Tornado Risks and Hazards in the Southeastern United States

FEMA

FEBRUARY 2007 TORNADO RECOVERY ADVISORY *FEMA DR-1679-RA1*

Purpose and Intended Audience

The purpose of this Tornado Recovery Advisory is to provide background on the tornado hazard in the Southeast. The general population, home owners and renters, policy makers, local officials, builders, and building departments should understand that tornado occurrence in the Southeast is not a rare event. In fact, of the top 20 states in tornado frequency, 5 are in the Southeast.

This advisory also identifies FEMA resources that can be used to help design and construct portions of almost any building type (including residences) to provide safe shelter from tornadoes, or to help minimize damage caused by these wind events.

This Recovery Advisory Addresses:

- Recent events
- Tornado occurrence outside "Tornado Alley"… how great is the risk?
- Can a building survive a tornado? Yes!
- Assessing risk
- Weather radios

See these 2007 Tornado Recovery Advisories for information about sheltering from tornadoes, and improving manufactured homes against damage from high winds:

- Storm Shelters: Selecting Design Criteria (Tornado Recovery Advisory No. 2)
- Residential Sheltering: In-Residence and Stand-Alone Shelters (Tornado Recovery Advisory No. 3)
- Understanding and Improving Performance of Older Manufactured Homes in High-Wind Events (Tornado Recovery Advisory No. 4)
- Understanding and Improving Performance of New Manufactured Homes in High-Wind Events (Tornado Recovery Advisory No. 5)

Recent Events

In the early morning hours of February 2, 2007, a small but devastating outbreak of three tornadoes struck central Florida from Lady Lake to New Smyrna Beach. Two of the tornadoes were rated by the National Weather Service as EF3 and the other was rated EF1 on the Enhanced Fujita Scale (see text box). The three tornadoes struck in the middle of the night. Twenty-one people were killed and dozens were injured. Total damage estimates are still being compiled from this event, but early estimates are that more than $150 million[1] in damage was caused by these tornados. Less than one month later, on March 1, 2007, Enterprise, Alabama experienced one

The Fujita Scale categorizes tornado severity based on observed damage. The six-step scale ranges from F0 (light damage) to F5 (incredible damage). As of February 2007, the National Weather Service uses the Enhanced Fujita Scale (EF Scale). This new scale ranges from EF0 to EF5. See http://www.spc.noaa.gov/efscale/ for further information on the EF Scale.

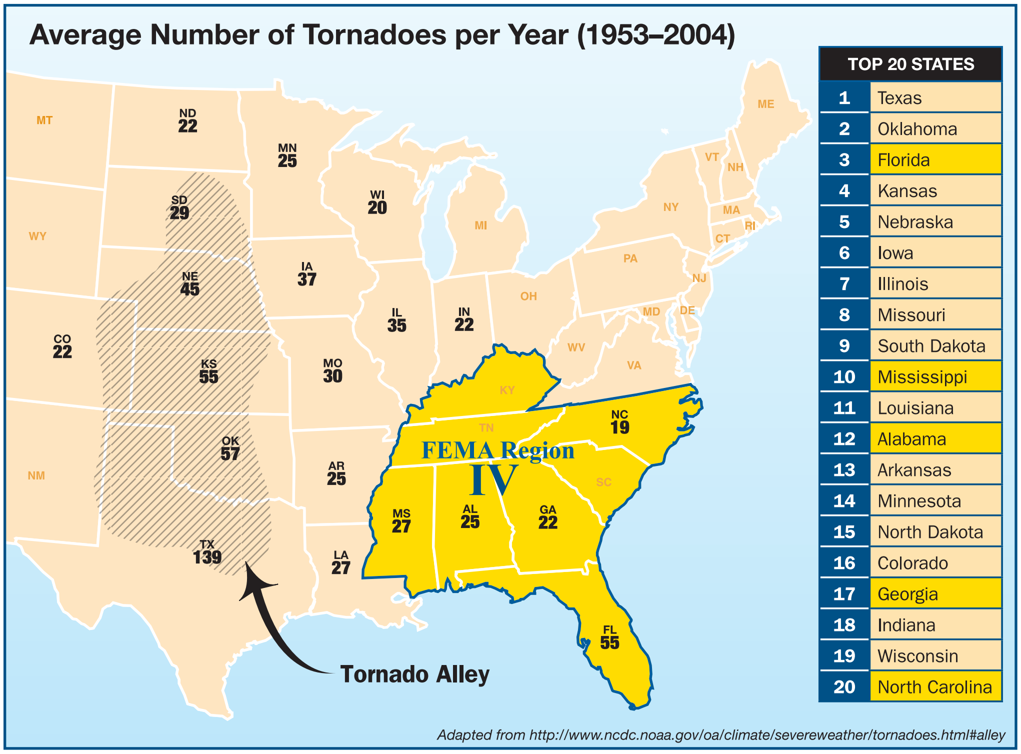
Fujita Scale		EF Scale	
Fujita Scale	3-Second Gust Speed (mph)	EF Scale	3-Second Gust Speed (mph)
F0	45–78	EF0	65–85
F1	79–117	EF1	86–109
F2	118–161	EF2	110–137
F3	162–209	EF3	138–167
F4	210–261	EF4	168–199
F5	262–317	EF5	200–234

1. St. Petersburg Times, "Facing Life Without Family" by Catherine Shoichet, March 2, 2007.

of the top 10 deadliest tornadoes to impact a school when, in the early afternoon hours, a tornado ripped through a high school, killing eight students. Later that day, a tornado severely damaged a hospital in Americus, Georgia. The March 1 storms caused damage and loss of life in several areas of both states.

Tornado Occurrence Outside "Tornado Alley"… How Great Is the Risk?

"Tornado Alley" is an area of the heart-land of the United States known for its tornado activity. Although the exact extent of Tornado Alley can be debated, most scientists agree that Texas, Oklahoma, and Kansas are well known for tornado risk and make up a large portion of Tornado Alley.



What most people may not be aware of is the amount of tornadic activity outside of Tornado Alley. FEMA Region IV has eight states subject to tornadoes and six subject to hurricanes (refer to map on this page).

Although hurricanes have received most of the attention in recent years in the Southeast, the threat and risk of tornadoes is real. The table below shows the number of tornado occurrences for each of the states in FEMA Region IV. For the 55-year study period, over 9,700 tornadoes have been recorded. The State of Florida alone has seen extreme numbers of tornado occurrences. For three of the years between 1997 and 2004, it experienced over 100 tornadoes (115 in 1997, 115 in 1998, and 105 in 2004).

Most tornadoes occurring in the Southeast (with the exception of Mississippi and Alabama) are typically weak or moderately strong (classified as F2 and smaller on the Fujita Scale). However, these weaker tornadoes can be as deadly as the stronger F3, F4, and F5 tornadoes. For example, over 50 of the 78 killer tornadoes that occurred in Florida between 1882 and 2007 were F2 or weaker. Further, tornadoes are not always single tornado events; sometimes outbreaks of several tornadoes are associated with a large storm system. Notable outbreaks in the Southeast include:

The Carolinas Outbreak of March 28, 1984

- 22 tornadoes responsible for 57 fatalities
- Approximately 1,250 injuries
- Approximately $200 million in damages
- 37% of fatalities occurred in manufactured homes

The Kissimmee Tornado Outbreak of February 22–23, 1998

- 7 tornadoes responsible for 42 fatalities
- Approximately 200 injuries
- Over $100 million in damages
- Three strongest tornadoes were rated F3, which destroyed over 300 buildings and damaged more than 7,000

States in FEMA Region IV	Total Tornado Occurrences (1950–2005)	Total Fatalities (1950–1995)[a]	
		Number	Rank
Florida	2,799	85[b]	
Mississippi	1,429	387	2
Alabama	1,301	282	4
Georgia	1,143	111	14
North Carolina	935	82	
Tennessee	788	184	7
South Carolina	718	47	
Kentucky	590	105	15

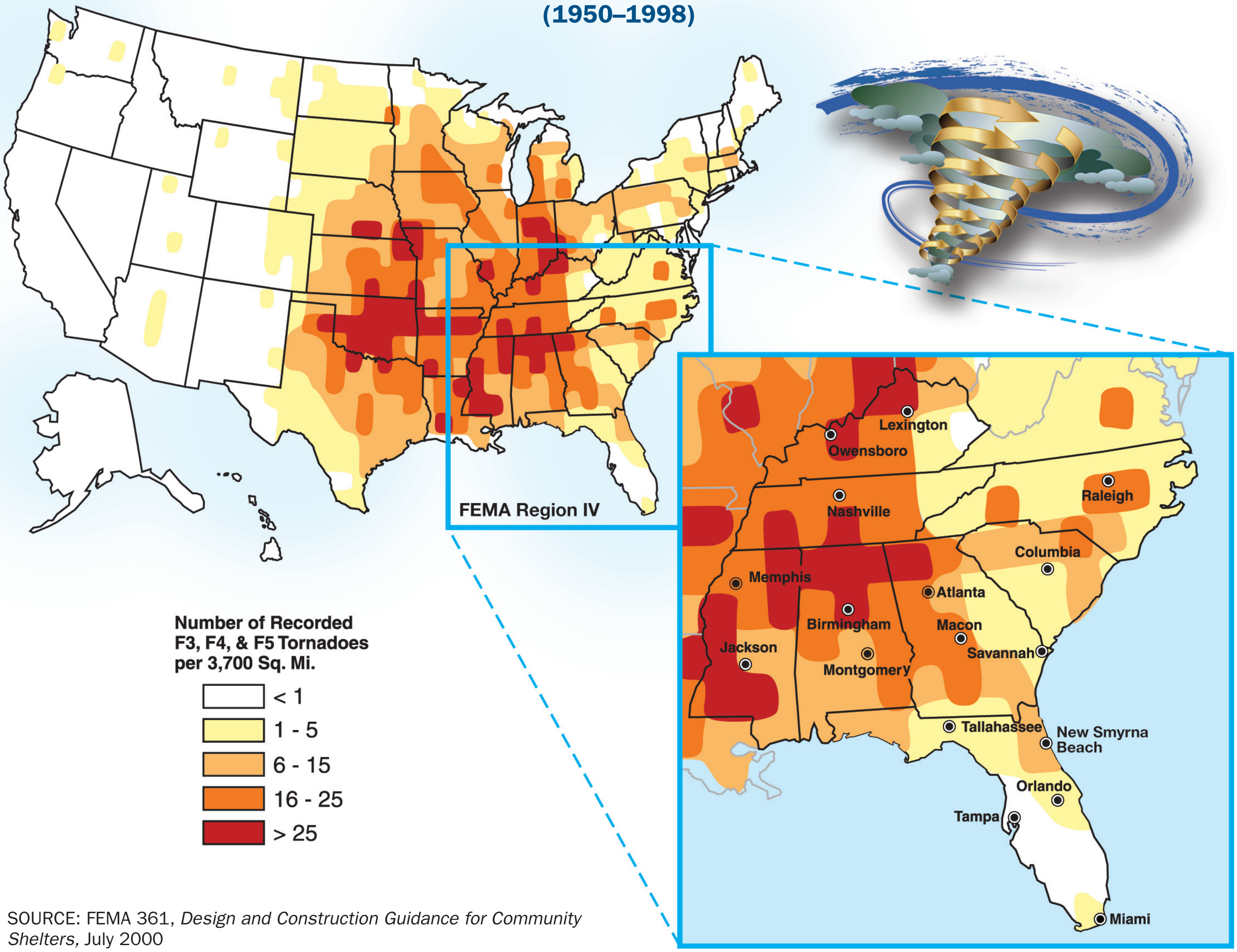
a. Texas is ranked highest with 475 fatalities for this period of time.

b. In Florida, an additional 21 fatalities occurred between 1995–2007, for a total of 166 (1950–2007).

