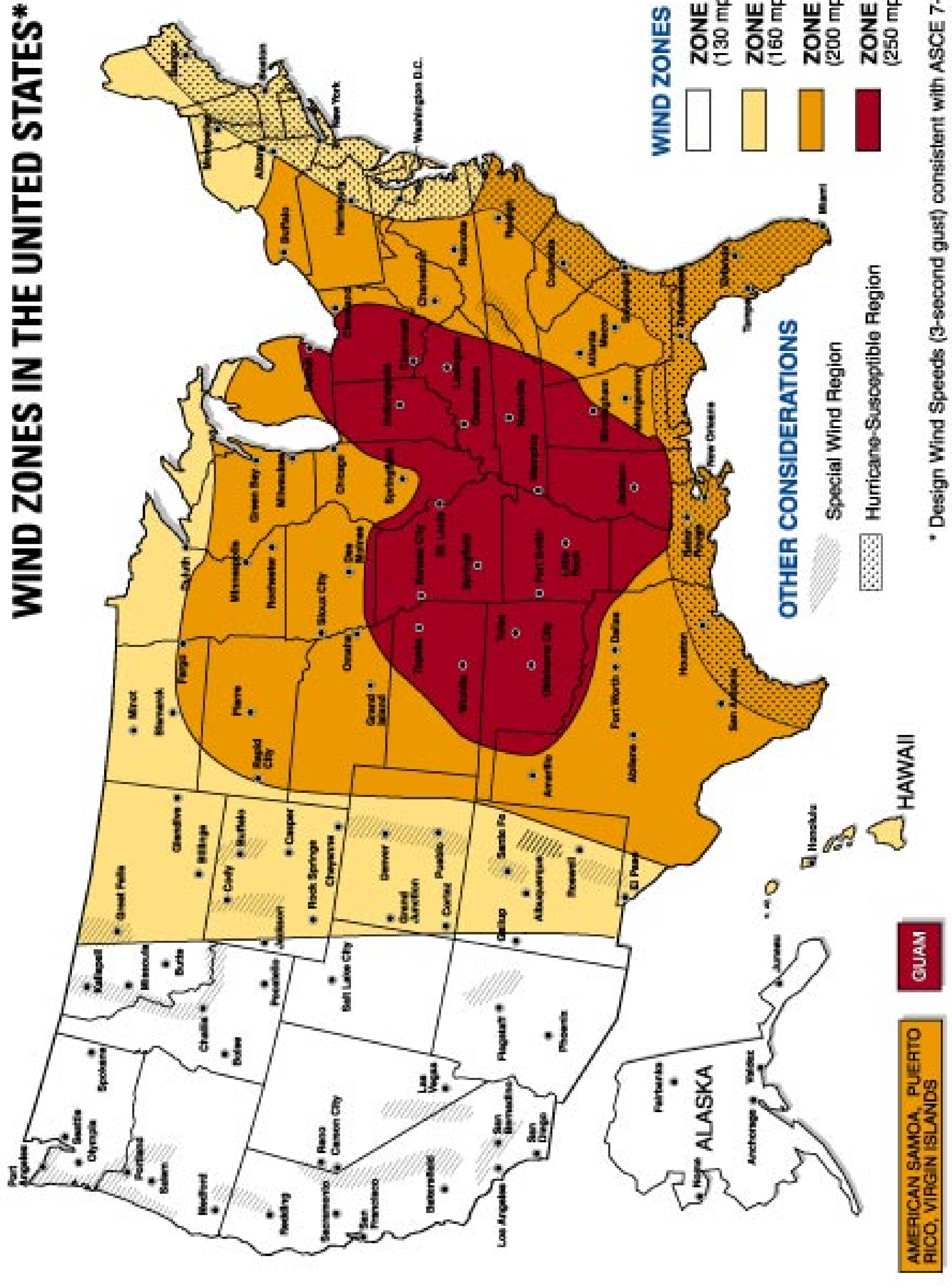
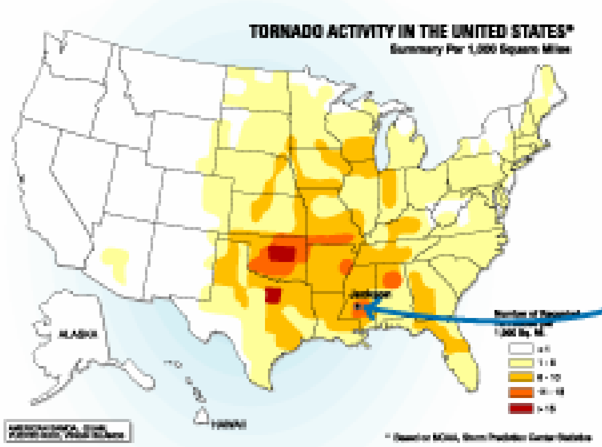


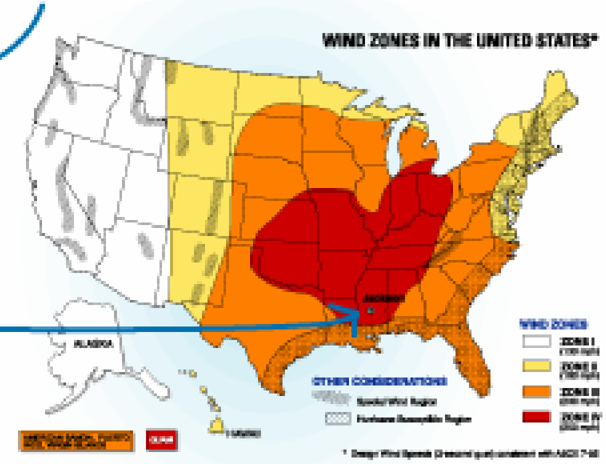
Figure I.2 Wind zones in the United States

Homeowner’s Worksheet: Assessing Your Risk

To complete the worksheet on the back of this page, refer to the tornado and wind zone maps on pages 3 and 6 (Figures I.1 and I.2). Using the map on page 3, note how many tornadoes were recorded per 1,000 square miles for the area where you live. Find the row on the worksheet that matches that number. Next, look at the map on page 6 and note the wind zone (I, II, III, or IV) in which you live. Find the matching column on the worksheet. Finally, find the box inside the worksheet that lines up with both the number of tornadoes per 1,000 square miles in your area and your wind zone. The color of that box tells you the level of your risk from extreme winds and helps you decide whether to build a shelter.



For example, if you live in Jackson, Mississippi, you would see that Jackson is in an area shaded medium orange on the map on page 3. So according to the map key, the number of tornadoes per 1,000 square miles in the Jackson area is 11 – 15.



On the map on page 6, Jackson appears within the red-shaded area. The map key tells you that Jackson is in Wind Zone IV.

