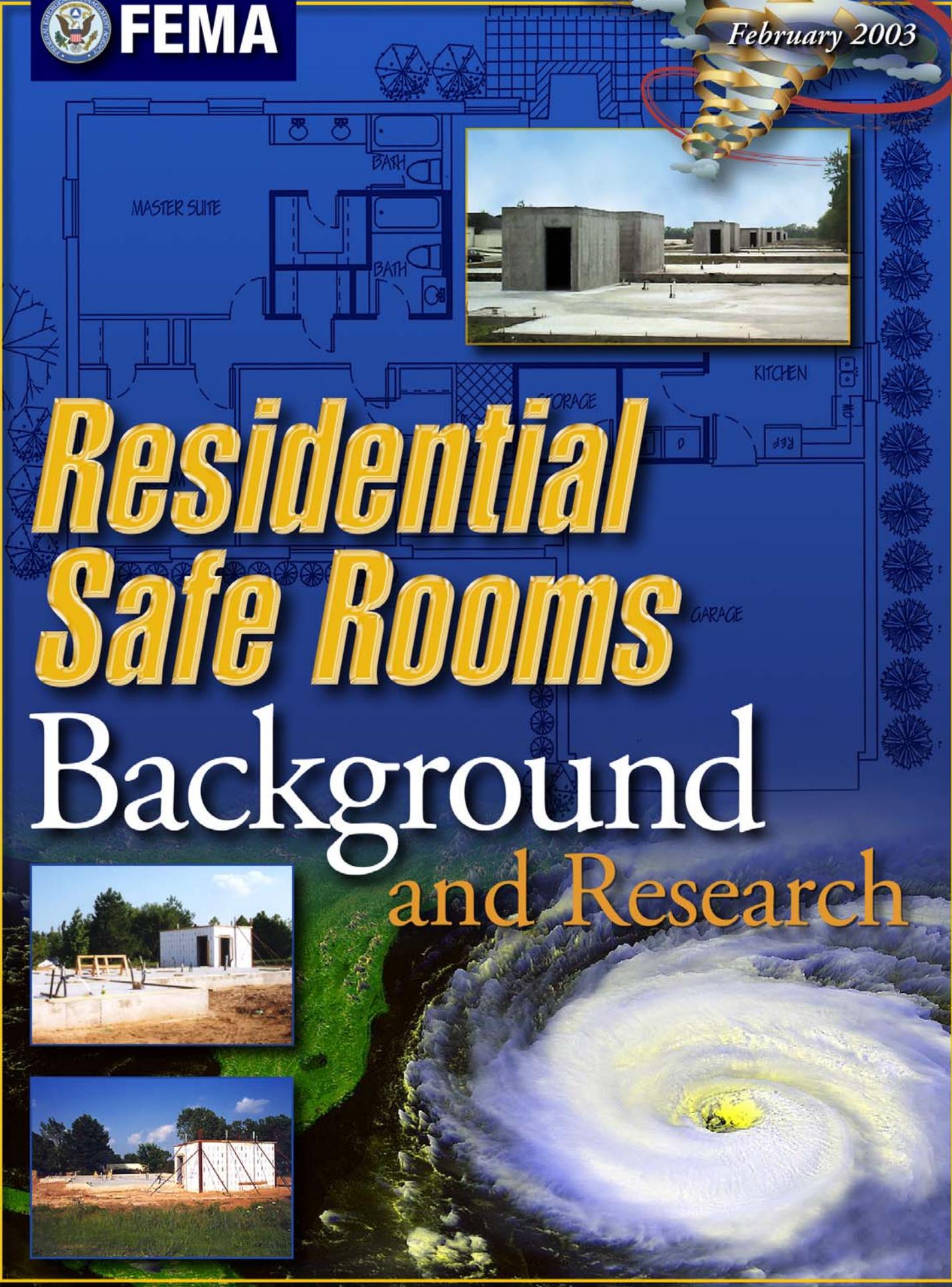




**FEMA**

February 2003



# *Residential Safe Rooms* Background and Research





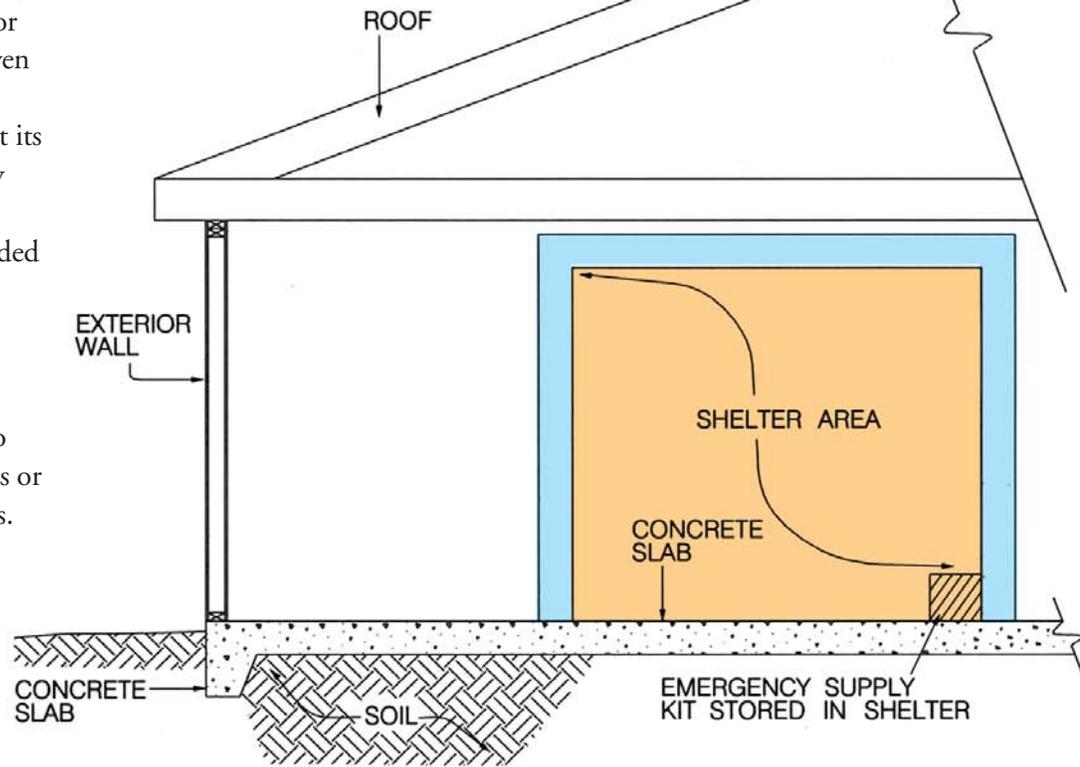
## What is a Wind Shelter?