Assessing Your Risk

To determine if you have a low, moderate, or high tornado risk, use the Frequency Map (below) to determine how many tornadoes were recorded per 3,700 square miles for the area where your building is located. Find the row in the "Risk Table" (below) that matches that number. Next, look at the Wind Zone Map (next page) and note the wind zone (I, II, III, or IV) in which your building is located. Find the matching column in the Risk Table and find the box that lines up with both the number of tornadoes per 3,700 square miles in your area and your wind zone. The color in that box tells you the level of your risk from extreme winds and helps you decide whether to build a shelter. A shelter is the preferred method of wind protection in high-risk areas.

Frequency of Recorded F3, F4, and F5 Tornadoes (1950–1998)



SOURCE: FEMA 361, *Design and Construction Guidance for Community Shelters,* July 2000

Levels of Risk During High-Wind Events

Number of Tornadoes per 3,700 Square Miles (see Wind Zone Map)	Wind Zone (see Frquency Map)			
	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

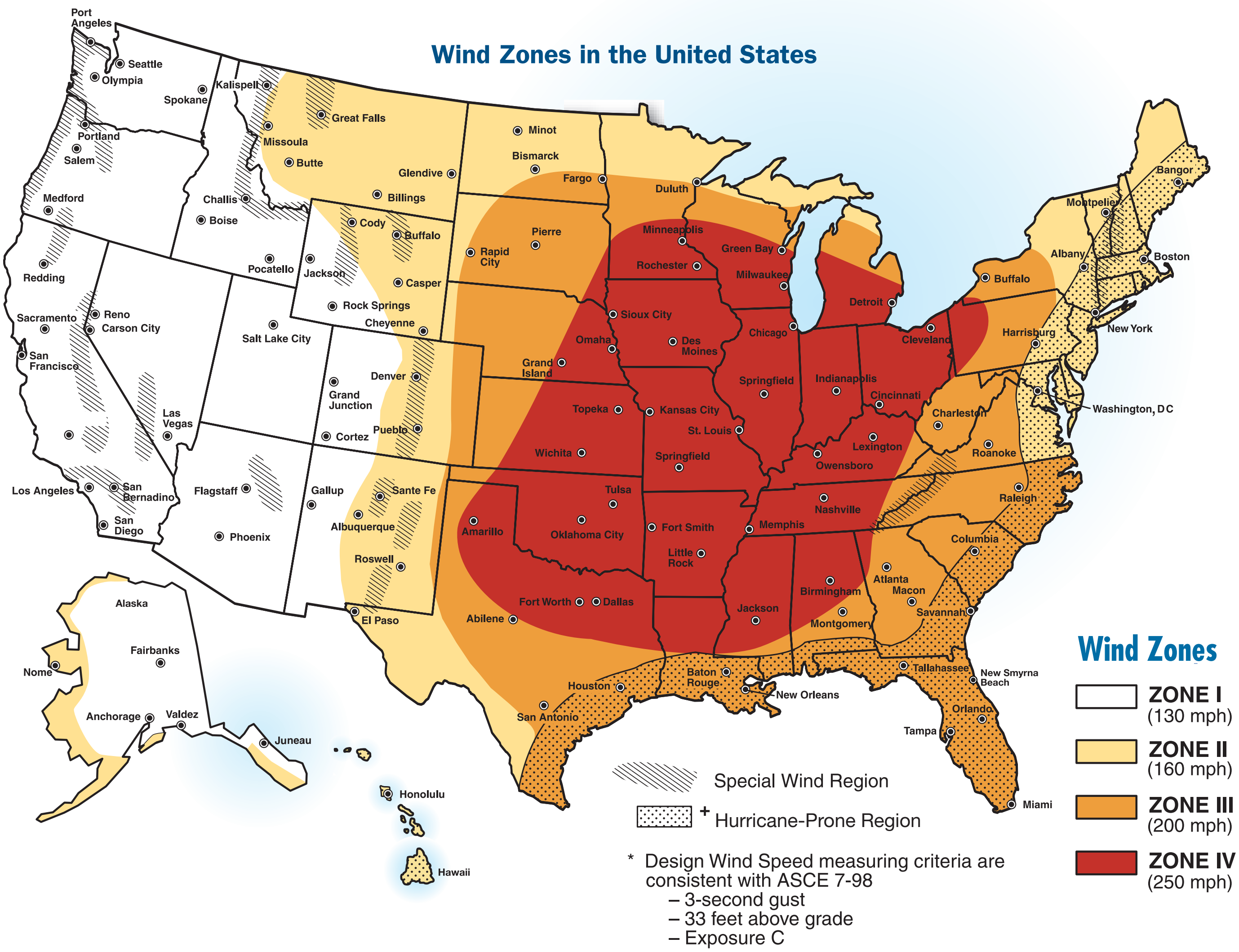
LOW Risk – Sheltering from high winds is a matter of preference.

MODERATE Risk – Shelter should be considered for protection from high winds.

HIGH Risk – Shelter is the preferred method of protection from high winds.

Note that some areas of low or moderate risk, shown as pale blue or medium blue on the Risk Table, are within the region of the United States that is also subject to hurricanes (see Wind Zone Map below). If you live in this hurricane-prone region, your risk is considered high even if the Risk Table only indicates a moderate or low risk.

Example: If your building is located in New Smyrna Beach, Florida, you would see that New Smyrna Beach is in an area shaded yellow on the Frequency Map (previous page). According to the map, the number of tornadoes per 3,700 square miles in the New Smyrna Beach area is 1–5. On the Wind Zone Map (below), New Smyrna Beach is within the dark orange area. The map key tells you that New Smyrna Beach is in Wind Zone III. The box in the Risk Table (previous page) where the 1–5 row and the Zone III column meet is shaded dark blue, which shows that the building is in an area of high risk.



Can a Building Survive a Tornado? Yes!

High-wind shelters can be designed and constructed to protect occupants from winds and windborne debris associated with all tornadoes (EF0–EF5). Buildings designed and constructed above basic code requirements (aka “hardened” buildings), and newer structures designed and constructed to modern, hazard-resistant codes can resist the wind load forces from weak tornadoes (EF1 or weaker). Furthermore, even when stronger tornadoes strike, not all damage is from the rotating vortex of the tornado. Much of the damage is from straight-line winds rushing toward and being pulled into the tornado itself. Many newer homes designed and constructed to modern codes, such as the *International Residential Codes* (IRC 2000 Edition and newer), with a load path to resist high wind forces (specified in building codes for hurricane resistance) may survive without structural failure. The primary damage to these newer homes is to the cladding and exterior systems: roof covering, roof deck, exterior walls and windows. This type of damage may be preventable on buildings that are designed and constructed according to the IRC 2000 (or newer) when the building experiences weaker tornadoes and the outermost winds from stronger tornadoes.

For most building uses, it is economically impractical to design the entire building to resist tornadoes. However, portions of buildings can be designed as shelters to provide occupant protection from tornadoes. For information on designing shelters to resist the strongest tornadoes and hurricane events, see the Tornado Recovery Advisory titled *Storm Shelters: Selecting Design Criteria.* For residential shelters, see the Tornado Recovery Advisory titled *Residential Sheltering: In-Residence and Stand-Alone Shelters.*

For existing buildings that do not have specifically designed tornado shelters or access to community tornado shelters, it is recommended that best available refuge areas be identified in advance by a qualified architect or engineer. For further information on best available refuge areas, see *Tornado Protection: Selecting Safe Areas in Buildings* (FEMA 431), November 2003.

Weather Radios

All individuals living or working in tornado-prone areas should have a weather radio within their home or place of work. A weather radio is particularly important for those living in an area that does not have storm warning sirens.

The National Oceanic and Atmospheric Administration (NOAA) Weather Radio (NWR) is a nationwide network of radio stations broadcasting continuous weather information directly from a nearby National Weather Service (NWS) office. NWR broadcasts National Weather Service warnings, watches, forecasts and other hazard information 24 hours a day, as well as post-event information for all types of hazards, both natural and technological.

NOAA Weather Radios are available at electronics stores across the country and range in cost from $25 up to $100 or more, depending on the quality of the receiver and number of features. The NWS does not endorse any particular make or model of receiver.

Features to look for in a NOAA Weather Radio:

- The most desirable feature is an alarm tone. This allows you to have the radio turned on but silent, listening for a special tone that is broadcast before watch and warning messages that give immediate information about a life-threatening situation.
- Specific Area Message Encoding (SAME) technology, a NOAA Weather Radio feature available since the mid 1990s, is capable of providing detailed, area-specific information. Unlike other NOAA Weather Radios, the SAME feature will filter out alerts that do not affect your immediate area.
- The NOAA radio should operate on batteries during times when electrical service may be interrupted. Look for radios with an AC adapter and battery compartment.
- The radio should be tunable to all seven NWR frequencies. For the latest list of frequencies and transmitter locations, check the NOAA Weather Radio Web site http://www.weather.gov/nwr.
- The hearing and visually impaired can receive watches and warnings by connecting weather radio alarms to other kinds of attention-getting devices, like strobe lights, pagers, bed-shakers, personal computers, and text printers.

Automated Spanish translation systems are being examined for use on transmitters serving a significant Hispanic population to broadcast Spanish translations of all emergency weather and natural hazard messages immediately after the official Emergency Alert System (EAS) warning is issued. For more information in Spanish, please visit the NOAA Web site http://www.weather.gov/nwr/indexsp.htm.

Other methods to receive forecasts, watches, and warnings directly from the NWS:

- Tune in to your local radio and television stations for the latest weather forecasts, watches, and warnings.
- NWS products and services are also available on the Internet at http://www.weather.gov/nwr. Delivery of data across the Internet, however, cannot be guaranteed because of potential interruption of service.
- Another low-cost method for receiving the NWS's essential information is available on a wireless data system called the Emergency Managers Weather Information Network (EMWIN). This system presents the information directly on your home or office computer. Users may set various alarms to be alerted to particular information, whether for their local area or adjacent areas. For more information, please visit the EMWIN Web site http://www.weather.gov/emwin/index.htm.

Useful Links and Resources

Taking Shelter from the Storm: Building a Safe Room Inside Your House (FEMA 320), March 2004, 2nd Edition

Design and Construction Guidance for Community Shelters (FEMA 361), July 2000

Tornado Protection: Selecting Safe Areas in Buildings (FEMA 431), November 2003

Storm Shelters: Selecting Design Criteria

FEMA

FEBRUARY 2007 TORNADO RECOVERY ADVISORY *FEMA DR 1679 RA2*

Purpose and Intended Audience

The intended audience for this Tornado Recovery Advisory is anyone involved in the planning, policy-making, design, construction, or approval of shelters, including designers, emergency managers, public officials, policy or decision-makers, building code officials, and home or building owners. Homeowners and renters should also refer to the Tornado Recovery Advisory titled *Residential Sheltering: In-Residence and Stand-Alone Shelter.* The purpose of this advisory is to identify the different types of shelter design guidance, code requirements, and other criteria that pertain to the design and construction of shelters for tornadoes and hurricanes. There are various storm shelter criteria, each of which offers different levels of protection to its shelter occupants.