The box where the 11-15 row and the Zone IV column meet is shaded dark blue, which shows that you live in an area of high risk. A shelter is the preferred method of wind protection in high-risk areas. Note that some areas of low or moderate risk, shown as pale blue or medium blue in the worksheet, are within the region of the United States that is subject to hurricanes (see Figure I.2). If you live in this hurricane-susceptible region, your risk is considered high, even if the worksheet indicates only a moderate or low risk.

NUMBER OF TORNADOES PER 1,000 SQUARE MILES (See Figure I.1)	WIND ZONE (See Figure I.2) I	II	III	IV
<1	LOW RISK	LOW RISK ★	LOW RISK ★	MODERATE RISK
1 - 5	LOW RISK	MODERATE RISK ★	HIGH RISK	HIGH RISK
6 - 10	LOW RISK	MODERATE RISK ★	HIGH RISK	HIGH RISK
11 - 15	HIGH RISK	HIGH RISK	HIGH RISK	HIGH RISK
>15	HIGH RISK	HIGH RISK	HIGH RISK	HIGH RISK

NUMBER OF TORNADOES PER 1,000 SQUARE MILES (See Figure I.1)	WIND ZONE (See Figure I.2)			
	I	II	III	IV
<1	LOW RISK	LOW RISK ★	LOW RISK ★	MODERATE RISK
1 - 5	LOW RISK	MODERATE RISK ★	HIGH RISK	HIGH RISK
6 - 10	LOW RISK	MODERATE RISK ★	HIGH RISK	HIGH RISK
11 - 15	HIGH RISK	HIGH RISK	HIGH RISK	HIGH RISK
>15	HIGH RISK	HIGH RISK	HIGH RISK	HIGH RISK

LOW RISK
Need for high-wind shelter is a matter of homeowner preference

MODERATE RISK
Shelter should be considered for protection from high winds

HIGH RISK
Shelter is preferred method of protection from high winds

★ Shelter is preferred method of protection from high winds if house is in hurricane-susceptible region

Emergency Planning and Emergency Supply Kit

Whether or not you decide that you need a shelter in your house, you can take two important steps to protect yourself and your family during a hurricane or tornado: prepare an emergency plan and put an emergency supply kit together. If you decide to build a shelter, your emergency plan should include notifying local emergency managers and family members or others outside the immediate area that you have a shelter. This will allow emergency personnel to quickly free you if the exit from your shelter becomes blocked by debris. You should also prepare an emergency supply kit and either keep it in your shelter or be ready to bring it with you if you need to evacuate your house. Some of the items that the emergency supply kit should include are:

- an adequate supply of water for each person in your household
- non-perishable foods that do not have to be prepared or cooked (if these include canned goods, remember to bring a can opener)
- a first-aid kit, including necessary prescription medicines
- tools and supplies:
  – flashlight (do not bring candles or anything that lights with a flame)
  – battery-operated radio
  – cellular phone or CB radio
  – extra batteries
  – wrench (to turn off household gas and water)
  – clothing and bedding
- special items:
  – for baby— formula, diapers, bottles, powdered milk
  – for adults— contact lenses and supplies, extra glasses

You can get more information about emergency planning from American Red Cross (ARC) and FEMA publications, which you can obtain free of charge by calling FEMA at 1-800-480-2520, or by writing to FEMA, P.O. Box 2012, Jessup, MD 20794-2012. These publications include the following:

Emergency Preparedness Checklist, FEMA L-154 (ARC 4471)

Food and Water in an Emergency, FEMA L-164 (ARC 5055)

Your Family Disaster Supplies Kit, FEMA L-189 (ARC 4463)

Preparing for Emergencies, A Checklist for People with Mobility Problems, FEMA L-154 (ARC 4497)

These publications are also available on the World Wide Web at the FEMA web site – http://www.fema.gov – and at the American Red Cross web site – http://www.redcross.org.

Section II: Planning Your Shelter

Now that you better understand your risk from a tornado or hurricane, you can work with your builder/contractor to build a shelter to protect yourself and your family from these extreme windstorms. This section describes how extreme winds can damage a building, explains the basis of the shelter designs presented in this booklet, and shows where you can build a shelter in your house.

Building Damage

Extreme winds can cause several kinds of damage to a building. Figure II.1 shows how extreme winds affect a building and helps explain why these winds cause buildings to fail.

To understand what happens when extreme winds strike, you must first understand that tornado and hurricane winds are not constant. Wind speeds, even in these extreme wind events, rapidly increase and decrease. An obstruction, such as a house, in the path of the wind causes the wind to change direction. This change in wind direction increases pressure on parts of the house. The combination of increased pressures and fluctuating wind speeds creates stress on the house that frequently causes connections between building components to fail. For example, the roof or siding can be pulled off or the windows can be pushed in.

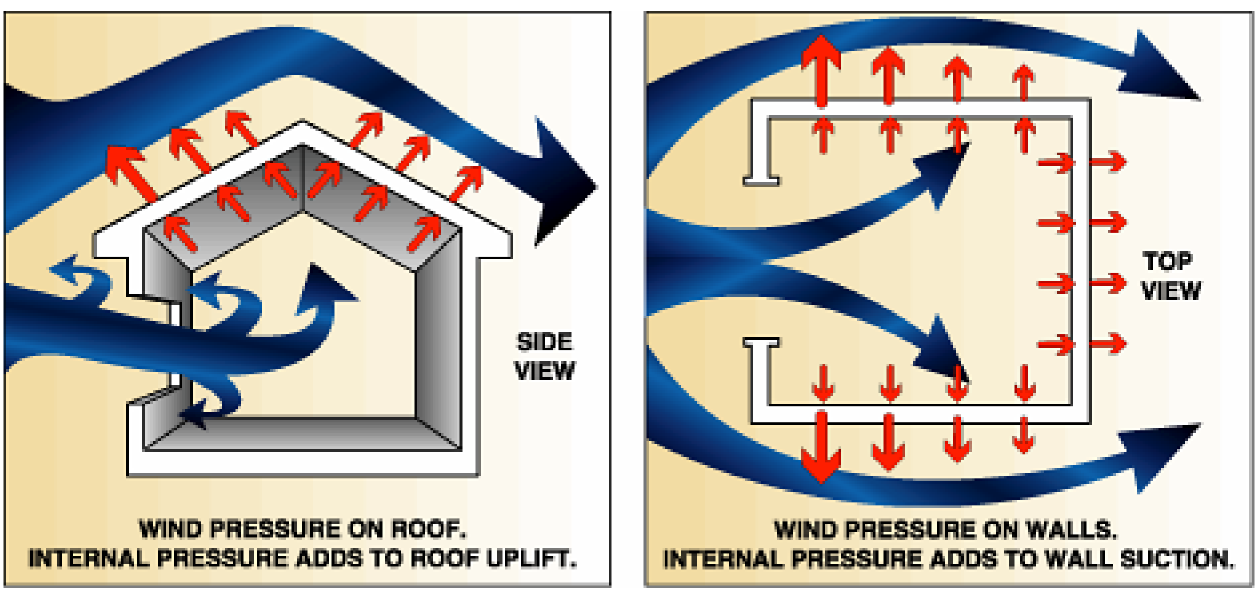


Figure II.1 Effect of extreme winds on building roof and walls

Buildings that fail under the effects of extreme winds often appear to have exploded, giving rise to the misconception that the damage is caused by unequal wind pressures inside and outside the building. This misconception has led to the myth that during an extreme wind event, the windows and doors in a building should be opened to equalize the pressure. In fact, opening a window or door allows wind to enter a building and increases the risk of building failure.