A wind shelter is an interior room or other space within a building, or even an entire separate structure, that is designed and constructed to protect its occupants from high winds, usually those associated with tornadoes or hurricanes. Wind shelters are intended to provide protection against both wind forces and the impact of windborne debris.

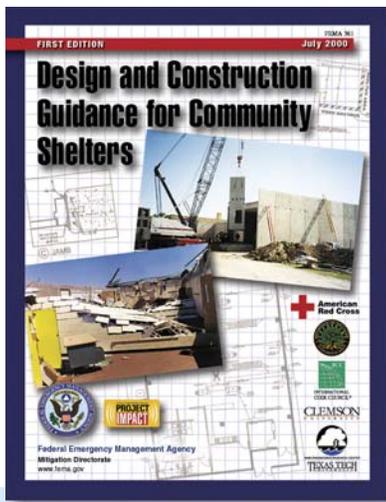
Wind shelters typically fall into two categories: (1) residential safe rooms or shelters and (2) community shelters. A residential safe room is a small, specially designed (“hardened”) room, such as a bathroom or closet, or other space within the house that is intended to provide a place of refuge only for the people who live in the house.

A residential shelter is similar in that it is intended to for use only by the occupants of a house, but it is a separate structure, often installed outside the house either aboveground or belowground. In contrast, a community shelter is intended to provide protection for a large number of people, anywhere from 12 to as many as several hundred.

Community shelters are usually built within or near large public, institutional, or commercial buildings such as schools, hospitals, and nursing homes. A community shelter can also be built in a neighborhood to provide protection for residents whose homes lack shelters. Although community shelters are designed to accommodate large numbers of people, they are not recovery shelters. In other words, they are not intended to provide housing for people whose homes have been damaged or destroyed during disasters.



Community shelters and residential safe rooms and shelters are alike in that they are intended to provide protection only during a short-term, high-wind event (i.e., an event that lasts no more than 36 hours, such as a tornado or hurricane). In other ways, however, they are quite different. This brochure focuses on residential safe rooms. For more information about community shelters, refer to the separate FEMA brochure *Community Wind Shelters* and to FEMA publication 361, *Design and Construction Guidance for Community Shelters*.



FEMA 361



## Types of Residential Safe Rooms

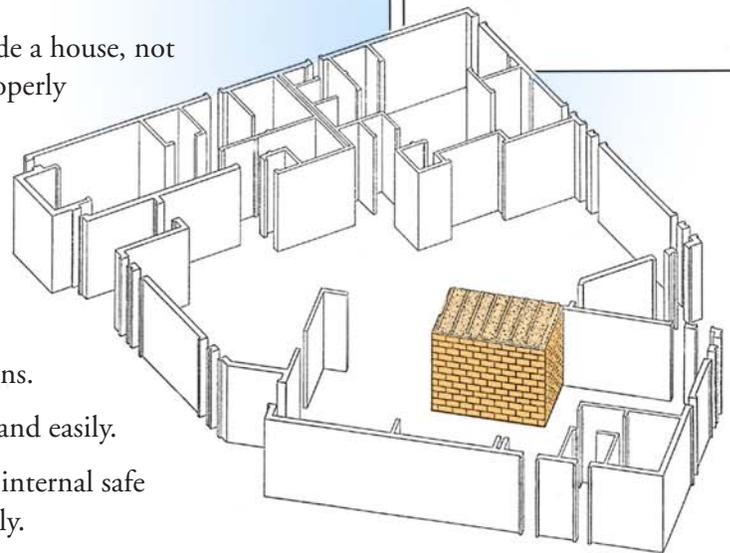
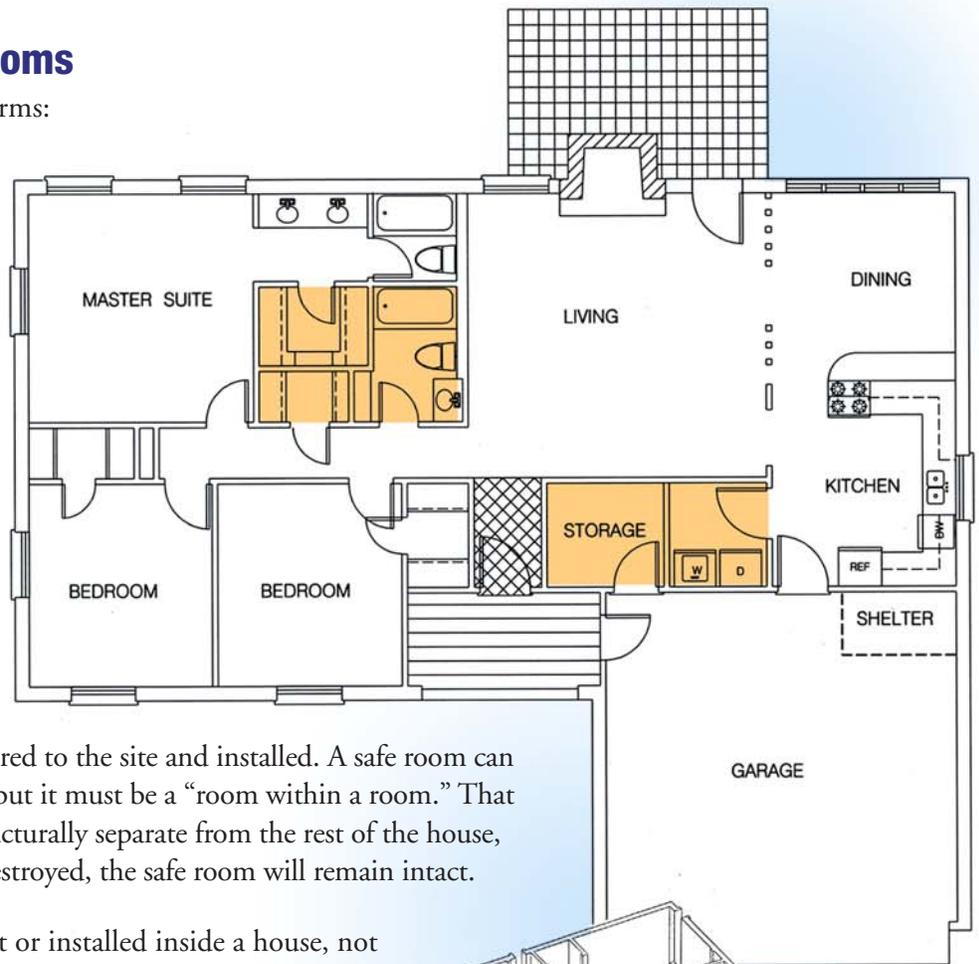
Residential safe rooms can take several forms:

- a room that normally serves another purpose, such as a bathroom or closet, and that has been strengthened (or “hardened”) to resist wind forces and the impacts of windborne debris
- a room specifically designed and constructed to serve as shelter space only
- an underground space created beneath the floor of a house or an attached garage

In general, residential safe rooms can be built onsite in a new or existing home or can be manufactured units delivered to the site and installed. A safe room can be built or installed anywhere in a house, but it must be a “room within a room.” That is, it’s walls, ceiling, and floor must be structurally separate from the rest of the house, so that even if the surrounding house is destroyed, the safe room will remain intact.

This brochure focuses on safe rooms built or installed inside a house, not on shelters built or installed elsewhere on the property. Properly designed and constructed in-residence safe rooms are preferable because they offer several advantages over exterior shelters:

- The occupants of a house equipped with an internal safe room can reach the shelter without having to leave the house and risk exposure to high winds and debris, lightning, or other storm conditions.
- An internal safe room can be reached more quickly and easily.
- For those reasons, the occupants of a house with an internal safe room are more likely to protect themselves adequately.

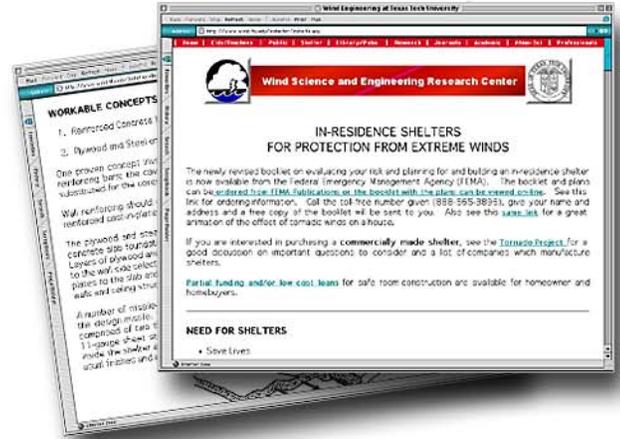


In some situations, however, building or installing an exterior shelter may be the only practical choice. For example, incorporating an in-residence safe room into an existing house may be impractical when extensive modifications to the structure of the house are necessary. For manufactured homes, an exterior shelter is usually the only practical solution. FEMA has not developed designs for exterior shelters, but the National Storm Shelter Association (NSSA) can provide information about exterior shelters that meet the engineering requirements established by FEMA. Visit the NSSA website at <http://www.nssa.cc/>.



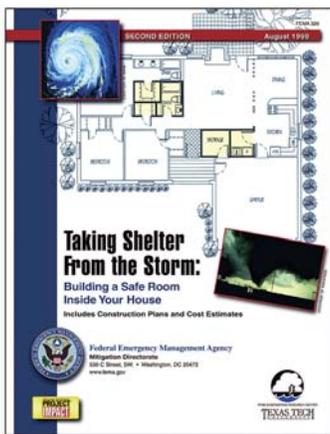
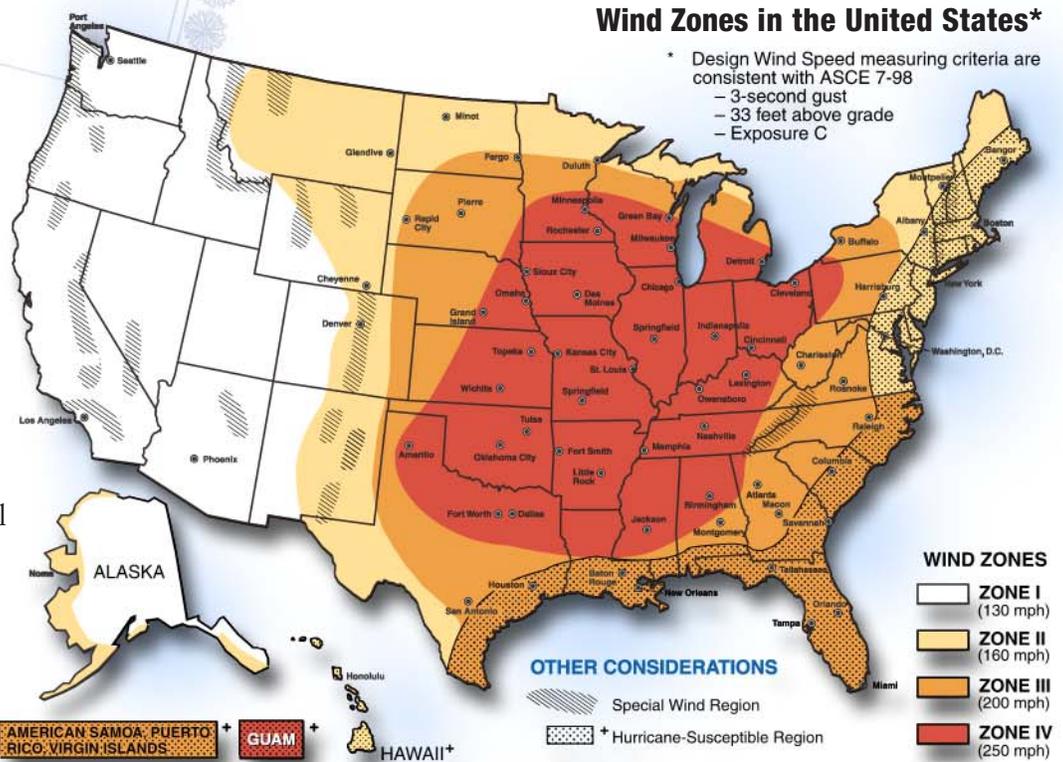
As mentioned earlier, a residential safe room can serve more than one purpose. Hardening a bathroom or closet to serve as a safe room makes more efficient use of space than building a room that serves as a safe room only. In smaller homes, providing for alternative safe room uses can be an important consideration.