This Recovery Advisory Addresses:

- How shelter construction is different from typical building construction
  - Structural systems
  - Windborne debris resistance
- Design criteria for different types of shelters
- Shelter considerations
- Useful links and shelter resources

See these 2007 Tornado Recovery Advisories for information about tornado risk, sheltering from tornadoes, and improving manufactured homes against damage from high winds:

- Tornado Risks and Hazards in the Southeastern United States (Tornado Recovery Advisory No. 1)
- Residential Sheltering: In-Residence and Stand-Alone Shelters (Tornado Recovery Advisory No. 3)
- Understanding and Improving Performance of Older Manufactured Homes in High-Wind Events (Tornado Recovery Advisory No. 4)
- Understanding and Improving Performance of New Manufactured Homes in High-Wind Events (Tornado Recovery Advisory No. 5)

How Shelter Construction is Different from Typical Building Construction

A shelter is typically an interior room, space within a building, or an entirely separate building, designed and constructed to protect its occupants from tornadoes or hurricanes. Shelters are intended to provide protection against both wind forces and the impact of windborne debris. The level of occupant protection provided by a space specifically designed as a shelter is intended to be much greater than the protection provided by buildings that comply with the minimum requirements of building codes. The model building codes do not provide design and construction criteria for life safety for sheltering nor do they provide design criteria for tornadoes.

Shelters typically fall into two categories: residential shelters and community (non-residential) shelters.

- There are two general types of residential shelters: in-residence shelters and shelters located adjacent to, or near, a residence. An ***in-residence shelter,*** also called a "safe room," is a small, specially designed ("hardened") room, such as a bathroom or closet that is intended to provide a place of refuge for the people who live in the house. An ***external residential shelter*** is similar in function and design, but it is a separate structure installed outside the house, either above or below ground. Refer also to the Tornado Recovery Advisory titled *Residential Sheltering: In-Residence and Stand-Alone Shelter.*

The term "hardened" refers to specialized design and construction applied to a room or building to allow it to resist wind pressures and windborne debris impacts during a high-wind event and serve as a shelter.

- A ***community shelter*** is intended to provide protection for a large number of people, anywhere from approximately 12 to as many as several hundred individuals. These shelters include not only public shelters but private shelters for businesses and other organizations.

Community storm shelter being constructed to FEMA 361 criteria in Wichita, Kansas.

Structural Systems

The primary difference in a building's structural system when designed for use as a shelter, rather than for conventional use, is the magnitude of the wind forces that it is designed to withstand.

Buildings are designed to withstand a certain wind speed (termed "design [basic] wind speed") based on historic wind speeds documented for different areas of the country. The highest design wind speed used in conventional construction is near the coastal areas of the Atlantic and Gulf Coasts and is in the range of 140–150 mph, 3-second gust in most locations. By contrast, the design wind speed recommended by FEMA[1] for shelters in these same areas is in the range of 200–250 mph, 3-second gust; this design wind speed is intended to provide "near-absolute protection."

Wind pressures are calculated as a function of the square of the design wind speed. As a result, the structural systems of a shelter are designed for forces up to three times higher than those used for typical building construction. Consequently, the structural systems of a shelter (and the connections between them) are very robust.

Windborne Debris Resistance

Windborne debris, commonly referred to as missiles, causes many of the injuries and much of the damage from tornadoes and hurricanes. Windows and the glazing in exterior doors of conventional buildings are not required to resist windborne debris, except for buildings in windborne debris regions.[2] Impact-resistant glazing can either be laminated glass, polycarbonate, or shutters. The ASCE 7 missile criteria were developed to minimize property damage and improve building performance; they were not developed to protect occupants. To provide occupant protection, the criteria used in designing shelters include substantially greater windborne debris loads.

> If glazing is present in a tornado shelter, it should be protected by an interior-mounted shutter that can be quickly and easily deployed by the shelter occupants.

The roof deck, walls, and doors of conventional construction are also not required by the building code to resist windborne debris. However, the roof deck and walls around a shelter space, and the doors leading into it, must resist windborne debris if the space inside is to provide occupant protection. Additional information regarding the different levels of windborne debris loads is provided below.

Design Criteria for Different Types of Shelters

Shelters will provide different levels of protection depending upon the design criteria used. The level of protection provided by a shelter is a function of the design wind speed (and resulting wind pressure) used in designing the shelter, and of the windborne debris load criteria.

Design wind speed and wind pressure criteria: Wind pressure criteria are given by different guides, codes and standards. Wind pressure criteria specify how strong the shelter must be. The design wind speed is the major factor in determining the magnitude of the wind pressure that the building is designed to withstand. In FEMA's shelter publications (see Useful Links on page 3), recommended design wind speeds range from 160 to 250 mph. The 2006 *International Residential Code* and the 2006 *International Building Code,* which establish the minimum requirements for residential and other building construction, include design wind speeds ranging from 90 to 150 mph throughout most of the country. The table on pages 4–5 provides a comparison of shelter design criteria options. The table on page 6 presents comparative data for two locations using the design criteria presented on pages 4–5.

1. FEMA 361, *Design and Construction Guidance for Community Shelters* (July 2000), available online at http://www.fema.gov/fima/fema361.shtm
2. ASCE 7, American Society of Civil Engineers Standard 7, *Minimum Design Loads for Buildings and Other Structures* (2005)

Windborne debris load criteria: The table on page 3 presents windborne debris criteria given in various guides, codes, and standards. The table shows the different test missiles and the corresponding momentum they carry with them as they strike a shelter. The first entries on this table (Tornado Missile Testing Requirements) are the FEMA missile guidance for residential and community shelters that provide near-absolute protection.

Tornado and Hurricane Windborne Debris Criteria

Guidance, Code, or Standard Criteria for the Design Missile	Debris Test Speed (mph)	Large Missile Specimen	Momentum at Impact (lb_f s)
Tornado Missile Testing Requirements			
FEMA 320 / FEMA 361	100	15# 2x4	68
International Code Council (ICC) Shelter Standard	100 (maximum) 80 (minimum)	15# 2x4 15# 2x4	68 55
Hurricane Missile Testing Requirements			
FEMA 320 / FEMA 361	100	15# 2x4	68
ICC Shelter Standard	102 (maximum) 64 (minimum)	9# 2x4 9# 2x4	42 26
Florida State Emergency Shelter Program (SESP) Criteria	50 (recommended) 34 (EHPA minimum)	15# 2x4 9# 2x4	34 14
IBC/IRC 2006, ASCE 7-05, Florida Building Code, ASTM E 1886 / E 1996	55 34	9# 2x4 9# 2x4	21 14

NOTES:

IBC/IRC – International Building Code/International Residential Code

lb_f-s – Pounds (force) seconds

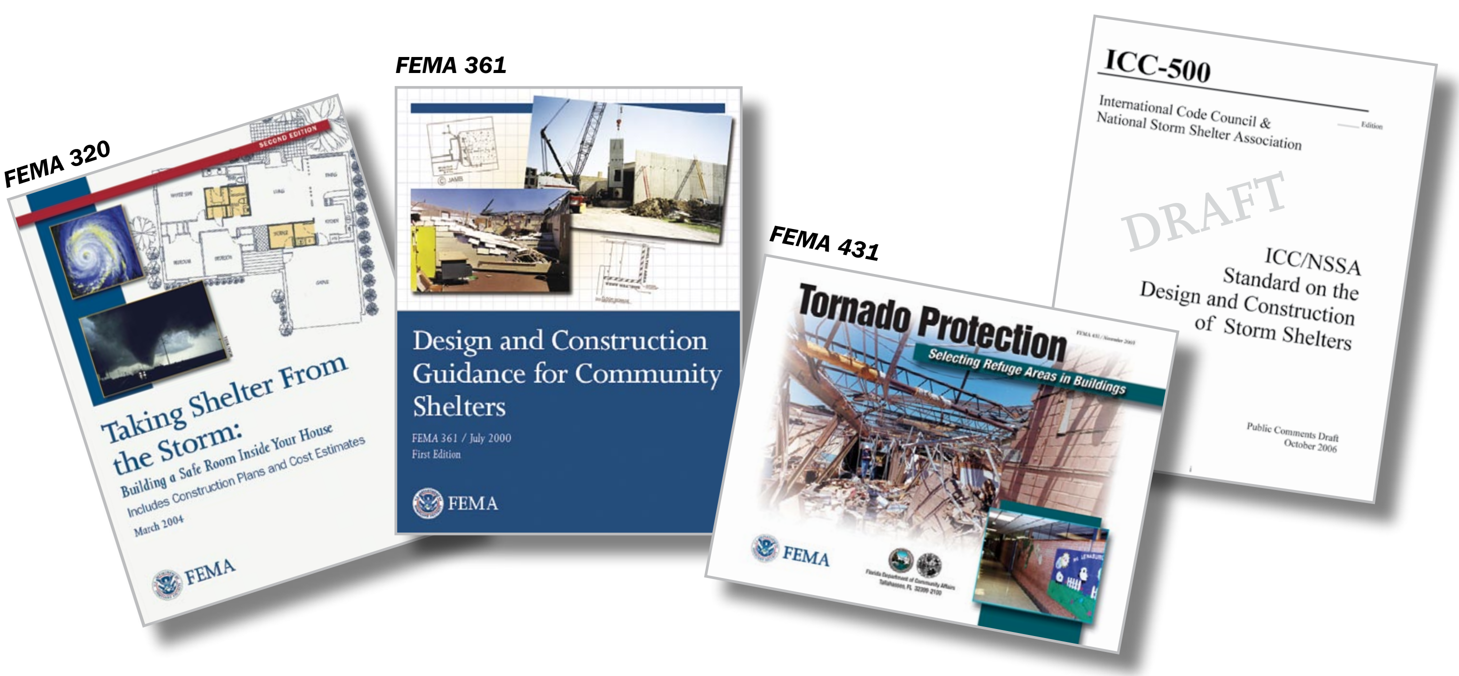
Useful Links and Shelter Resources:

Taking Shelter From the Storm: Building a Safe Room Inside Your House (FEMA 320), FEMA, Washington, DC, Second Edition, March 2004.

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

Tornado Protection: Selecting Refuge Areas in Buildings (FEMA 431), FEMA, Washington, DC, November 2003.

Standard on the Design and Construction of Storm Shelters, International Code Council and the National Storm Shelter Association (ICC-500), (Anticipated Release) Late 2007.