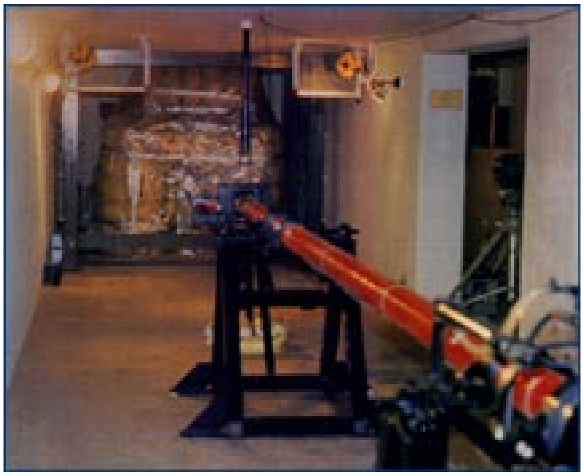
Damage can also be caused by flying debris (referred to as windborne missiles). If wind speeds are high enough, missiles can be thrown at a building with enough force to penetrate windows, walls, or the roof. For example, an object such as a 2” x 4” wood stud weighing 15 pounds, when carried by a 250-mph wind, can have a horizontal speed of 100 mph and enough force to penetrate most common building materials used in houses today. Even a reinforced masonry wall will be penetrated unless it has been designed and constructed to resist debris impact during extreme winds. Because missiles can severely damage and even penetrate walls and roofs, they threaten not only buildings but the occupants as well.

Palm tree pierced by plywood missile, Hurricane Andrew

Basis of Shelter Design

The purpose of a shelter is to provide a space where you and your family can survive a tornado or hurricane with little or no injury. In hurricane-prone areas, the shelter cannot be built where it can be flooded during a hurricane. Your shelter should be readily accessible from all parts of your house, and it should be free of clutter. To protect the occupants during extreme windstorms, the shelter must be adequately anchored to the house foundation to resist overturning and uplift. The connections between all parts of the shelter must be strong enough to resist failure, and the walls, roof, and door must resist penetration by windborne missiles.

Extensive testing by Texas Tech University and other wind engineering research facilities has shown that walls, ceilings, and doors commonly used in house construction cannot withstand the impact of missiles carried by extreme winds. The shelter designs in this booklet account for these findings by specifying building materials and combinations of building materials that will resist penetration by missiles in extreme winds.



Missile (debris) launcher, Wind Engineering Research Center (WERC), Texas Tech University

The shelter designs, including both materials and connections, are based on wind speeds that are rarely exceeded in the United States. Therefore, a shelter built according to these designs is expected to withstand the forces imposed on it by extreme winds without failing. Those forces may cause cracks or other signs of stress in the materials or connections used in the shelter, and they may cause materials or connections to yield. However, the intent of the designs is not to produce a shelter that will always remain completely undamaged, but rather a shelter that will enable its occupants to survive an extreme windstorm with little or no injury.

It is very important to note that predicting the exact strength of tornadoes and hurricanes is impossible. That is another reason why the shelter designs in this booklet are based on extreme wind speeds and why the primary consideration is life safety.

Designing a building to resist damage from more than one natural hazard requires different, sometimes competing, approaches. For example, building a structure on an elevated foundation to raise it above expected flood levels can increase its vulnerability to wind and seismic damage. These design approaches need to be thoroughly considered. In floodprone areas, careful attention should be given to the warning time, velocity, depth, and duration of flood waters. These flooding characteristics can have a significant bearing on the design and possibly even the viability of a shelter. Your local building official or licensed professional engineer or architect can provide you with information about other natural hazards that affect your area and can recommend appropriate designs.

2" x 4" wood stud launched at 100 mph pierces unreinforced masonry wall, WERC, Texas Tech University

Shelter Size

The amount of floor area per person that your shelter must provide depends partly on the type of windstorm the shelter is intended to protect you from. Tornadoes are not long-lasting storms, so if you are relying on your shelter only for tornado protection, you will not need to stay in the shelter for a long time. As a result, comfort is not of great concern, and a shelter that provides about 5 square feet of floor area per person will be big enough.

When the shelter is intended to provide protection from storms such as hurricanes, which can last up to 12 hours, the comfort of the occupants should be considered. For this type of shelter, the recommended amount of floor area per person is about 10 square feet. Necessities, such as water and toilet facilities, should be provided. The shelter designs in this booklet are based on a maximum floor area of 64 square feet and a maximum wall length of 8 feet. A shelter of that size used for hurricane protection can accommodate up to six people in reasonable comfort. If you plan to build a shelter with any wall longer than 8 feet, consult a licensed professional engineer or architect.

NOTE

The shelter designs in this booklet are applicable for any on-site construction. However, in a modular house, the shelter location would be limited to the basement or the belowground module. A modular house is a house constructed of modular units that have been built elsewhere, brought to the site, and installed on a permanent foundation.

New vs. Existing Houses

The shelter designs in this booklet were developed primarily for use in new houses, but some can be used in existing houses. When a new house is being built, the builder/contractor can construct walls, foundations, and other parts of the house as required to accommodate the shelter. Modifying the walls or foundation of an existing house as necessary for the construction of a shelter is more difficult. As a result, some of the shelter designs in this booklet are not practical for existing houses. The following sections discuss this issue further.

In this booklet, the term “retrofit” refers to the process of making changes to an existing house.