Additional information about in-residence safe rooms, including design, construction, and related publications is available on the Texas Tech University website at <http://www.wind.ttu.edu/inshelter/inshelte.asp>.



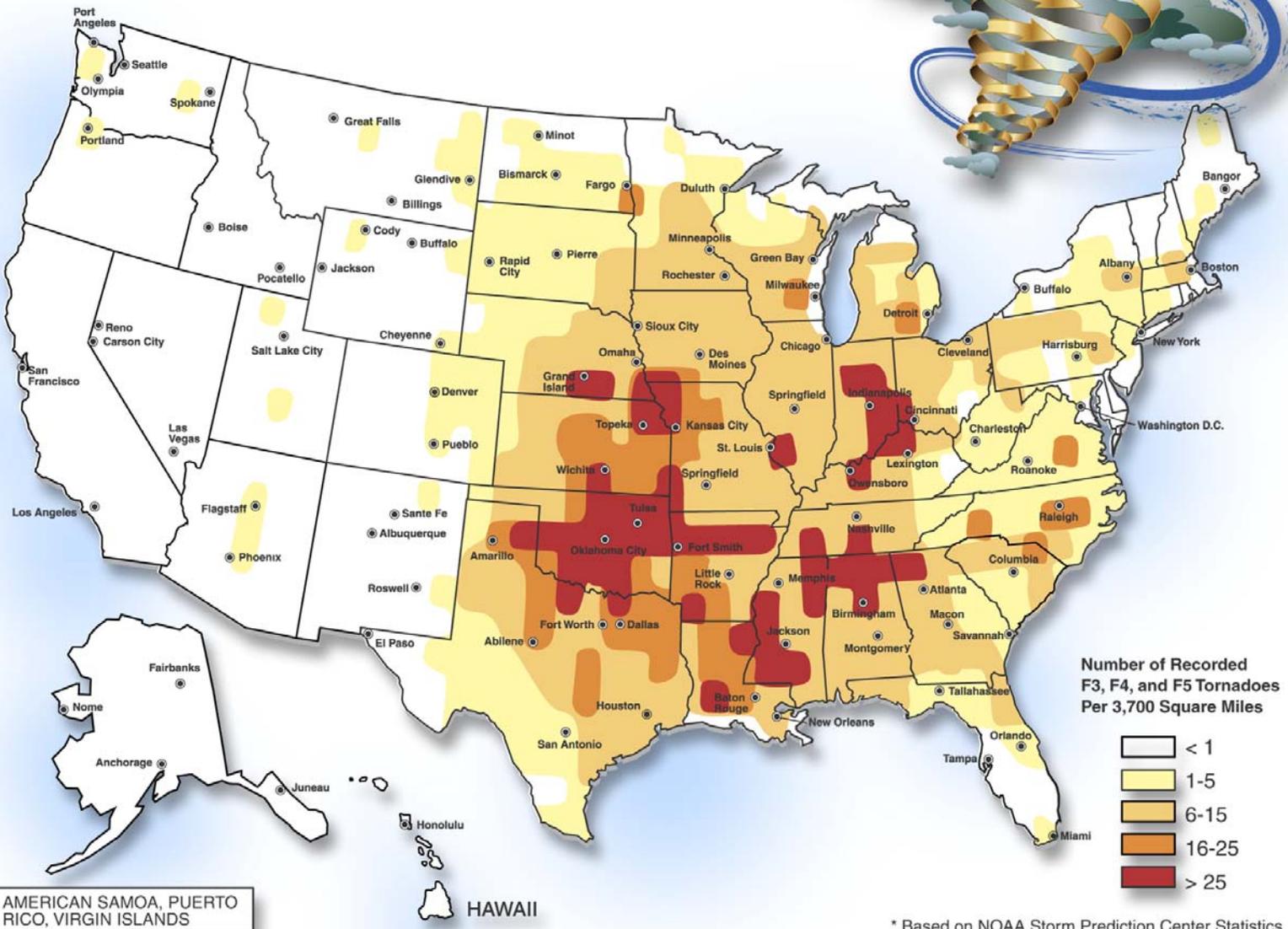
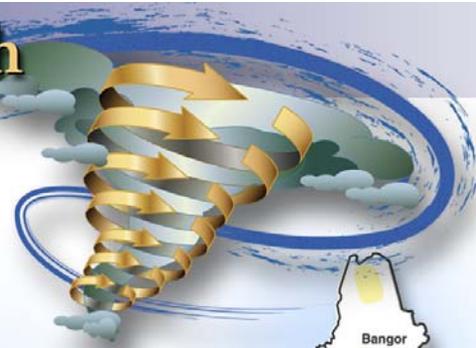
## Where Are Safe Rooms Needed?

In areas subject to extreme-wind events, homeowners should consider building a residential safe room. As noted in the following sections, wind hazards, such as those associated with tornadoes and hurricanes, vary throughout the United States. The decision to build a safe room will be based largely on the magnitude of the wind hazard in a given area and on the level of risk considered acceptable.



FEMA 320

FEMA Publication 320, *Taking Shelter From the Storm: Building a Safe Room Inside Your House*, contains tornado and hurricane statistics, wind speed and wind hazard data, a homeowner risk assessment worksheet, construction drawings for various types of residential safe rooms, and other information that will help a homeowner assess the risk in a specific area, determine the need for a safe room, and choose a safe room design. The construction drawings include all the information a contractor would need to build a safe room that provides adequate protection from the most severe wind events.



## Tornadoes – Understanding the Hazards

A tornado is a violently rotating column of air that extends from a thunderstorm cloud to the ground. 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. As shown by the map, tornadoes occur primarily in the central and eastern portions of the United States.