Wind Shelter Design and Construction Codes, Standards, Guidance Comparison Table[1]

Title or Name of Document	Code, Reg, Standard, or Statute?	Wind Hazard	Wind Map
FEMA Shelter Publications: **FEMA 320** *Taking Shelter From the Storm: Building a Safe Room Inside Your House* (1999) **FEMA 361** *Design and Construction Guidance for Community Shelters* (2000)	FEMA guidance document, not a code or standard. "Best Practice" for high-wind shelters	Tornado and Hurricane	**FEMA 320:** Hazard map, but wind speeds not used for design **FEMA 361:** Map with four wind speed zones for design (wind mri[2] is 10,000–100,000 years). This map is often referred to as the "FEMA 361 map"
International Code Council/National Storm Shelter Association (ICC/NSSA) High Wind Shelter Standard (ICC-500) – currently in development, tentatively available for adoption in January 2008.	Consensus standard for shelter design and construction, available for adoption in January 2008. To be incorporated by reference into the 2009 IBC and IRC.	Tornado and Hurricane	**Tornado:** Uses FEMA 361 map **Hurricane:** Uses revised ASCE 7 map with contours at 10,000 year mri with minimum shelter design wind speed of 160 mph, maximum approximately 240 mph
Florida State Emergency Shelter Program (SESP) – Florida Interpretation of the American Red Cross (ARC) 4496 Guidance. Note: shelters in this category will range from Enhanced Hurricane Protection Area (EHPA) recommended design levels, shown in this row, to the code requirement levels (next row), to the ARC 4496 requirements (see below).	Guidance in the FBC "recommending" above-code requirements for EHPAs. See also Appendix G of the State Emergency Shelter Program (SESP) report for the detailed design guidance.	Tornado and Hurricane	Florida Building Code (FBC) map, based on ASCE 7 (maps basically equivalent); mri is 50–100 years in coastal areas and adjusted with importance factor
Florida Building Code (FBC) EHPAs – code requirements for public "shelters" (FBC Section 423.25).	Statewide code requirements for EHPAs	Hurricane	FBC map, based on ASCE 7 (maps basically equivalent); mri is 50–100 years in coastal areas and adjusted with importance factor
Institute for Business and Home Safety (IBHS) Fortified Home Program – intended as guidance to improve the performance of residential buildings during natural hazard events, including high-wind events – not considered adequate for sheltering.	Guidance provided to improve performance of regular (non-shelter) buildings in high winds	Tornado and Hurricane	ASCE 7 or modern State building code map
FBC 2000 and later, International Building Code (IBC)/International Residential Code (IRC) 2000 and later/ASCE 7-98 and later.	Building code and design standards for regular (non-shelter) buildings. Some additional guidance is provided in commentary.	Hurricane	ASCE has its own wind speed map based on historical and probabilistic data; mri is 50–100 years in coastal areas and adjusted with importance factor
American Red Cross (ARC 4496) *Standards for Hurricane Evacuation Shelter Selection.*	Guidance for identifying buildings to use as hurricane evacuation shelters	Hurricane	None
Pre-2000 Building Codes	Building code and design standards for regular (non-shelter) buildings	Hurricane	Each of the older codes used their own published wind contour maps
Areas of Refuge/Last Resort	Guidance from FEMA and others for selecting best-available refuge areas	Tornado and Hurricane	None

NOTES:

1. The wind shelter guidance and requirements shown here are presented from highest to least amount of protection provided.
2. Mean recurrence intervals (mri) for wind speeds maps are identified by the code or standard that developed the map. Typically, the mri for non-shelter construction in non-hurricane-prone areas is 50 years and in hurricane-prone regions, approximately 100 years.

Part 2 of table (continued from page 4)

Wind Design Coefficient Considerations[3,4]	Debris Impact Criteria[5]	Remarks
FEMA 320: N/A – prescriptive design guidance for maximum hazard **FEMA 361:** Use FEMA 361 wind speed map with four zones. Calculate pressures using ASCE 7 methods and use I=1.0, K_d=1.0, Exposure C, no topographic effects, GCpi=+/-0.55 (this will account for atmospheric pressure change [APC])	Test all shelters with the representative missile: a 15-lb 2x4 at 100 mph (horizontal) and 67 mph (vertical)	**FEMA 320:** Intent is to provide "near-absolute protection." No certification is provided. **FEMA 361:** Intent is to provide "near-absolute protection." Shelter operations guidance is provided. Occupancy issues addressed. Wall section details provided. No certification is provided.
Tornado: Use FEMA 361 wind speed map. Calculate pressures using ASCE 7 methods and use I=1.0, K_d=1.0, Exposure as appropriate, no topographic effects, GCpi=+/-0.55 or +/-0.18+APC **Hurricane:** Use revised ASCE 7 map and methods and use I=1.0, all other items as per ASCE 7, no APC consideration required.	Test shelters with representative missile (missile speed dependent on site design wind speed): **Tornado:** 15-lb 2x4 at 85–100 mph (horizontal) and 2/3 of this speed (vertical). **Hurricane:** 9-lb 2x4 at 68–105 mph (horizontal) and a lower speed (vertical)	Intent is to provide a standard for the design and construction of high-wind shelters. Will not use term "near-absolute protection." Occupancy, ventilation, and use issues are also addressed. Shelter operations guidance is provided in the commentary only (commentary is a separate document—not a consensus document).
Recommends that designer add 40 mph to basic wind speed identified on map, Exposure C, I=1.15, K_d=0.85, GCpi as required by design (typically +/-0.18), but recommends +/-0.55 for tornado shelter uses	In windborne debris region (120 mph+): Small – pea gravel; Large – 9-lb 2x4 at 34 mph (horizontal), up to 60 feet above grade, but recommends 15-lb 2x4 at 50 mph (horizontal)	The building, or a portion of a building, is defined as an essential facility and as a shelter. Designer is required to submit signed/sealed statement to building department and State offices stating the structure has been designed as a shelter (EHPA plus added recommended criteria).
Use basic wind speed at site as identified on FBC wind speed map, use exposure at site, use I=1.15, K_d=0.85, GCpi as required by design (typically +/-0.18)	In windborne debris region (120 mph+): Small – pea gravel; Large – 9-lb 2x4 at 34 mph (horizontal), up to 60 feet above grade	The building or a portion of a building is defined as an essential facility and as an EHPA. Designer is required to submit signed/sealed statement to building department and State offices stating the structure has been designed as an EHPA.
Based on regional hazards, recommendations are provided to improve and strengthen the load path and the performance of the building exterior	Window and glazing protection is recommended for most hurricane-prone areas, not just areas with a basic wind speed of 120 mph and greater	This program provides design and construction guidance to improve building performance for high-wind events. Compliance will likely improve building performance but does not imply that the building is safe or that it is appropriate to use as a shelter.
Method is basis of most wind pressure calculation methods. All items in design process are site-specific. Use I=1.15 for critical and essential facilities	In windborne debris region (120 mph+): Small – pea gravel; Large – 9-lb 2x4 at 34 mph (horizontal), up to 60 feet above grade. Note: 2006 IBC requires the 9-lb 2x4 (large) missile to be tested at 55 mph for critical and essential facilities	Code requires increased design parameters only for buildings designated as critical or essential facilities.
None	None	Provides guidance on how to select buildings and areas of a building for use as a high-wind shelter or refuge area. Does not provide or require a technical assessment of the proposed shelter facility.
Typically these older codes provided a hurricane regional factor for design wind speeds, but little attention was paid to components and cladding	Not required for all buildings. Where required, the Standard Building Code[6] developed and recommended debris impact standards for use in hurricane-prone regions	These codes specified limited hazard-resistant requirements. Some guidance was provided with SSTD 10 from SBCCI for the design and construction of buildings in high-wind and hurricane-prone regions. Buildings constructed to these early codes were not required to have structural systems capable of resisting wind loads.
None	None	Best available refuge areas should be identified in all buildings without shelters. FEMA 431, *Tornado Protection: Selecting Refuge Areas in Buildings,* provides guidance to help identify the best available refuge areas in existing buildings. Because best available refuge areas are not specifically designed as shelters, their occupants may be injured or killed during a tornado or hurricane.

NOTES (continued):

3. ASCE 7-05 *Building Design Loads for Buildings and Other Structures* (2005) is the load determination standard referenced by the model building codes. The wind design procedures used for any shelter type in this table use one of the wind design methods as specified in ASCE 7-05, but with changes to certain design coefficients that are identified by the different codes, standards, or guidance summarized in this table.
4. From ASCE 7 method: I = importance factor; K_d = wind directionality factor; GCpi = internal pressure cofficient
5. Roof deck, walls, doors, openings, and opening protection systems must all be tested to show resistance to the design missile for the FEMA, ICC, and FL EHPA criteria.
6. From the Southern Building Code Congress International, Inc. (SBCCI).

The table below shows comparative data for two locations for the design criteria presented in the previous table. Where no guidance is provided for sheltering or basic construction, "N/A" (not applicable) is stated. Where the requirement is not required, "Not required" is stated.

Design Criteria Comparison

Shelter Design Standard, Code, or Document	Data[1]	Example Location #1: Miami, FL	Example Location #2: Atlanta, GA
FEMA 320/361	Design wind speed	200 mph	200 mph
	Pressure on windward wall	107 psf[2]	107 psf
	Pressure on roof section	257 psf (suction)	257 psf (suction)
	Test missile momentum at impact	68 lb_f-s[2]	68 lb_f-s
ICC-500 (pending 1/08)	Design wind speed	200 mph (tornado) 225 mph (hurricane)	200 mph (tornado) 160 mph (hurricane)
	Pressure on windward wall	107 psf (tornado) 136 psf (hurricane)	107 psf (tornado) 69 psf (hurricane)
	Pressure on roof section	257 psf (tornado, suction) 325 psf (hurricane, suction)	257 psf (tornado, suction) 202 psf (hurricane, suction)
	Test missile momentum at impact	68 lb_f-s (tornado) 42-26 lb_f-s (hurricane)	68 lb_f-s (tornado) 42-26 lb_f-s (hurricane)
FBC EHPA/SESP (using + 40 mph recommendation)	Design wind speed	186 mph	130 mph
	Pressure on windward wall	91 psf	44 psf
	Pressure on roof section	217 psf (suction)	106 psf (suction)
	Test missile momentum at impact	34 lb_f-s	34 lb_f-s
FBC EHPA	Design wind speed	146 mph	N/A
	Pressure on windward wall	39 psf	N/A
	Pressure on roof section	117 psf (suction)	N/A
	Test missile momentum at impact	14 lb_f-s	N/A
IBHS	Design wind speed	150 mph	90 mph
	Pressure on windward wall	41 psf	15 psf
	Pressure on roof section	124 psf (suction)	44 psf (suction)
	Test missile momentum at impact	14 lb_f-s	14 lb_f-s
ASCE 7-05/IBC 2006 (ASTM E 1996)	Design wind speed	150 mph	90 mph
	Pressure on windward wall	41 psf	15 psf
	Pressure on roof section	124 psf (suction)	44 psf (suction)
	Test missile momentum at impact	14 lb_f-s	Not required
ARC 4496	Design wind speed	N/A	N/A
	Pressure on windward wall	N/A	N/A
	Pressure on roof section	N/A	N/A
	Test missile momentum at impact	N/A	N/A
Pre-2000 Building Codes	Design wind speed	140 mph and less	90 mph and less
	Pressure on windward wall	< 40 psf (varies)	< 15 psf (varies)
	Pressure on roof section	< 120 psf (varies)	< 45 psf (varies)
	Test missile momentum at impact	Not required by all codes	Not required
Areas of Last Resort	Design wind speed	Unknown	Unknown
	Pressure on windward wall	Unknown	Unknown
	Pressure on roof section	Unknown	Unknown
	Test missile momentum at impact	Not required	Not required

NOTES:

1. Wind pressures were calculated based on a 40-foot x 40-foot square building, with a 10-foot eave height and a 10-degree roof pitch.
2. psf – Pounds per square foot; lb_f-s – Pounds (force) seconds

Residential Sheltering: In-Residence and Stand-Alone Shelters

FEBRUARY 2007 TORNADO RECOVERY ADVISORY *FEMA DR 1679 RA3*

Intended Audience and Purpose

The purpose of this advisory is to alert homeowners, renters, apartment building owners, and manufactured home park owners about the concept of in-residence and stand-alone storm shelters.