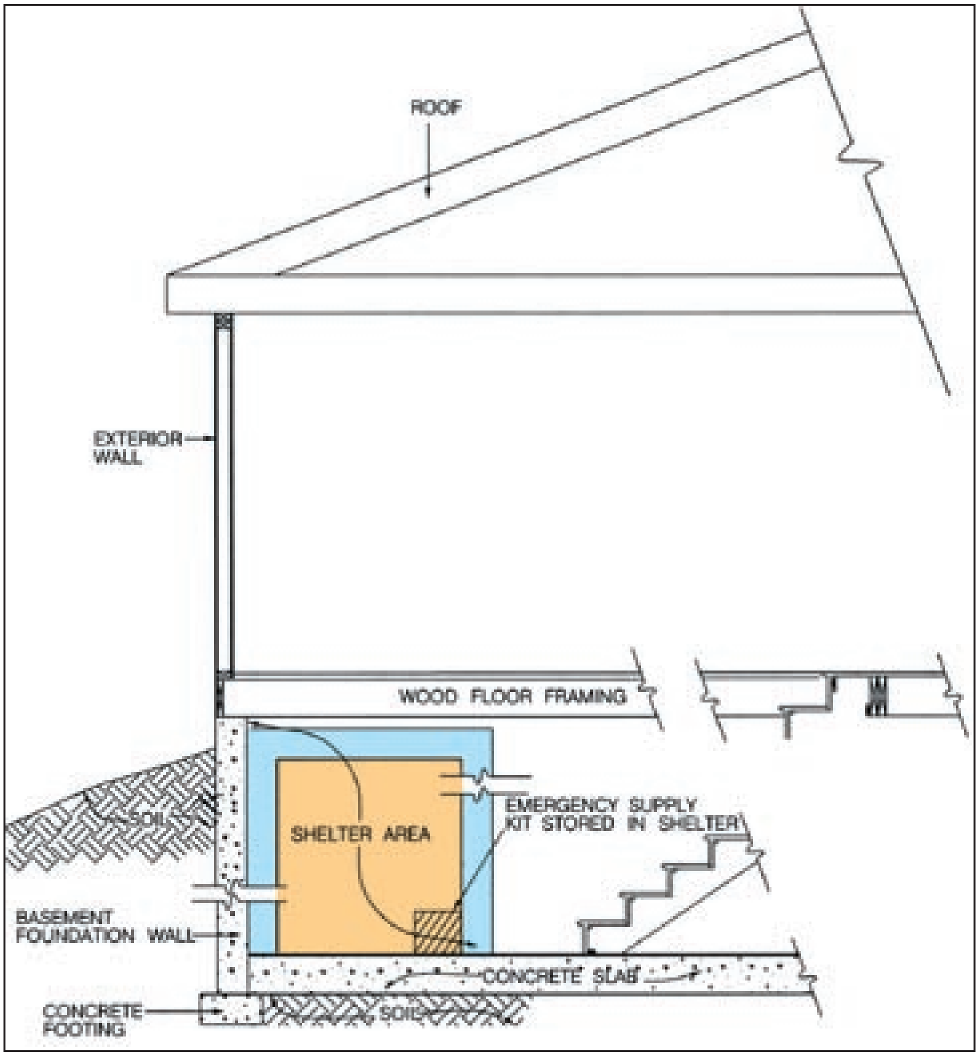
Foundation Types

Houses on the following types of foundations are suitable for the installation of a shelter:

- basement
- slab-on-grade
- crawlspace

A house on a basement foundation (see Figure II.2) is usually built on a foundation constructed of poured concrete or concrete masonry. Most concrete foundations are reinforced with steel bars or straps, but many concrete masonry foundation walls have no steel reinforcement. The framing for the floor above the basement is supported by the exterior foundation walls and sometimes by a center beam.

Figure II.2 Cross-section: typical basement foundation, with shelter



In a new or existing house with a basement, the shelter should be built in the basement. You can build the shelter as an entirely separate structure with its own walls, or you can use one or more of the basement walls as walls of the shelter. If you use the basement walls, they will have to be specially reinforced. Typical reinforcement techniques used in residential basement walls will not provide sufficient protection from missiles. In new construction, your builder/contractor can reinforce the walls near the shelter during the construction of your house. Reinforcing the basement walls of an existing house is not practical.

The likelihood of missiles entering the basement is lower than for above ground areas; however, there is a significant chance that missiles or falling debris will enter the basement through an opening left when a window, a door, or the first floor above has been torn off by extreme wind. Therefore, your basement shelter must have its own reinforced ceiling; the basement ceiling (the first floor above) cannot be used as the ceiling of the shelter.

The least expensive type of shelter that can be built in a basement is a lean-to shelter, which is built in the corner of the basement and uses two basement walls. The lean-to shelter uses the fewest materials, requires the least amount of labor, and can be built more quickly than other types of basement shelters.

In general, it is easier to add a basement shelter during the construction of a new house than to retrofit the basement of an existing house. If you plan to add a basement shelter as a retrofitting project, keep the following points in mind:

- You must be able to clear out an area of the basement large enough for the shelter.
- Unless the exterior basement walls contain steel reinforcement as shown on the design drawings provided with this booklet, these walls cannot be used as shelter walls since they are not reinforced to resist damage from missiles and uplift from extreme winds.
- Exterior basement walls that are used as shelter walls must not contain windows, doors, or other openings.
- The shelter must be built with its own ceiling, so that the occupants will be protected from missiles and falling debris.

A slab-on-grade house (see Figure II.3) is built on a concrete slab that is installed on compacted or natural soil. The concrete may be reinforced with steel that helps prevent cracking and bending. If you are building a new slab-on-grade house and want to install a concrete or concrete masonry shelter, your builder/contractor must make the slab thicker where the shelter will be built. The thickened slab will act as a footing beneath the walls of the shelter to provide structural support. It will also help anchor the shelter so that it will stay in place during an extreme wind event, even if the rest of the house is destroyed.

In an existing house, removing part of the slab and replacing it with a thickened section would involve extensive effort and disruption inside the house. Therefore, building a shelter with concrete or concrete masonry walls in an existing slab-on-grade house is generally not practical. You can, however, build a wood-frame shelter, because its walls are not as heavy and do not require the support of a thickened slab. A wood-frame shelter can be created from an existing room, such as a bathroom or closet, or built as a new room in an open area in the house, such as a garage.

You can also build a shelter as an addition to the outside of a slab-on-grade house. This type of shelter must have not only proper footings but also a watertight roof. Because a shelter built as an outside addition will be more susceptible to the impact of missiles, it should not be built of wood framing. Instead, it should be built of concrete or concrete masonry. Access to this type of shelter can be provided through an existing door or window in an exterior wall of the house.