Tornadoes are rated by the National Weather Service according to the Fujita Damage Scale. Fujita ratings vary from F0, for light damage, to F5, for total destruction.

All tornadoes produce high winds and carry windborne debris that can pose a danger to lives and property. Violent tornadoes (those rated F4 and F5) are capable of tremendous destruction with wind speeds of up to 250 mph near ground level. Violent tornadoes can rip buildings from their foundations, and the debris carried by their winds can easily break windows and even penetrate the walls or roof of a building.



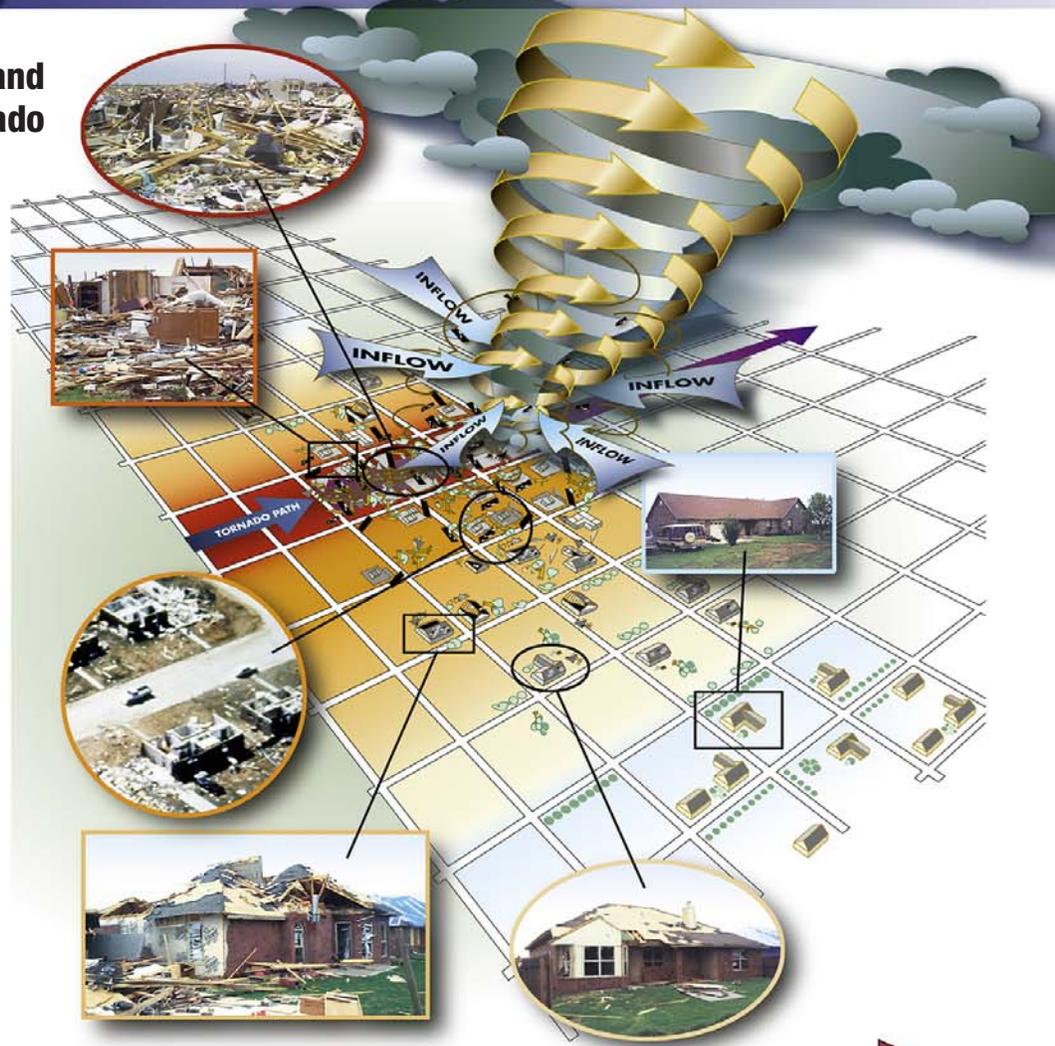
A **tornado watch** is issued to alert people to the possibility of tornado development in an area. A **tornado warning** means that a tornado has been spotted, or that Doppler radar indicates a thunderstorm circulation that can spawn a tornado.



## Potential Impact and Damage From a Tornado

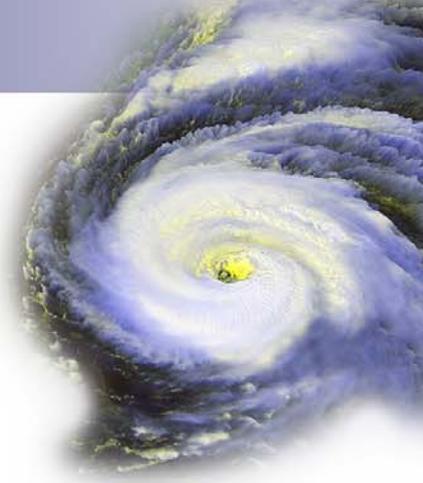
Tornado damage paths over 50 miles long and over 1 mile wide have been reported. A good example of the destructiveness of tornadoes is the damage caused by the 67 tornadoes that struck Oklahoma and Kansas on May 3, 1999, which included many F4 and F5 tornadoes. This tornado outbreak resulted in 49 deaths 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.