This Recovery Advisory Addresses:

- Consider a shelter for your home
- In-residence shelter construction and retrofitting options
- Sheltering options for when you can't place a shelter within your home
- Areas of last resort for those residents that don't have access to a shelter
- Emergency planning

See these 2007 Tornado Recovery Advisories for information about tornado risk, sheltering from tornadoes, and improving manufactured homes against damage from high winds:

- Tornado Risks and Hazards in the Southeastern United States (Tornado Recovery Advisory No. 1)
- Storm Shelters: Selecting Design Criteria (Tornado Recovery Advisory No. 2)
- Understanding and Improving Performance of Older Manufactured Homes in High-Wind Events (Tornado Recovery Advisory No. 4)
- Understanding and Improving Performance of New Manufactured Homes in High-Wind Events (Tornado Recovery Advisory No. 5)

Consider a Shelter for Your Home

The purpose of having a shelter (also known as a "safe room") in or near your home is to protect you and your family from injury or death caused by extreme winds. Shelters are intended to allow occupants to survive tornadoes and hurricanes with little or no injury. To determine your exposure to tornadoes, refer to FEMA 320, *Taking Shelter From the Storm: Building a Safe Room Inside Your House* (Second Edition, March 2004).[1] This publication provides information that can help you decide whether or not to construct a shelter to protect you and your family from injury or death during a tornado or hurricane. Additional information is provided in the Tornado Recovery Advisory titled *Tornado Risks and Hazards in the Southeastern United States.*

After determining that you live in a tornado- or hurricane-prone region, it is important to understand the risks. Most homes, even new ones constructed according to current building codes, do not provide adequate protection for occupants seeking refuge from tornadoes. A tornado or hurricane can cause wind and windborne debris loads on your house that are much greater than those on which building code requirements are based. Only specially designed and constructed shelters, which are voluntarily built above the minimum code requirements, offer occupant protection during a tornado or strong hurricane.

It is also important to remember that shelters offering protection against high-wind events should not be placed where flood waters have the potential to endanger occupants within the shelter. If your shelter is located where coastal or riverine flooding may occur during hurricanes, it should not be occupied during a hurricane. However, occupying such a shelter during a tornado may be acceptable, provided that the shelter is located where it will not be flooded by rains associated with other storm and tornado events. Consult your local building official or local National Flood Insurance Program representative to determine whether your home, or a proposed stand-alone shelter site, is susceptible to riverine or coastal flooding.

1. FEMA 320 is available online at http://www.fema.gov/plan/prevent/saferoom/fema320.shtm. Hardcopies may be obtained at no cost by calling 800-480-2520.

In-Residence Shelter Construction and Retrofitting Options

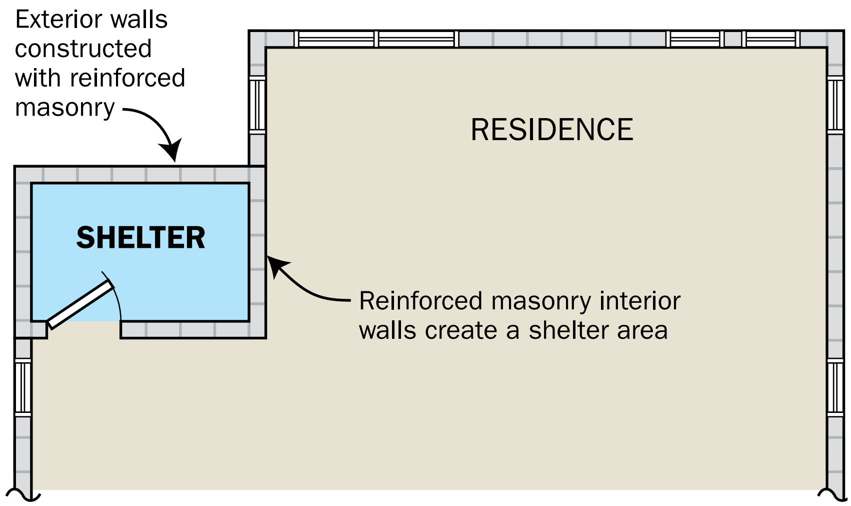
Constructing a shelter within your home puts it as close as possible to your family. A shelter may be installed during the initial construction of a home, or retrofitted afterward. As long as the design and construction requirements and guidance are followed, the same level of protection is provided by either type of shelter.

New Construction

FEMA 320 provides detailed drawings and specifications that can be used by a builder/contractor to construct a shelter in your home. The designs provided are for shelters constructed of wood, masonry, or concrete. All of them are designed to resist 250-mph (3-second gust) wind speeds and impacts from windborne debris. Pre-fabricated shelters are also available for installation by a builder/contractor when first building your home. The basic cost to design and construct a shelter during the construction of a new house is approximately $6,000, with larger, more refined, and more comfortable designs costing more than $15,000.

It is relatively easy and cost-effective to add a shelter when first building your home. For example, when the home is constructed with exterior walls made from concrete masonry units (CMU, also commonly known as “concrete block,” see sketch this page), the protection level in FEMA 320 can be achieved by slightly modifying the exterior walls at the shelter space with additional steel reinforcement and grout. The shelter is easily completed by adding interior walls constructed of reinforced CMU, a concrete roof deck over the shelter, and a special shelter door, as shown under construction in bottom photograph.

CMU was used for the exterior walls at this house under construction (New Smyrna Beach, FL).



Sketch of floor plan showing location of shelter area in house.

View of an in-residence shelter under construction. Steel reinforced and fully grouted CMU surround the shelter space (New Smyrna Beach, FL).

Retrofitting Existing Houses

FEMA 320 provides general guidance for retrofitting a house with a shelter. Building a shelter in an existing house will typically cost 20 percent more than building the same shelter in a new house while under construction. Because the shelter is being used for life safety, and because your home might be exposed to wind loads and debris impacts it was not designed to resist, an architect or engineer (A/E) should be employed to address special structural requirements, even if inclusion of an A/E in such a project is not required by the local building department.

Recommendations for Sheltering When You Cannot Place a Shelter Within Your Home

Many reasons may prevent a homeowner or renter from installing or constructing a shelter within their home. These reasons may include: lack of permission (the resident does not own the home or does not have rights to modify or change the home), lack of available space, or lack of technical or economic practicality. Nonetheless, homeowners or renters may want to proceed with installing a shelter. Stand-alone shelters can be designed and constructed outside of a residence. These shelters can provide the same level of protection against high winds and windborne debris as do the in-residence shelters.

Small Stand-Alone Shelters

Some site-built homes, and most manufactured homes, do not lend themselves to the structural modifications and retrofitting required to install or construct an in-residence shelter. In these instances, a stand-alone shelter may be constructed (either above-grade, partially above-grade [see photograph to right], or below grade) near the residence. Small stand-alone shelters can be constructed to accommodate the occupants of one house, a few houses, or a small apartment building. This photo, from Wichita, KS, shows how a manufactured home community provided small, pre-fabricated shelters as a refuge for the residents. Each shelter provides safety for several homes in the community.

View of a pre-fabricated shelter that serves a few manufactured homes (Wichita, KS).

Community Shelters

A community shelter can be constructed to accommodate the occupants of several apartments or homes (site-built or manufactured homes, see photograph to right). For information about community shelters, refer to the Tornado Recovery Advisory titled *Storm Shelters: Selecting Design Criteria.* Many different types of shelters can be designed and constructed to meet the needs of large groups of residents. A shelter may be a single-use building, or it may be a multi-use building, such

View of a partially below-grade community shelter at a manufactured home community (Wichita, KS).

as a clubhouse (at community pools, golf courses, etc.), school building, or recreation center. Selecting the right type of shelter will be a collective decision made by the residents, funding agencies, and property owners and managers. For information on community shelters for larger populations, including planning and operational issues, see FEMA 361, *Design and Construction Guidance for Community Shelters* (2000).[2]

For further information about pre-fabricated and stand-alone shelters, contact the National Storm Shelter Association (http://www.nssa.cc)

Areas of Last Resort

Occupants of dwellings that do not have in-residence shelters, or access to stand-alone or community shelters, should identify the best available refuge area within their home before an emergency happens. When people identify and take refuge in the best available space within a building, they are less likely to be injured or killed. However, it is important to remember that "best available refuge areas" are not specifically designed as shelters, so occupants may be injured or killed during a tornado or hurricane event.

View of remnants of an interior room of a house that survived a strong tornado.

The following criteria should be used in identifying the best available refuge area in your home:

- Choose the lowest floor of the residence (a basement is preferable, or first floor if there is no basement).
- Choose a small interior room without windows (i.e., none of the room's walls is an exterior wall), such as a bathroom or closet, preferably with only one door.
- Choose a room located away from masonry chimneys, trees, or power poles.

Avoid selecting a refuge area that is near a masonry chimney (Moore, OK).

- Keep the room relatively free of clutter so you and the other residents can enter and remain in the room for up to several hours.

Emergency Supply Kits and Weather Radios

FEMA 320 provides information to use in preparing a Family Emergency Plan and an Emergency Supply Kit for the shelter. Further, all individuals living or working in tornado-prone areas should have a weather radio within their home or place of work. For more information about weather radios, see the Tornado Recovery Advisory titled *Tornado Risks and Hazards in the Southeastern United States.*

2. FEMA 361 is available online at http://www.fema.gov/fima/fema361.shtm.

Understanding and Improving Performance of Older Manufactured Homes During High-Wind Events

FEMA

FEBRUARY 2007 TORNADO RECOVERY ADVISORY *FEMA DR 1679 RA4*

Purpose and Intended Audience

High-wind events can damage or destroy manufactured homes. While revisions to manufactured home standards continue to improve performance, older manufactured homes remain in use and are particularly vulnerable to high winds. The series of tornadoes that struck Central Florida on February 2, 2007 is but one high-wind event that has shown the vulnerability of older manufactured homes. The tornadoes destroyed numerous older manufactured homes and forced numerous others off their foundations. The purpose of this Tornado Recovery Advisory is to provide guidance on methods to reduce wind damage to manufactured homes constructed before July 13, 1994. Guidance for reducing damage to manufactured homes constructed after July 13, 1994 is contained in the Tornado Recovery Advisory titled *Understanding & Improving Performance of New Manufactured Homes During High-Wind Events.*

This recovery advisory is directed to owners of "older" (pre-1994) manufactured homes. Building officials, manufactured home installers and contractors, and operators of manufactured home communities may also find it informative.