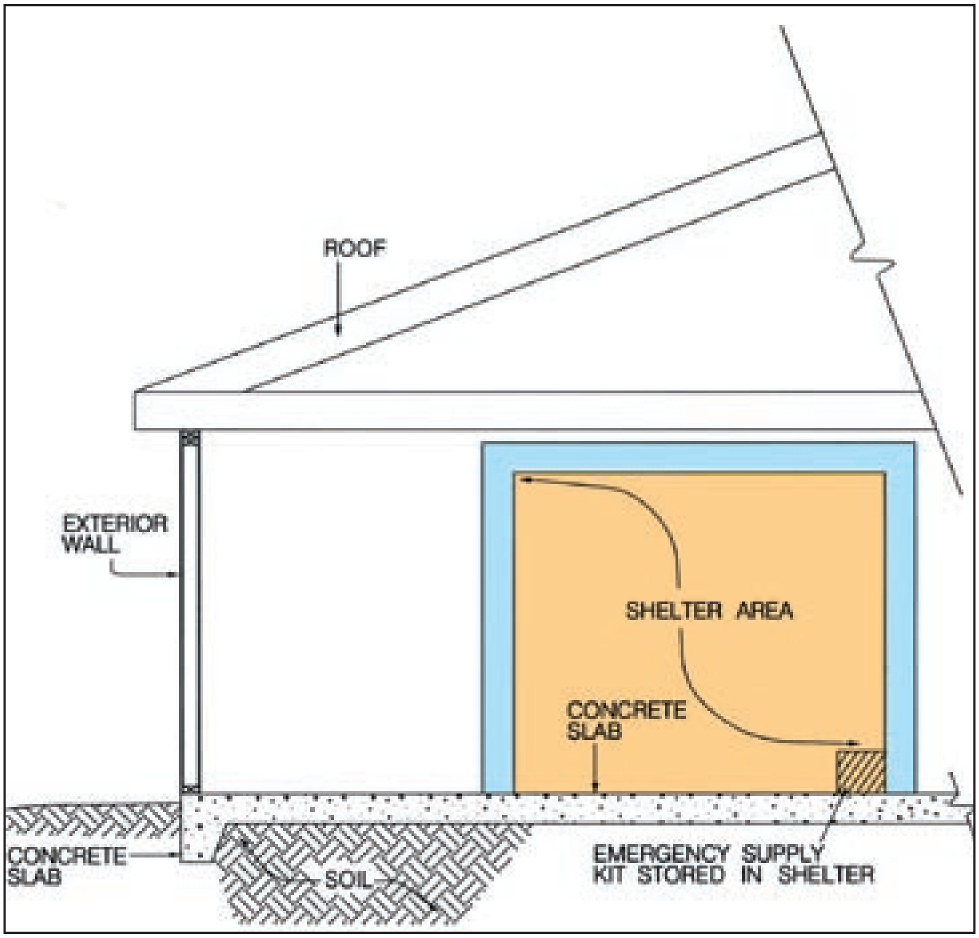


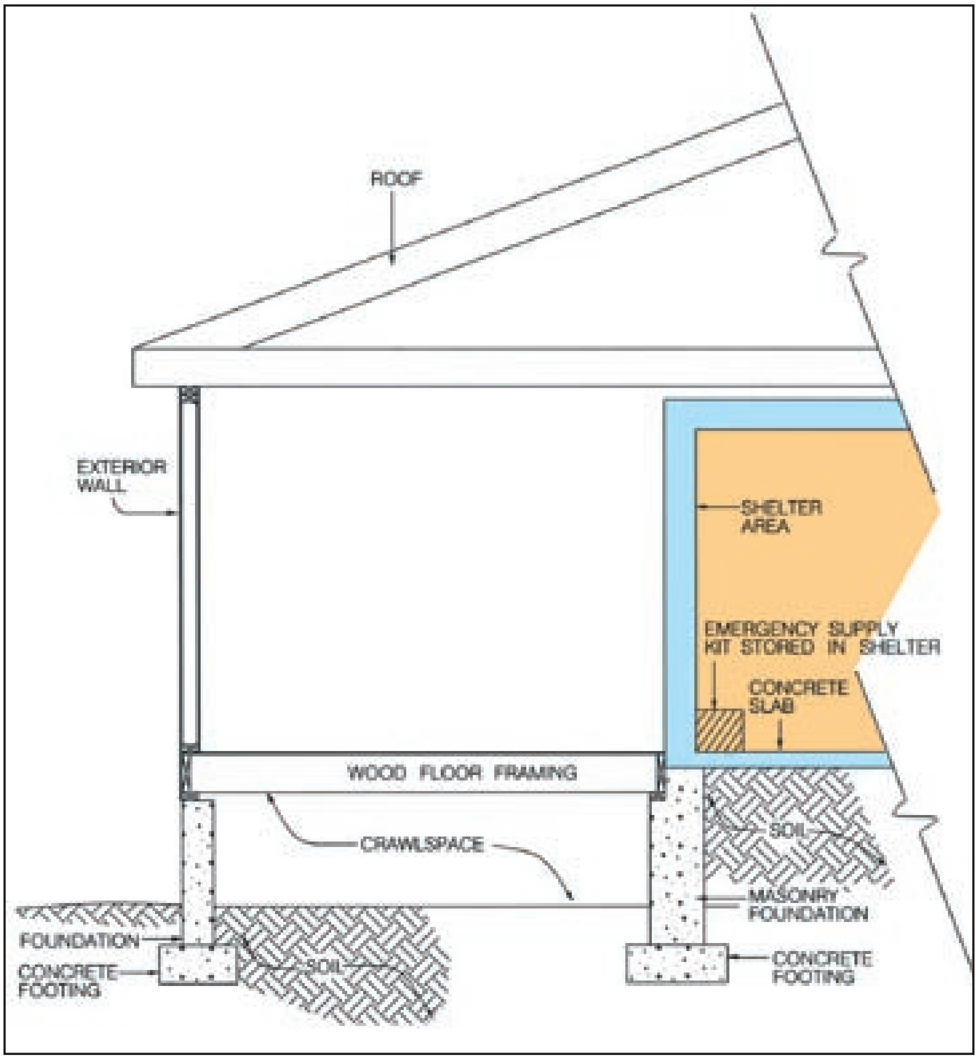
Figure II.3 Cross-section: typical slab-on-grade foundation, with shelter

In general, it is easier to add a shelter during the construction of a new slab-on-grade house than to retrofit an existing slab-on-grade house. If you plan to add a shelter to a slab-on-grade house as a retrofitting project, keep the following points in mind:

- The walls of the shelter must be completely separate from the structure of the house. Keeping the walls separate makes it possible for the shelter to remain standing even if portions of the house around it are destroyed by extreme winds.
- If you are creating your shelter by modifying a bathroom, closet, or other interior room with wood-frame walls, the existing walls, including sheathing on either the inside or outside of the walls, such as drywall or plaster, must be removed and replaced with walls and a ceiling resistant to the impact of windborne missiles and other effects of extreme winds.
- If you intend to build a shelter with concrete or concrete masonry walls, a section of your existing slab floor will have to be removed and replaced with a thicker slab. As noted above, this is usually not practical in an existing house.