## Fujita Tornado Damage Scale

F0	F1	F2	F3	F4	F5
					
<p><b>F0 Light:</b> Some damage can be seen to poorly maintained roofs. Unsecured lightweight objects, such as trash cans, are displaced.</p>	<p><b>F1 Moderate:</b> Minor damage to roofs occurs, and windows are broken. Larger and heavier objects become displaced. Minor damage to trees and landscaping can be observed.</p>	<p><b>F2 Considerable:</b> Roofs are damaged. Manufactured homes, on nonpermanent foundations, can be shifted off their foundations. Trees and landscaping either snap or are blown over. Medium-sized debris becomes airborne, damaging other structures.</p>	<p><b>F3 Severe:</b> Roofs and some walls, especially unreinforced masonry, are torn from structures. Small ancillary buildings are often destroyed. Manufactured homes on nonpermanent foundations can be overturned. Some trees are uprooted.</p>	<p><b>F4 Devastating:</b> Well constructed homes, as well as manufactured homes, are destroyed. Some structures are lifted off their foundations. Automobile-sized debris is displaced and often tumbles. Trees are often uprooted and blown over.</p>	<p><b>F5 Incredible:</b> Strong frame houses and engineered buildings are lifted from their foundations or are significantly damaged or destroyed. Automobile-sized debris is moved significant distances. Trees are uprooted and splintered.</p>

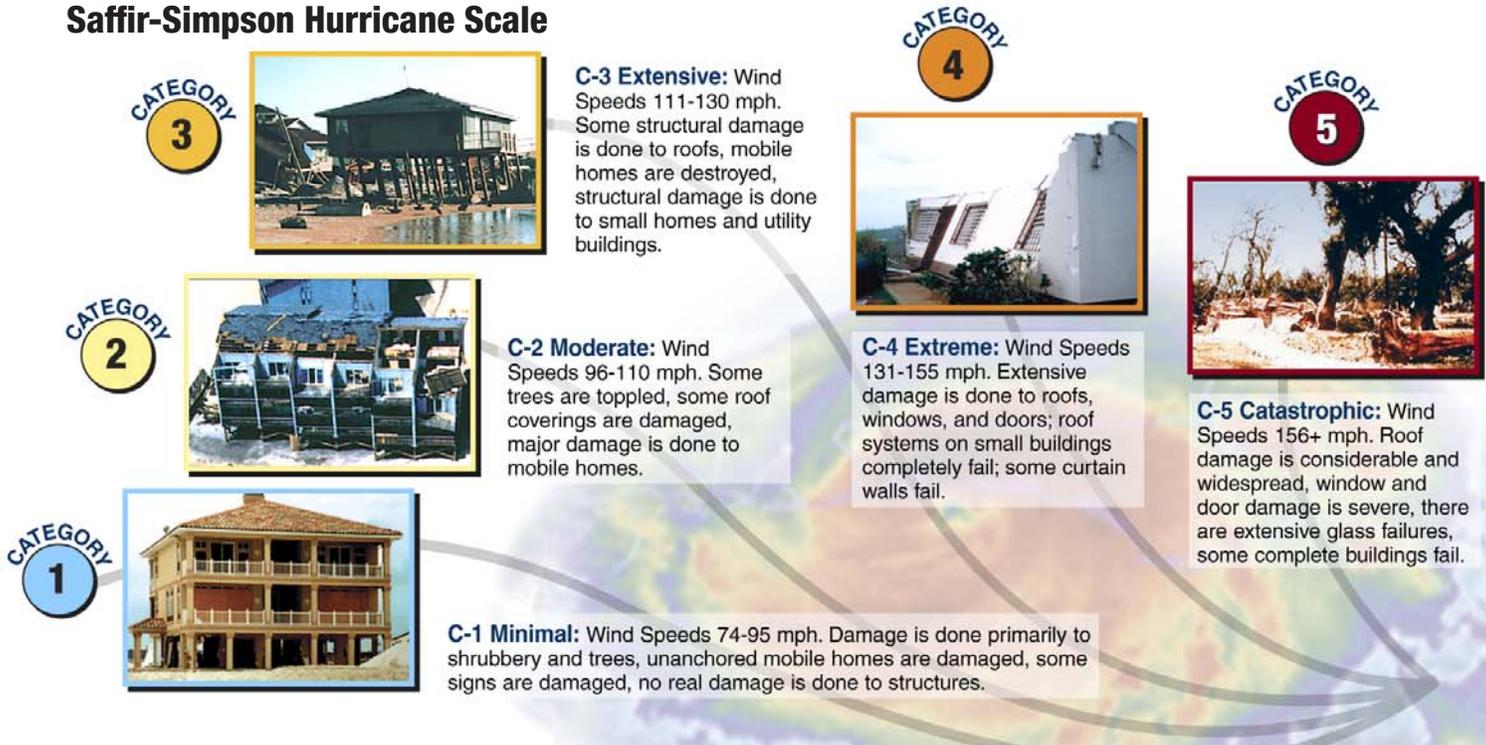


## Hurricanes – Understanding the Hazards

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 the core of a hurricane, winds can grow with great velocity. As the storm moves ashore, it can push ocean waters inland while spawning tornadoes and producing torrential rains and floods.

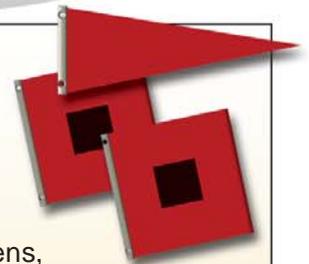
On average, 10 tropical storms (6 of which become hurricanes) develop each year in the Atlantic Ocean. Approximately five hurricanes strike the United States mainland every 3 years; two of those storms will be major hurricanes (Category 3 or greater on the Saffir-Simpson Hurricane Scale).

### Saffir-Simpson Hurricane Scale



In the western Pacific, hurricanes are called *typhoons* and affect the Pacific Islands, including Hawaii, Guam, and American Samoa. 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.

Although the highest wind speeds associated with hurricanes are not as great as those of the most severe tornadoes, hurricane winds and the debris they can carry are still extremely dangerous. The loss of life and property from hurricane-generated winds can be staggering. An example of a hurricane that caused severe wind damage is Hurricane Andrew, which made landfall in southeastern Florida in August 1992, generating strong winds and heavy rain over a vast portion of southern Dade County. The high winds associated with this Category 4 storm (131 mph to 155 mph) caused extensive damage in areas well beyond the reach of storm surge – areas where building or installing a residential safe room would be an appropriate and effective means of providing protection from high winds and windborne debris.



When a hurricane threatens, weather services issue hurricane watches and warnings. A **hurricane watch** is issued when a hurricane is possible within 36 hours. A **hurricane warning** is issued when a hurricane is expected within 24 hours. An evacuation notice may be issued in conjunction with a hurricane warning.