This Recovery Advisory Addresses:

- Manufactured home ages
- Vulnerabilities of older manufactured homes to high-wind events
- Recommendations[1]

See these 2007 Tornado Recovery Advisories for information about tornado risk, sheltering from tornadoes, and improving manufactured homes against damage from high winds:

- Tornado Risks and Hazards in the Southeastern United States (Tornado Recovery Advisory No. 1)
- Storm Shelters: Selecting Design Criteria (Tornado Recovery Advisory No. 2)
- Residential Sheltering: In-Residence and Stand-Alone Shelters (Tornado Recovery Advisory No. 3)
- Understanding and Improving Performance of New Manufactured Homes During High-Wind Events (Tornado Recovery Advisory No. 5)

Manufactured Home Ages

Although there are no strict definitions of "older" and "new" manufactured homes, the following descriptions, which are based on the evolution of manufactured home construction standards, are useful.

"Older" Manufactured Homes

This category includes "pre-code" homes and "early code" homes. Some manufactured homes considered "older" may be relatively new from an expected service life standpoint, but are still old from a wind resistance standpoint. For this recovery advisory, any manufactured home constructed before July 13, 1994, is considered an older manufactured home.

Pre-Code Manufactured Homes: This refers to homes built before June 15, 1976, when the Department of Housing and Urban Development (HUD) began regulating construction. Prior to 1976, manufactured

1. Actions recommended by this recovery advisory can reduce damage to manufactured homes during high-wind events. The actions will not, however, strengthen older manufactured homes enough to allow occupants to safely remain in their homes during tornadoes or hurricanes. When advised by local or State authorities, occupants of manufactured homes should find suitable shelter when tornadoes or hurricanes threaten.

housing was essentially unregulated and wide variations in construction quality and strength existed. Pre-code manufactured homes were often called trailers or mobile homes because they were intended to be moved from place to place.

Early Code Manufactured Homes: These are homes built after June 15, 1976 (and before July 13, 1994) when the Manufactured Home Construction and Safety Standards (MHCSS), developed by HUD, first went into effect. After 1976, homes became known as "manufactured housing." The MHCSS specified minimum wind pressures that manufactured homes must be designed to resist. It also contained general criteria for anchoring homes to resist wind forces. The wind pressures required by the MHCSS correspond to a sustained wind speed of around 70 miles per hour (mph) in an Exposure C area. This is approximately equivalent to 85 mph peak gust winds.

This home, constructed before 1976, was destroyed in the February 2007 tornadoes.

"New" Manufactured Homes

Hurricane Andrew destroyed numerous manufactured homes in 1992. In response to this damage, the MHCSS standards were strengthened on July 13, 1994. The strengthened standards apply to homes placed in higher wind speed areas. These 1994 revisions, which remain in effect today, established three types of homes: HUD Zone I, HUD Zone II, and HUD Zone III homes.

- HUD Zone I homes are those homes designed to the original 1976 standards.
- HUD Zone II homes are designed to resist sustained wind speeds of 100 mph (equivalent to approximately 120 mph peak gust winds).
- HUD Zone III homes are designed to resist a sustained wind speed of 110 mph (equivalent to approximately 130 mph peak gust winds).

NOTE: "Sustained" wind speeds are approximately fastest mile wind speeds; "gust" wind speeds are approximately 3-second gusts wind speeds.

This home, constructed between 1976 and 1994, was severely damaged by one of the February 2007 tornadoes.

How Older Manufactured Homes are Vulnerable to High-Wind Events

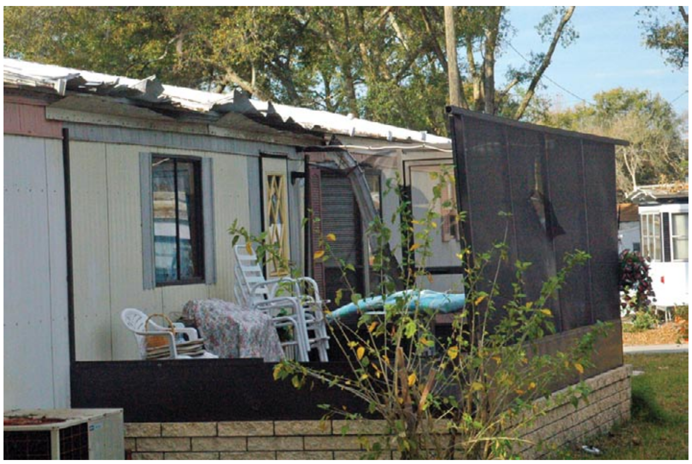
High-wind events such as tornadoes and hurricanes can damage nearly all buildings not specifically designed to resist the strong forces generated by these events. New "engineered buildings," those designed by professionals to meet the latest building codes and standards, have generally performed well in high-wind events while older buildings and non-engineered buildings often have not. Pre-code manufactured homes, particularly those that have not been well maintained and those that have had non-engineered additions or modifications made to them, have often performed poorly.

Damage can be grouped into two categories: direct damage to the home itself and damage that results from failures in the home's anchorage system.

The roof of this older manufactured home was blown off by high winds.

The entire roof structure of this older manufactured home was lost and wall panels were lifted from the home.

Portions of the roof and wall sheathing of this older manufactured home were lost. Flying debris broke unprotected glass in the doors and windows.



This older manufactured home once had an attached screened-in porch. The porch roof blew off and lifted portions of the home's roof. Fortunately, the high winds lasted only seconds and the rest of the roof was not severely damaged. Had the storm lasted longer, the entire roof would have likely been lost.

Loss of roofing likely originated where the roof of the addition was fastened to the home's roof.

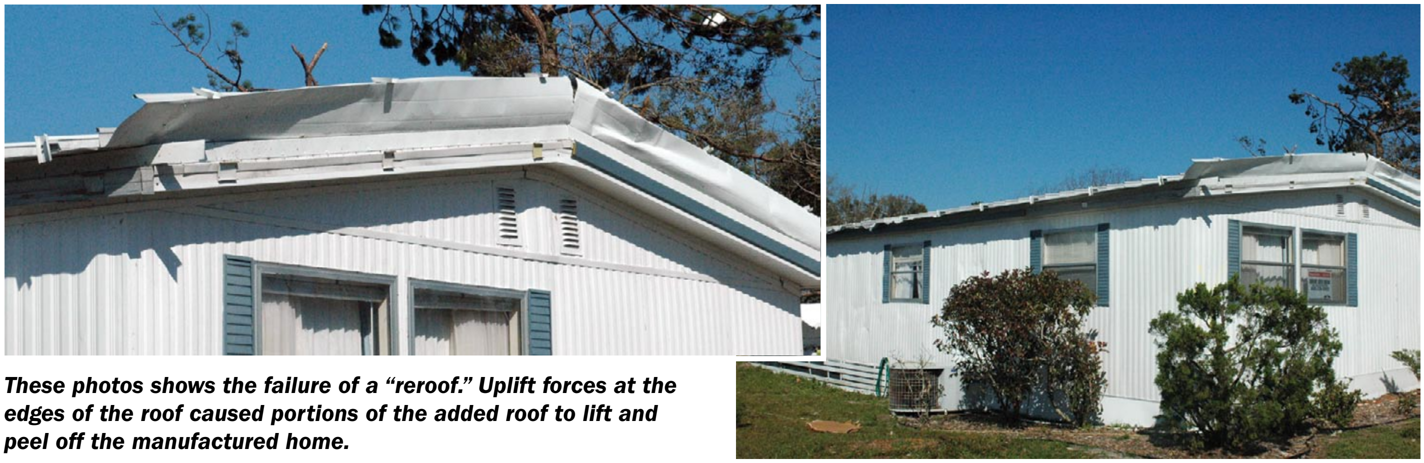
Direct Damage

Direct damage often includes blown-off roof panels, loss of roof framing, loss of wall panels and framing, and breakage of unprotected windows. Window damage occurs as a result of high wind pressures or from the impact of flying debris generated by high winds.

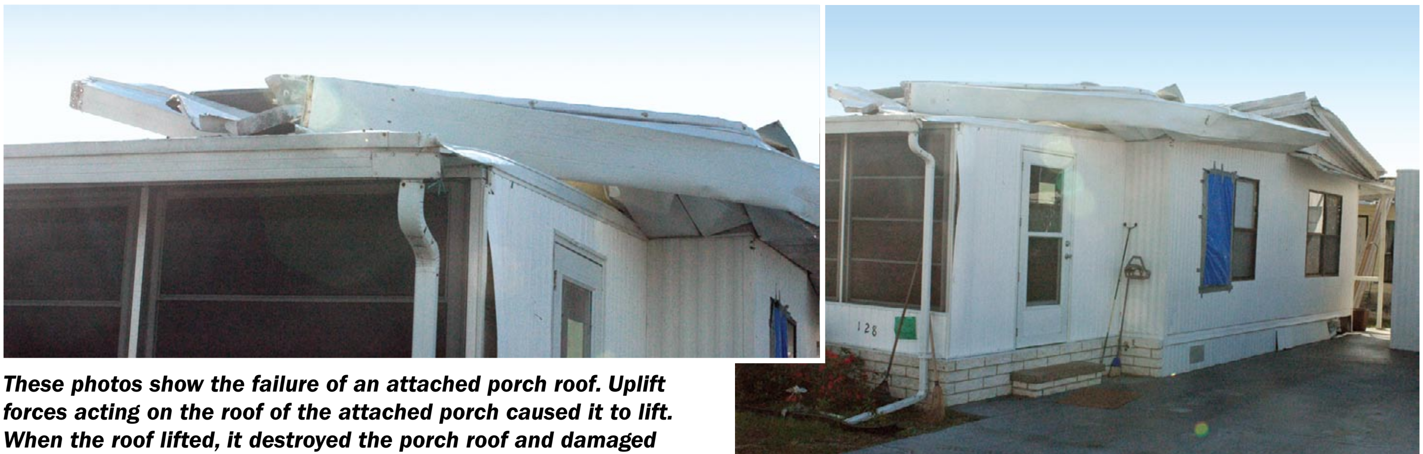
Compared to new manufactured homes, the roofs and walls of many older manufactured homes are poorly fastened, particularly those constructed before 1976. Damage from high-wind events is quite common. Once walls and roofs are damaged, rainwater can freely enter the home and saturate its interior. Water damage often results in a total loss of the home and its contents.

The potential for damage to manufactured homes is increased significantly when additions like carports, awnings, or porches are fastened to the home. These additions concentrate wind forces where they are fastened to the home. The increased forces can overload connections used to hold the home together and can result in a failure of the members or connections in the home. Most home manufacturers prohibit attachments to their homes unless special provisions to support attachments were incorporated into the home when it was manufactured. The attachments themselves, unless engineered, also violate local code requirements in many jurisdictions.

Reroofing is another type of "addition" that involves installing a new roof covering or a new roof structure over an existing roof. Depending on the method used to attach the new roof, wind loads can be concentrated into



These photos shows the failure of a "reroof." Uplift forces at the edges of the roof caused portions of the added roof to lift and peel off the manufactured home.