A house built on a crawlspace (see Figure II.4) usually has a floor constructed of wood framing. Along its perimeter, the floor is supported by the exterior foundation walls. The interior part of the floor is supported by beams that rest on a foundation wall or individual piers. Crawlspace foundation walls may be concrete, but are usually constructed of concrete masonry. Crawlspace foundation walls are often unreinforced and therefore provide little resistance to the stresses caused by extreme winds.

Figure II.4 Cross-section: typical crawlspace foundation, with shelter



Building a shelter inside a house on a crawlspace foundation is more difficult than building a shelter inside a house on a basement or slab-on-grade foundation. The main reason is that the entire shelter, including its floor, must be separate from the framing of the house. As shown in Figure II.4, a shelter built inside the house cannot use the floor of the house. The shelter must have a separate concrete slab floor installed on top of earth fill and must be supported by concrete or concrete masonry foundation walls. An alternative approach, which may be more economical, is to build an exterior shelter on a slab-on-grade adjacent to an outside wall of the house and provide access through a door installed in that wall.

Ventilation in the area below the floor of the house is also an important issue. The wood-framed floor of a house on a crawlspace foundation is typically held 18 to 30 inches above the ground by the foundation walls. The space below the floor is designed to allow air to flow through so that the floor framing will not become too damp. It is important that the installation of the shelter not block this air flow.

In general, it is much easier to build a shelter inside a new crawlspace house than in an existing crawlspace house. If you plan to add a shelter to an existing crawlspace house as a retrofitting project, keep the following in mind:

- The shelter must have a separate foundation. Building the foundation inside the house would require cutting out a section of the existing floor and installing new foundation members, fill dirt, and a new slab – a complicated and expensive operation that is often not practical.
- A more practical and more economical approach would be to build an exterior shelter, made of concrete or concrete masonry, on a slab-on-grade foundation adjacent to an outside wall of the house, as described above.

WARNING

You should not install a shelter in a house supported by piles, piers, or columns. With building connectors commercially available, there is no economical way to separate the shelter from the floor framing and ensure that the shelter will withstand the forces of extreme winds.

You may be tempted to build a shelter under a house on a pile, pier, or column foundation. However, if the house is in a storm surge area or other flood hazard area, the area under the house would be below the flood level. A shelter built in that area would trap its occupants in rising flood waters. See the warning on page 5 for more information.

Shelter Location

There are several possible locations in your house for a shelter. Perhaps the most convenient and safest is below ground level, in your basement. If your house does not have a basement, you can install an in-ground shelter beneath a concrete slab-on-grade foundation or a concrete garage floor. Basement shelters and in-ground shelters provide the highest level of protection against missiles and falling debris.

Another alternative shelter location is an interior room on the first floor of the house. Researchers, emergency response personnel, and people cleaning up after a tornado have often found an interior room of a house still standing when all other above ground parts of the house have been destroyed. Closets, bathrooms, and small storage rooms offer the advantage of having a function other than providing occasional storm protection. Typically, these rooms have only one door and no windows, which makes them well-suited for conversion to a shelter. Bathrooms have the added advantage of including a water supply and toilet.

Regardless of where in your house you build your shelter, the walls and ceiling of the shelter must be built so that they will protect you from missiles and falling debris, and so that they will remain standing if your house is severely damaged by extreme winds. If sections of your house walls are used as shelter walls, those sections must be separated from the structure of the house. This is true regardless of whether you use interior or exterior walls of the house.

Figures II.5 through II.7 are typical floor plans on which possible locations for shelters are shown with yellow highlighting. These are not floor plans developed specifically for houses with shelters. They show how shelters can be added without changes to the layout of rooms.

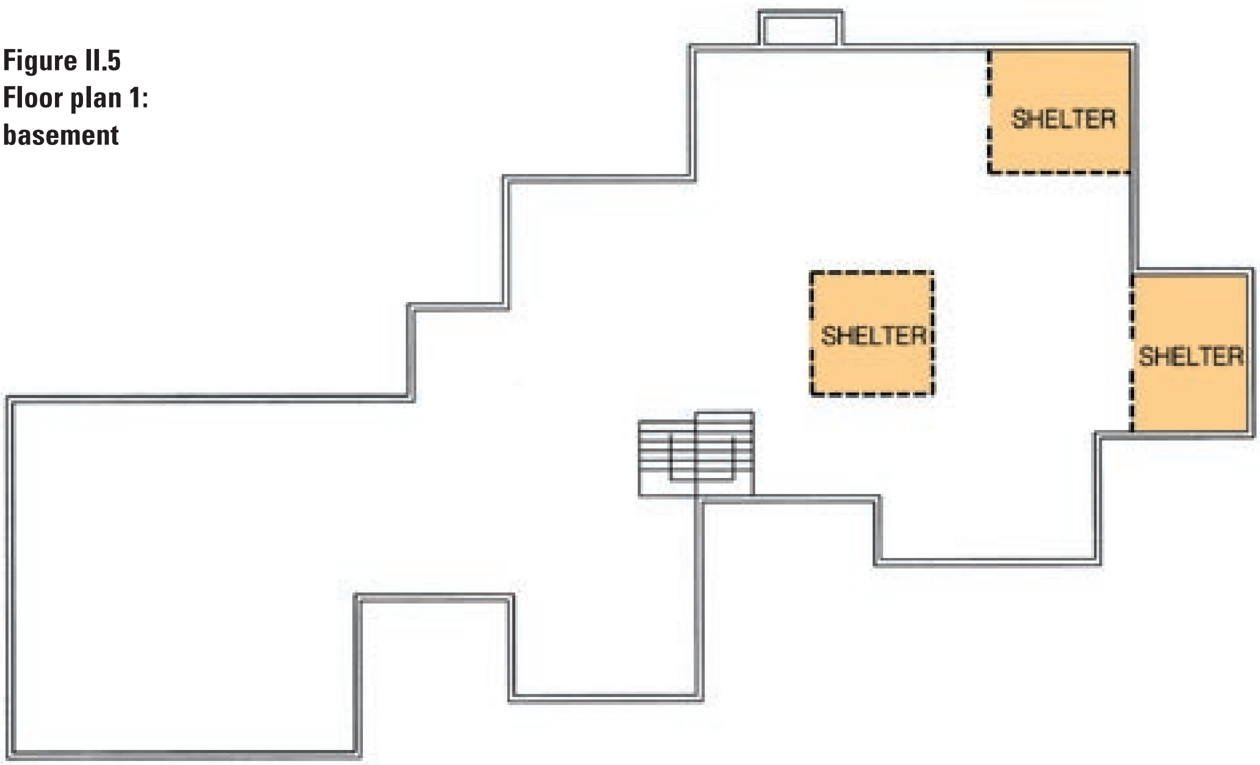
Floor Plan 1: basement

Possible shelter locations in a basement include the following:

- in a corner of the basement, preferably where the basement walls are below the level of the ground
- in a bathroom, closet, or other interior room in the basement
- in a freestanding addition to the basement

A space that is to be used for a shelter must be kept free of clutter so that the shelter can be quickly and easily entered and so that the shelter occupants will not be injured by falling objects. For this reason, a bathroom is often a better choice for a shelter than a closet or other space used for storage. Remember, if the basement is below the level of storm surge or the level of flooding from any other source, it is not a suitable location for a shelter. In this situation, a possible alternative would be to build an exterior shelter, adjacent to your house, on a slab-on-grade above the flood level.