### Safe Room Strength – Testing and Design

For FEMA, the goal of safe room design and construction is to provide “near-absolute protection” from the forces of winds and debris during a storm with winds as high as 250 mph. A safe room that provides near-absolute protection will protect its occupants from death and injury; the safe room itself, however, may be damaged by high winds or debris. As a result, repairs to the walls, ceilings, and door of a safe room may be necessary after an extreme-wind event.

Clearly, to provide the desired level of protection, a safe room needs an extremely strong structure to resist high-wind forces and an extremely resistant envelope (walls, roof, and floor) to resist the impact of windborne debris. To support the development of adequate safe room designs, the Wind Engineering Research Center of Texas Tech University conducted extensive laboratory tests of safe room construction materials. The testing program included determining wind pressure and debris impact loads resulting from various wind speeds and testing the ability of building materials (roof and wall sections, doors, and door hardware) to resist those loads and impacts.

Of particular interest in the testing program was the impact of windborne debris on walls, doors, and roofs. Although much was known about the ability of small high-velocity

projectiles to penetrate various materials, little prior testing had been conducted on the larger, slower moving objects likely to make up the most damaging windborne debris during a tornado. The Texas Tech research included firing a test missile – a 15-pound, 12-foot-long 2x4 – at combinations of wall, ceiling, and door construction materials. The missile was fired at speeds of 67 mph and 100 mph to simulate the speeds of similar-sized debris driven vertically downward and horizontally, respectively, by 250 mph storm winds.





Safe rooms designs based on the results of the Texas Tech research typically call for larger, stronger, and a greater number of construction materials (e.g., concrete blocks, reinforcing rods, connectors, and door hardware) than designs for standard residential construction.

The following are examples of wall and door materials that passed the debris impact test (further information is available on the Texas Tech University website at

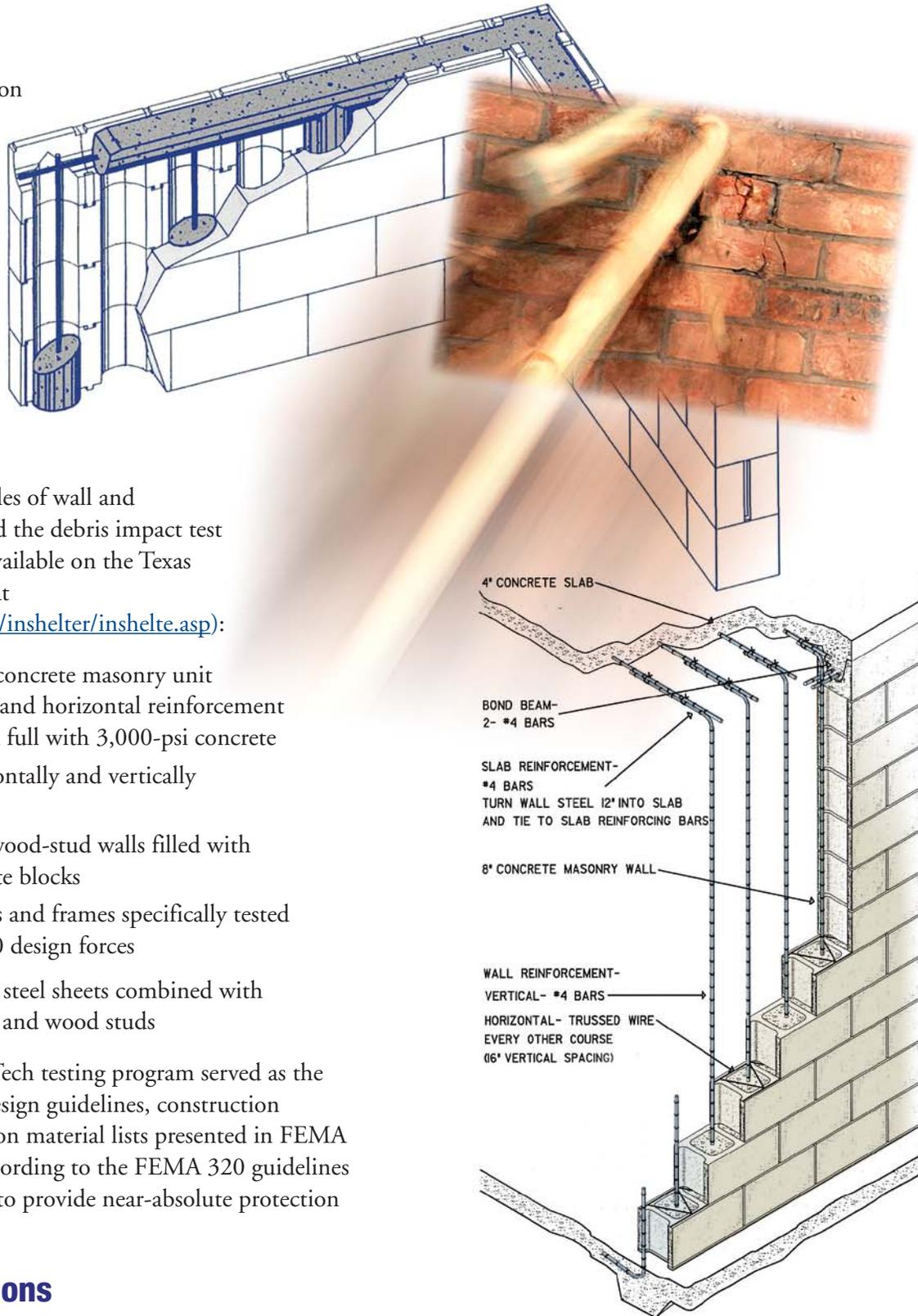
<http://www.wind.ttu.edu/inshelter/inshelte.asp>):

- 6-inch to 12-inch concrete masonry unit walls, with vertical and horizontal reinforcement and all cells poured full with 3,000-psi concrete
- 6-inch-thick horizontally and vertically reinforced concrete
- plywood-covered wood-stud walls filled with dry-stacked concrete blocks
- hollow metal doors and frames specifically tested to meet FEMA 320 design forces
- 12-gauge or greater steel sheets combined with plywood sheathing and wood studs

The results of the Texas Tech testing program served as the basis for the safe room design guidelines, construction drawings, and construction material lists presented in FEMA 320. Safe rooms built according to the FEMA 320 guidelines and criteria are expected to provide near-absolute protection for their occupants.