These photos show the failure of an attached porch roof. Uplift forces acting on the roof of the attached porch caused it to lift. When the roof lifted, it destroyed the porch roof and damaged the roof over the original home. Where open areas exist, as in the porch shown, the addition must resist uplift forces that act on the top and underside of the roof.

only a few members or connections. The concentration of wind loads can overload members and connections and can result in structural failures. Also, many reroofs create roof overhangs that, while desirable from a home maintenance standpoint, increase loads on the home and its foundation and make the home more vulnerable to wind damage.

Anchorage Failure

Anchorage failures involve the home being lifted, slid, or rolled off its foundation. An anchorage failure can destroy a home even when there is no direct wind damage to the home itself.

Anchorage failures are much more common in older homes than in newer homes. Older homes generally weigh less than newer manufactured homes and are thus more vulnerable to displacement from wind forces. Historically, it appears that minimal attention was paid to the anchorage of these homes compared to the observed anchorages in newer homes.

This manufactured home rolled off its foundation after anchors used to secure it pulled out of the ground. Only six anchors (three per side) secured the 30-foot-long section of home. Twelve anchors would have been appropriate. The home lifted off its foundation and rolled approximately 70 feet before coming to a rest on its roof.

Anchorage failures typically result from:

- Too few anchors used to secure the home
- Improper anchors selected for the soils present on site
- Corroded anchors or anchor straps

The ground anchor above pulled out of the ground 8 inches. Either improper anchors were selected or too few were installed. The anchor spacing at this home was approximately 12 feet.

This ground anchor failed just below the anchor head where corrosion had weakened the anchor shaft. Like many older-style anchors and straps, the anchors and straps were not galvanized and were susceptible to corrosion.

This 4-foot-long ground anchor with a 6-inch diameter helix pulled out of the soil. Soils in the area consisted of loose sands. Longer anchors with larger diameter helices would have been a better choice for this soil type. The anchor spacing at this home was approximately 10 feet.

The following examples of anchorage failures were observed in older manufactured homes after the February 2007 Florida tornadoes.

Recommendations

Home Strengthening

Unfortunately, relatively few inexpensive measures exist that can significantly increase the strength of an older manufactured home. Most fasteners that hold a home together are concealed and the home would need to be partially disassembled to gain access to improve connections. Also, particularly in the case of the roof, adding fasteners usually involves penetrating exterior surfaces of the home and these penetrations increase the potential for leakage.

To increase the wind resistance of the roof, additional fasteners can be installed to better fasten the metal roof panels to the roof framing, followed by the installation of a single-ply roof membrane. As part of the improvements, portions of the metal roof panels can be removed to access areas where the roof framing connects to the wall framing. This will enable roof/wall connections to be strengthened.

If a new roof structure over the existing roof is desired, the new structure should be designed to resist components and cladding loads for the basic wind speed identified in the 2006 *International Residential Code,* the 2006 edition of National Fire Protection Association (NFPA) 5000 *Building Construction and Safety*

Code, or American Society of Civil Engineers (ASCE) 7-05 *Minimum Design Loads for Buildings and Other Structures* for the site on which the home is located.

Attachments and Attached Structures

Home owners are advised that, prior to 1994, most homes were not designed or approved by the manufacturer to have attachments connected to them. Attached structures should not be added to homes not designed to support them. All attachments or structures attached to existing older manufactured homes should be removed or reconfigured so they are supported independently of the home. For best performance, no connections, other than flashing required for weather-tightness, should remain between the manufactured home and the addition. Regardless of whether the added structure is attached to the home or is free-standing next to it, all added structures should be constructed to meet local code requirements using the same standards as those for residential site-built construction. The design of additions should not use reduced wind criteria that are occasionally considered for ancillary structures like agricultural buildings and minor storage facilities. Where no code is locally adopted, the 2006 *International Residential Code,* the 2006 *International Building Code* or the 2006 edition of NFPA 5000 *Building Construction and Safety Code* should be followed.

Anchorages and Strapping

Anchors and straps should be inspected regularly and all corroded straps or anchors should be removed and replaced and all loose straps should be tightened. Specific tensioning limits are usually not specified in ground anchor or manufactured home installation instructions. However, the straps should be tightened sufficiently to remove all slack and to allow the strap to move only ¼ inch or so under firm hand pressure. In interior areas (more than 3,000 feet from the coast) anchors and straps should be inspected every 5 years. For homes situated within 3,000 feet of the coast, anchors and straps should be inspected every 2 years. When new anchors and straps are installed, only galvanized materials (with a minimum coating of 0.6 ounce per square foot) should be used. Anchor heads should remain approximately 1 inch above adjacent grade to help prevent corrosion resulting from water accumulating near the anchor head and strap.

High-wind events can cause homes secured with ground anchors to shift across their piers. This shift increases loads on portions of the footings below the piers, which increases the potential for footing damage. Shifting also makes the home more vulnerable to anchorage failures during subsequent high-wind events. When the centerline of the home's frame is not located within 2½ inches of the center of its piers, the home should be lifted and re-set to properly center the home's steel frames.

When a home is exposed to high winds, it can move (as described above) and cause anchors and straps to become loose. Loose straps render anchors ineffective at resisting winds from subsequent events. Anchor straps can loosen even without a home being exposed to high winds, particularly if soils are relatively soft or if anchors were inadequately pre-tensioned after their installation. For these reasons, manufactured homes secured with ground anchors should have their anchors checked periodically and re-tensioned when straps are found loose. As described above, loose straps should be tightened to remove all slack and to allow the strap to move only ¼ inch or so under firm hand pressure.

Homes should be anchored in both the lateral and longitudinal direction. Lateral anchorage requirements depend on the design wind speed for the area and on the length and width of the home. The greater the design wind speed, the closer the required anchor spacing. Also, narrow single-unit homes, which are more prone to overturning, require closer anchor spacing than wider double-unit homes and longer homes require more lateral anchors than shorter homes. The type of pads used under the masonry piers that support the home should also be considered. Closer anchor spacing is suggested when ABS (Acrylonitrile Butadiene Styrene) pads are used. ABS pads are a relatively new style of pad that is used in lieu of heavier concrete pads. They are lightweight and typically manufactured from recycled plastics. Closer anchor spacing will limit home movement and will help prevent fracturing of the ABS pads. Lateral ground anchors should also be placed within 2 feet of the ends of the home. Use the table on the following page to identify maximum interval spacing and calculate the number of anchors needed for lateral anchorage. For example, if a double-wide home is sited in a 110 mph wind zone and placed on concrete pads, it should have ground anchors spaced at maximum intervals of 6 feet, 8 inches. Therefore, a 64-foot-long double-wide home would require 20 lateral anchors (10 per side) and a 72-foot-long double-wide home would require 24 anchors. For longitudinal anchorage, 4 ground anchors per section end are recommended. A total of 8 longitudinal ground anchors should be installed for single-wide homes and 16 should be installed for double-wide homes.

Lateral Ground Anchor Spacing

	Single Wide		Double Wide	
Design Wind Speed	**ABS Pads**	**Concrete Pads**	**ABS Pads**	**Concrete Pads**
90 mph	5’4”	6’8”	5’4”	6’8”
110 mph	5’4”	6’8”	5’4”	6’8”
130 mph	4’0”	5’4”	4’0”	5’4”

NOTES:

(1) The design wind speed is the 3-second gust wind speed per ASCE 7-05 and the 2006 Edition of the International Building Code. The anchor spacing listed above is appropriate for Exposure B and C conditions. A licensed professional engineer should design anchorage for homes placed in Exposure D areas and for homes placed within 1,500 feet of the coast (as required by the MHCSS).

(2) Ground anchor spacing is based on homes weighing an average of 20 pounds per square foot, with steel I-beam frames spaced at intervals of 96 inches or more, with roof slopes between 15 degrees and 20 degrees, and with wall heights up to 8 feet. The spacing is appropriate for homes placed on masonry piers up to 36 inches tall. When the manufacturer’s installation instructions are not available, a licensed professional engineer should design anchor spacing for homes that weigh less, have narrower I-beam frame spacing or taller walls, are placed on taller piers, or have steeper or shallower roofs. For HUD Zone I style homes, each lateral ground anchor should be strapped to the nearest and furthest I-beam. For HUD Zone II and Zone III homes, each lateral ground anchor should be strapped to the furthest I-beam and the corresponding wall tie.

(3) When the manufacturer’s installation instructions or local codes specify ground anchor spacing different than that listed above, anchors should be installed at the closest anchor spacing specified for improved resistance to hurricanes and tornadoes.

The ground anchor spacings shown are greater than Florida 15C-1 requirements. For homes in Florida, locate anchors at 5 feet, 4 inches (maximum).

When no provisions exist to tie an older manufactured home’s walls to the anchoring system, over-the-roof ties help prevent direct damage to the home. However, the effective installation of over-the-roof ties is challenging. Over-the-roof ties need to be placed directly over roof framing members so they do not deform or puncture the roof. They also need to be fastened in place to ensure they do not move off the roof framing members. Fastening over-the-roof straps requires penetrating the roof. This will increase the potential for roof leaks.

The Florida Department of Highway Safety requirements include provisions for over-the-roof ties. Their standards place over-the-roof ties at roughly 20-foot intervals. Investigations following recent tornadoes revealed numerous homes were damaged or destroyed that had factory or field-installed roof ties installed in the 18-foot to 20-foot range. This suggests that closer over-the-roof tie spacing is prudent. When ground anchors are installed at the spacing recommended above, placing an over-the-roof tie at every other ground anchor is appropriate. When ground anchors are spaced at 8-foot intervals, over-the-roof ties should be located at each anchor.

Homes located in Special Flood Hazard Areas (SFHAs) should follow installation recommendations contained in the revised FEMA 85, *Manufactured Homes in Flood Hazard Areas – A Multi-Hazard Foundation and Installation Guide.* The revised FEMA 85 is due to be completed in 2007. The ground anchor spacing table included in this Recovery Advisory was developed from FEMA 85.

Understanding and Improving Performance of New Manufactured Homes During High-Wind Events

FEBRUARY 2007 TORNADO RECOVERY ADVISORY *FEMA DR 1679 RA5*

Purpose and Intended Audience

The purpose of this Tornado Recovery Advisory is to provide guidance on reducing damage to new manufactured homes from high-wind events including tornadoes and hurricanes. For this recovery advisory, any manufactured home constructed after July 13, 1994 is considered a new manufactured home. Guidance for improving manufactured homes constructed before July 13, 1994, is contained in the Tornado Recovery Advisory titled *Understanding and Improving Performance of Older Manufactured Homes During High-Wind Events.*

This recovery advisory has been prepared for owners of new manufactured homes. Prospective purchasers of manufactured homes, building officials, manufactured home installers, contractors, and operators of manufactured home communities may also find it informative.

This Recovery Advisory Addresses:

- Manufactured home ages
- Vulnerabilities of new manufactured homes to tornadoes and hurricanes
- Recommendations[1]

See these 2007 Tornado Recovery Advisories for information about tornado risk, sheltering from tornadoes, and improving manufactured homes against damage from high winds:

- Tornado Risks and Hazards in the Southeastern United States (Tornado Recovery Advisory No. 1)
- Storm Shelters: Selecting Design Criteria (Tornado Recovery Advisory No. 2)
- Residential Sheltering: In-Residence and Stand-Alone Shelters (Tornado Recovery Advisory No. 3)
- Understanding and Improving Performance of Older Manufactured Homes in High-Wind Events (Tornado Recovery Advisory No. 4)

Manufactured Home Ages

Although there are no strict definitions of "older" and "new" manufactured homes, the following descriptions, which are based on the evolution of manufactured home construction standards, are useful.