Figure II.5
Floor plan 1:
basement



Floor Plan 2: house on a slab-on-grade or crawlspace foundation

Possible shelter locations in a house on a slab-on-grade or crawlspace foundation include the following spaces on the first floor:

- bathroom
- closet
- storage room
- laundry room (provided the load-bearing wall between it and the garage, as shown in Figure II.6, can be properly separated from the structure of the house)
- corner of the garage

Regardless of where the shelter is built, it must be equipped with a door that will resist the impact of missiles. Remember, if the first floor of the house is below the level of storm surge or the level of flooding from any other source, it is not a suitable location for a shelter. In this situation, a possible alternative would be to build an exterior shelter on a slab-on-grade elevated on fill above the flood level.

Figure II.6
Floor plan 2: house on slab-on-grade or crawlspace foundation

Floor Plan 3: house on a slab-on-grade foundation

Possible locations for an in-ground shelter include the following:

- below the slab in a closet or storage room
- below the floor of the garage, in an area where cars will not be parked

Because of the difficulty of installing an in-ground shelter in an existing house, this type of shelter is practical only for new construction. Remember, if the first floor of the house is below the level of storm surge or the level of flooding from any other source, it is not a suitable location for a shelter. In this situation, a possible alternative would be to build an exterior shelter on a slab-on-grade elevated on fill above the flood level.

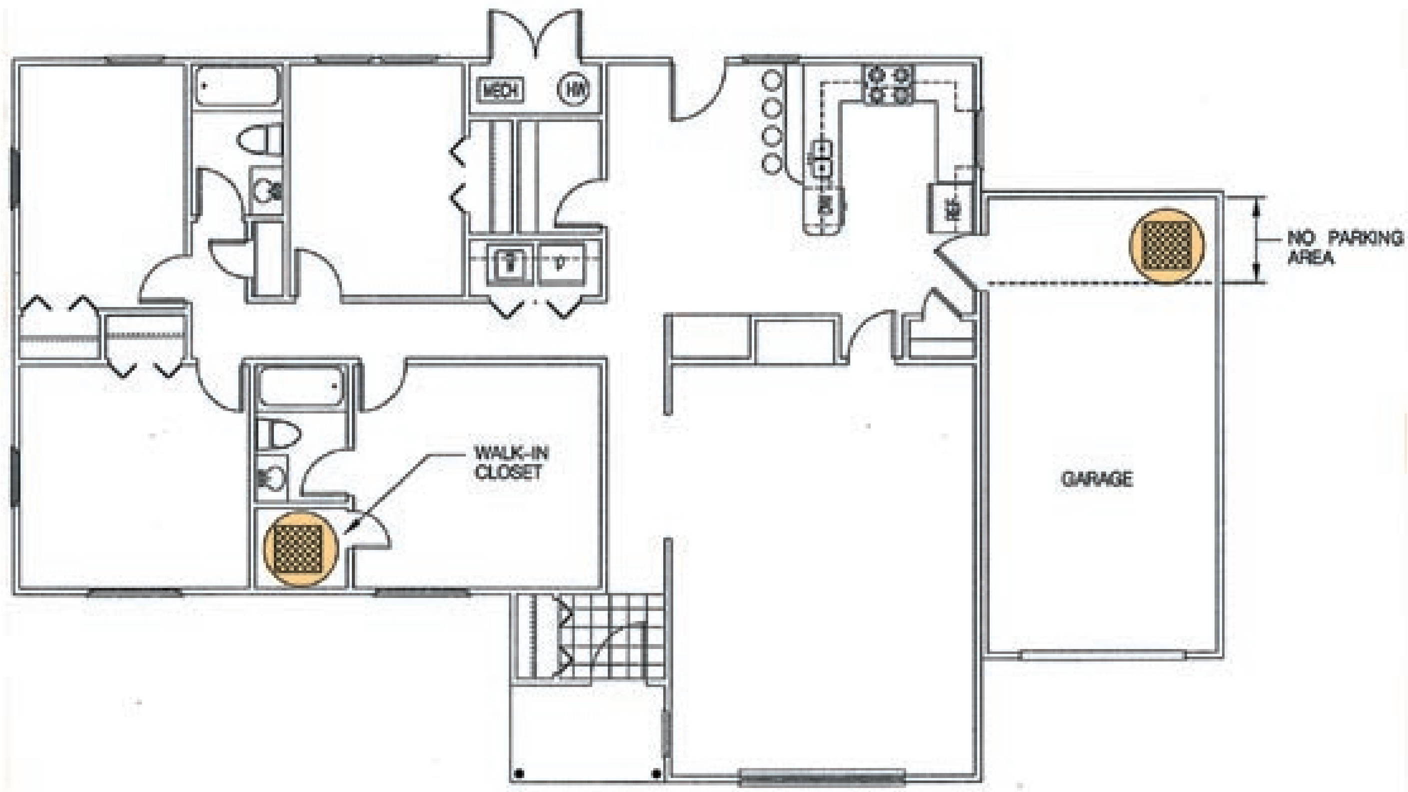


Figure II.7
Floor plan 3: house on slab-on-grade foundation

Tables II.1 and II.2 will help you decide what type of shelter is appropriate for your circumstances. Table II.1 applies to the construction of shelters in new houses. Table II.2 applies to retrofit situations, in which a shelter is being added to an existing house.