### Other Considerations

Although essential to successful performance, strength is not the sole consideration in safe room design and construction. A residential safe room must also be readily accessible, provide for the comfort of its occupants, and be equipped with emergency supplies.





## Accessibility

Residential safe rooms should be constructed in such a way that they are readily accessible to all family members or other occupants of the home. The path to the safe room should not be blocked with furniture or stored items. Also, if the safe room is normally used for another purpose (a closet for example), care should be taken not to clutter the floor with anything that could restrict the usable safe room space. Special needs, such as those of vision- or mobility-impaired users, should be considered when decisions are made concerning the type and location of the safe room.

## Occupant Comfort

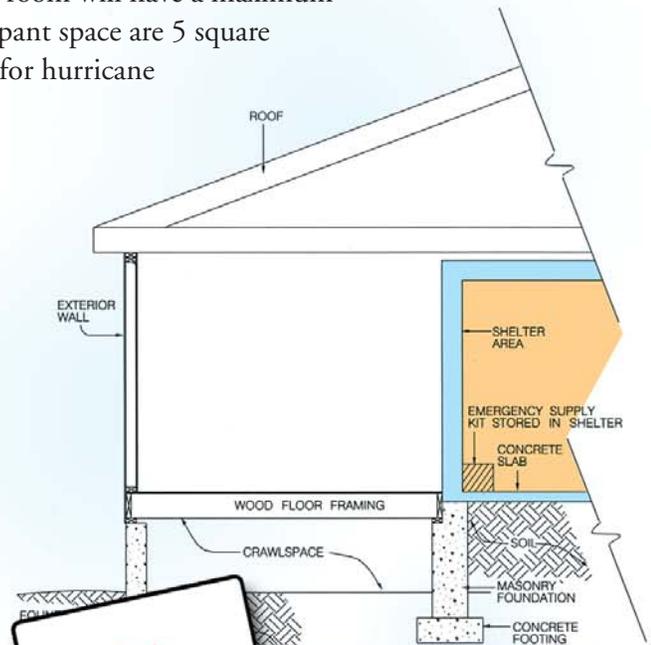
The primary goal of a residential safe room is to provide for the safety, not the comfort, of its occupants. The comfort of shelter occupants will depend largely on the amount of space provided per occupant and adequate lighting, water and food, and toilets. The **amount of space** required per person depends on the duration of occupancy. For this reason, the required space differs between safe rooms intended for tornado protection and those intended for hurricane protection. Historical data indicate that a tornado safe room will typically have a maximum occupancy time of 2 hours. By contrast, a hurricane safe room will have a maximum occupancy time of 36 hours. The recommended minimums for occupant space are 5 square feet per person for tornado safe rooms and 10 square feet per person for hurricane safe rooms.

Note that these square footage figures are minimums; larger amounts of space are required for special situations. For example, the 5-square-foot minimum for tornado safe rooms assumes that the safe room occupants will be standing for the duration of the event. Larger amounts of space are required for seated occupants and those with special needs, such as wheelchair users. Additional information about required safe room space is presented in FEMA Publication 320.

Adequate supplies of **water** are essential for both tornado and hurricane safe rooms. **Food** should be provided in hurricane safe rooms, but is not a major consideration in tornado safe rooms, because of the short duration of use.

## Emergency Supplies

All residential safe rooms should be equipped with emergency supplies, including flashlights, fire extinguishers, first-aid kits, radios (including weather radios and extra batteries), and a signaling device (such as an air horn).

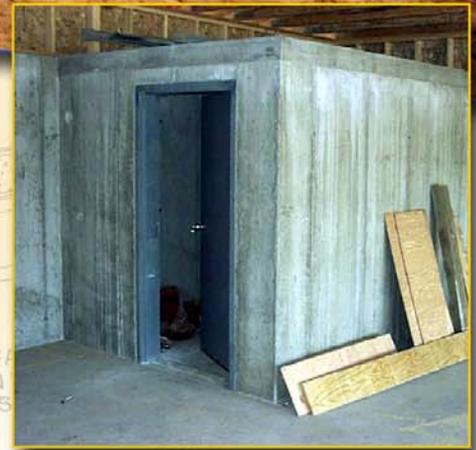




## New Construction vs. Retrofitting

An additional consideration is whether a safe room will be built as *new* or *retrofit* construction. Building a safe room as a part of a new home is generally more efficient and economical than retrofitting (modifying an existing home to meet specific design requirements).

Retrofit safe room construction involves making all changes necessary to strengthen an existing room or area of a house so that it will provide the required resistance to wind forces and debris impact. This process could involve extensive modifications to the foundation, frame, envelope, connections, and other building components. In addition, a residential safe room created through retrofitting must be structurally separate from the surrounding house (i.e., a room within a room) so that damage to the house would not affect the safe room. Although retrofit shelter construction can be disruptive to building occupants, as well as more expensive than new construction, it may be the only option in some circumstances.



## Sources of Safe Room Information

### Publications

FEMA has prepared a series of case studies that document the construction of wind shelters, including residential safe rooms. The issues covered include the need for shelters and safe rooms, design and construction, costs and funding mechanisms, and performance in actual storms.

Other sources of wind shelter information include the following:

*Association Standard for the Design, Construction, and Performance of Storm Shelters*, National Storm Shelter Association, Lubbock, TX, 2001.

*Design and Construction Guidance for Community Shelters* (FEMA 361), FEMA, Washington, DC, July 2000.

*Safe Room & Community Shelter Resource CD* (FEMA 388-CD), FEMA, Washington, DC, October 2001.

*Taking Shelter From the Storm: Building a Safe Room Inside Your House* (FEMA 320), FEMA, Washington, DC, August 1999.

*Tornado Protection – Selecting Safe Areas in Buildings*, Florida Department of Community Affairs, Tallahassee, FL, March 2002.

Copies of FEMA publications are available from the FEMA Publications Distribution Center at 1-800-480-2520.

### Related Websites

FEMA Safe Rooms – <http://www.fema.gov/mit/saferoom/>

Texas Tech University Wind Science and Engineering Research Center – <http://www.wind.ttu.edu/>

National Storm Shelter Association – <http://www.nssa.cc/>