Table II.1
Appropriate types of shelters for new houses

	APPROPRIATE SHELTER TYPE		
SHELTER CONSIDERATIONS (NEW HOUSES)	BASEMENT	ABOVE-GROUND	IN-GROUND*
House located in storm surge area		✓	
House located in flood hazard area		✓	
High water table		✓	
Low cost	✓		✓
Long-term shelter occupancy	✓	✓	
Least likely to be hit by missiles			✓

Table II.2
Appropriate types of shelters for existing houses

	APPROPRIATE SHELTER TYPE		
SHELTER CONSIDERATIONS (EXISTING HOUSES)	BASEMENT	ABOVE-GROUND	IN-GROUND*
House located in storm surge area		✓	
House located in flood hazard area		✓	
High water table		✓	
Low cost	✓	✓	
Easiest retrofit	✓		
Long-term shelter occupancy	✓	✓	
Least likely to be hit by missiles			✓
Ease of separation from structural framing of house	✓		
Minimal disruption to house	✓		
Ease of accessibility		✓	

* The in-ground shelters referred to in this booklet are built belowground inside a house and therefore can be entered directly from within the house. Other types of in-ground shelters are available that are designed to be installed outside a house. Entering one of these exterior in-ground shelters would require leaving the house. This booklet does not contain any designs or other information about exterior in-ground shelters.

Construction Materials

The materials your builder/contractor will need to build your shelter should be available from building material suppliers in your community. These materials have been carefully selected for their strength, durability, and/or ability to be readily combined in ways that enable them to withstand the forces of extreme winds and the impact of windborne missiles. Your builder/contractor should not substitute any other material for those specified in the designs.

One of the most vulnerable parts of your shelter is the door. The materials specified for doors in the shelter designs in this booklet were tested by the Wind Engineering Research Center at Texas Tech University for their ability to carry wind loads and prevent penetration by missiles. The installation of the door is as important as the materials used in its construction. Please confirm with your builder/contractor that the door to your shelter can be installed the way it is shown in the designs included with this booklet.

A complete list of the shelter construction materials, with their expected strengths or properties, is included in the shelter designs provided in this booklet. Your builder/contractor should use it when buying the materials for your shelter.

Shelter Cost

The cost of your shelter will vary according to the following:

- the size of the shelter
- the location of the shelter
- the number of exterior house walls used in the construction of the shelter
- the type of door used
- the type of foundation on which your house is built
- your location within the United States (because of regional variations in labor and material costs)
- whether you are building a shelter into a new house or retrofitting an existing house

Table II.3 shows the average costs for building three types of shelters – lean-to, aboveground (AG), and in-ground – in new houses on basement, slab-on-grade, and crawlspace foundations according to the design plans in this booklet. These costs are for shelters with a floor area of 8 feet by 8 feet.

Table II.3 Average cost for an 8-foot by 8-foot shelter in a new house

FOUNDATION TYPE	SHELTER TYPE[1]	AVERAGE COST
Basement	Lean-To	$3,000
	AG – Reinforced Masonry	$3,500
	AG – Wood-Frame w/Plywood & Steel Sheathing	$5,000
	AG – Wood-Frame w/Concrete Masonry Unit Infill	$4,500
	In-Ground	NA
Slab-on-Grade	Lean-To	NA
	AG – Reinforced Masonry	$3,500
	AG – Wood-Frame w/Plywood & Steel Sheathing	$4,500[2]
	AG – Wood-Frame w/Concrete Masonry Unit Infill	$4,000[2]
	In-Ground	$2,000
Crawlspace	Lean-To	NA
	AG – Reinforced Masonry	$4,500
	AG – Wood-Frame w/Plywood & Steel Sheathing	$6,000
	AG – Wood-Frame w/Concrete Masonry Unit Infill	$5,500
	In-Ground	NA

NA = shelter type not applicable for the foundation type shown

[1] AG = aboveground shelter (which can also be built in a basement)

[2] A first-floor, wood-framed interior room, such as a bathroom or closet, would be a normal part of a new house; therefore, the dollar amount shown is the additional cost for building the room as a shelter rather than as a standard interior room.

The cost of retrofitting an existing house to add a shelter will vary with the size of the house and its construction type. In general, shelter costs for existing houses will be approximately 20 percent higher than those shown in Table II.3.

Section III: Building Your Shelter

Your builder/contractor can use the the design drawings in this booklet to build a shelter for any of the wind zones shown on the map in Figure I.2. The design drawings provided include the details for building five types of shelters: concrete, concrete masonry, wood-frame, lean-to, and in-ground. Each of these alternatives is expected to perform equally well in resisting material fatigue and connection failures caused by extreme winds.

The materials and connections were chosen for their “ultimate strength,” which means that the materials are expected to resist the loads imposed on them until they or the connections between them fail. The forces of extreme winds may cause cracks or other signs of stress in the materials or connections, and they may cause materials or connections to yield. However, the intent of the designs is not to produce a shelter that will always remain completely undamaged, but rather a shelter that will enable its occupants to survive an extreme windstorm with little or no injury. The shelter itself may need to be extensively repaired or completely replaced after an extreme wind event.

The shelter size and materials specified in the drawings are based on principles and practices used by structural engineering professionals and the results of extensive testing for effects of missile impact. Before increasing the shelter size or using material types, sizes, or spacings other than those specified in the drawings, review the changes with a licensed professional structural engineer.

The information in this section includes the following:

- design drawings and details for shelters in basements, above the ground, and in the ground
- designs for both slab-on-grade and crawlspace foundations
- general design notes and fastener and hardware schedules
- materials lists with quantities and specifications

The Wind Engineering Research Center at Texas Tech University has been involved in shelter design for many years. If you or your builder/contractor have questions about the design drawings in this booklet, call the Wind Engineering Research Center at (806) 742-3479, ext. 336 for technical guidance.

The following is an index of the design drawings provided in this booklet:

Sheet No.	Drawing No.*	Title
1 of 14	1	Index Sheet
2 of 14	2	General Notes
3 of 14	IG-1	In-Ground Shelter – Sections and Details
4 of 14	B-1	Basement Lean-To
5 of 14	B-2	Basement Shelter – Corner Location
6 of 14	AG-1	CMU/Concrete Alternative Plans
7 of 14	AG-2	CMU/Concrete Wall Sections
8 of 14	AG-3	CMU/Concrete Sections – Ceiling Alternatives
9 of 14	AG-4	Wood-Frame Shelter Plan – Plywood Sheathing w/ CMU Infill
10 of 14	AG-5	Wood-Frame Shelter Plan – Plywood and Steel Wall Sheathing
11 of 14	AG-6	Wood-Frame Shelter – Foundation Sections
12 of 14	12	Misc. Details
13 and 14 of 14	13 and 14	Materials Lists

* IG = In-Ground, B = Basement, AG = Aboveground

How To Use the Drawings

- Drawings shall not be scaled to determine dimensions.
- If there is a conflict between a dimension shown on the drawings and a scaled dimension, the dimension shown on the drawing shall govern.
- If there is a conflict between the drawings and local codes, the local codes shall govern.
- If there is a conflict among the general notes, specifications, and plans, the order of precedence is notes, then specifications, then plans.