"Older" Manufactured Homes: This category includes "pre-code" homes and "early code" homes. Some manufactured homes considered "older" may be relatively new from an expected service life standpoint, but are still old from a wind resistance standpoint. For this recovery advisory, any manufactured home constructed before July 13, 1994 is considered an older manufactured home.

Pre-Code Manufactured Homes: This refers to homes built before June 15, 1976, when the Department of Housing and Urban Development (HUD) began regulating construction. Prior to 1976, manufactured housing was essentially unregulated and wide variations in construction quality and strength existed. Pre-code manufactured homes were often called trailers or mobile homes because they were intended to be moved from place to place.

Early Code Manufactured Homes: These are homes built after June 15, 1976 (and before July 13, 1994) when the Manufactured Home Construction and Safety Standards (MHCSS), developed by HUD, first

1. Actions recommended by this recovery advisory will reduce damage to manufactured homes during tornadoes or hurricanes. The actions will not, however, strengthen newer manufactured homes enough to allow occupants to safely remain in their homes during a high-wind event. When advised by local or State authorities, occupants of manufactured homes should find suitable shelter when tornadoes or hurricanes threaten.

went into effect. After 1976, homes became known as "manufactured housing." The MHCSS specified minimum wind pressures that manufactured homes must be designed to resist. It also contained general criteria for anchoring homes to resist wind forces. The wind pressures required by the MHCSS correspond to a sustained wind speed of around 70 miles per hour (mph) in an Exposure C area. This is approximately equivalent to 85 mph peak gust winds.

"New" Manufactured Homes: Hurricane Andrew destroyed numerous manufactured homes in 1992. In response to this damage, the MHCSS standards were strengthened on July 13, 1994. The strengthened standards apply to homes placed in higher wind speed areas. These 1994 revisions, which remain in effect today, established three types of homes: HUD Zone I, HUD Zone II, and HUD Zone III homes.

- HUD Zone I homes are those homes designed to the original 1976 standards.
- HUD Zone II homes are designed to resist sustained wind speeds of 100 mph (equivalent to approximately 120 mph peak gust winds).
- HUD Zone III homes are designed to resist sustained wind speeds of 110 mph (equivalent to approximately 130 mph peak gust winds).

In Florida new homes must be HUD Zone II or HUD Zone III.

NOTE: "Sustained" wind speeds are approximately fastest mile wind speeds; "gust" wind speeds are approximately 3-second gusts wind speeds.

How New Manufactured Homes are Vulnerable to Tornadoes and Hurricanes

Properly installed and maintained manufactured homes designed and installed to the 1994 HUD standard perform much better than older manufactured housing, particularly in areas with higher design wind speeds. However, even new manufactured homes are often damaged by high-wind events. Damage can be grouped into two categories: direct damage to the home itself and damage that results from failures in the home's anchorage system. Although manufactured homes and site-built homes may have similar vulnerabilities to direct damage, some of the vulnerabilities to anchorage failures are unique to manufactured homes.

Direct Damage

Direct damage often includes blown-off roof panels, loss of roof framing, loss of wall panels and framing, and breakage of unprotected windows. Window damage occurs as a result of high wind pressures or from the impact of flying debris generated by high winds.

Direct damage to new manufactured homes usually results from connection failures. Nails or staples used to secure roofing, siding, roof sheathing, or wall sheathing can be overloaded during high-wind events. Nails or staples can either be pulled out or the material they secure can be torn away from the heads of the nails or tops of the staples.

Attachments: The potential for damage to manufactured homes increases significantly when additions like carports, awnings, or porches are fastened to the home. These additions concentrate wind forces where they are fastened to the home. The increased forces can overload connections used

Wind damage to a new manufactured home.

Damage to new manufactured home resulting from improper carport attachment.

Damage to new manufactured home resulting from improper attachment of a screened enclosure.

Glazing damage caused by windborne debris from nearby damaged homes and attachments.

to hold the home together and cause failure of the members or connections in the home.

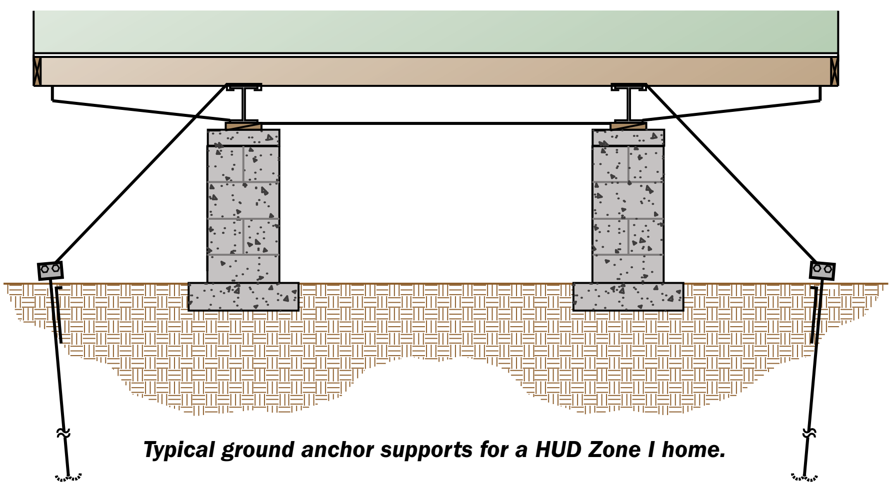
Most home manufacturers prohibit attachments to their homes unless special provisions to support attachments were incorporated into the home when it was manufactured. The attachments themselves, unless engineered, also violate local code requirements in many jurisdictions.

Windborne Debris: Damage from windborne debris is also common in manufactured homes. New manufactured homes sited in communities that contain older manufactured homes or in communities where attached structures are prevalent are particularly vulnerable. Those homes and attached structures are often damaged from high-wind events. The resulting debris forms missiles, which can strike surrounding homes.

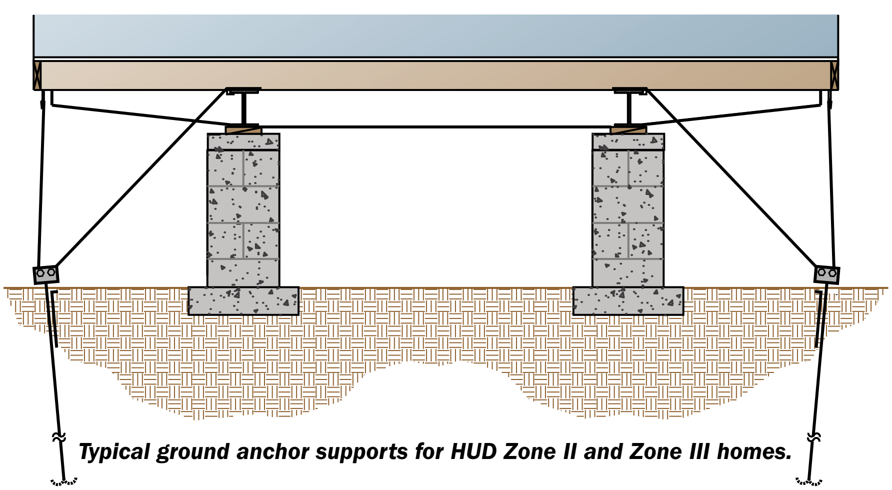
Manufactured Home Anchorage

Anchorage failures involve the home being lifted, slid, or rolled off its foundation. An anchorage failure can destroy a home even when there is no direct wind damage to the home itself.

HUD standards require that the manufacturers of all homes include provisions (at least one method) for securing and anchoring homes to resist wind forces. For homes designed to be installed in Wind Zone I areas, the design criteria in the standards require only diagonal (or frame) ties to be secured to the main frame members (usually two steel I-beams under each section). For homes designed to be installed in Wind Zone II areas, the standards require that homes be provided with vertical wall ties at each frame tie location or anchor. In the State of Florida, statutes contained in the Department of Highway Safety and Motor Vehicles Division of Motor Vehicles Chapter 15C-1 also require longitudinal ties to resist manufactured home movement along the length of the home.



Typical ground anchor supports for a HUD Zone I home.



Typical ground anchor supports for HUD Zone II and Zone III homes.

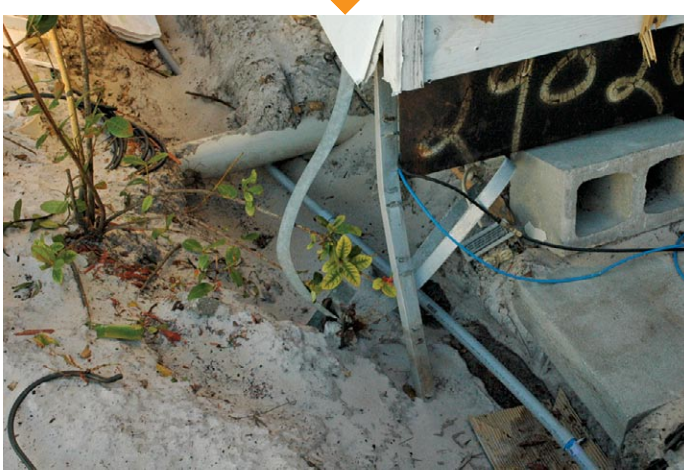
In most manufactured homes, anchorage is provided by ground anchors and steel straps. Ground anchors consist of a steel shaft (preferably galvanized to resist corrosion) and one or two helical steel plates that are augured into the earth. Most ground anchors contain heads specifically designed to accept the steel straps that connect the anchor to the home's frames and wall ties. Ground anchors installed at, or near, a vertical angle are typically provided with stabilizer plates to increase their resistance to lateral movement or displacement.

By their very nature, ground anchors move when loads are applied. During a high-wind event, winds apply loads to the home, which in turn applies loads to the ground anchors. Ground

This home, which was secured with ground anchors, moved enough to allow it to fall from its supporting piers.

After falling from its supports, the home moved approximately 3 feet.

Fractured ABS stabilizer plates may have contributed to the failure of the support system.



When the home shifted, anchor straps became loose.

Wall ties that secured the home to ground anchors were torn from the home.

anchors are typically allowed to move up to 3 inches laterally or 2 inches vertically to resist wind loads. When a home is secured with ground anchors, it too can move up to 3 inches laterally or 2 inches vertically. The amount of movement that a manufactured home secured with ground anchors may experience greatly exceeds the amount of movement experienced by site-built homes (or manufactured homes) properly placed on conventional foundations.

During high-wind events, homes secured with ground anchors may move enough to force them off their supporting piers. This risk exists even for newly installed homes. The home shown in the photos on the previous page was installed in November 2006 and was damaged by the Florida tornadoes of February 2007. While the home fell off its piers, the limited damage to siding and roof sheathing suggests that the home was not exposed to design-level wind forces.

Recommendations

Home Strengthening

Adding fasteners to improve wind performance usually involves removing siding, roofing, or sheathing. Typically, this type of improvement can best be done when repairs or maintenance are being completed on a home. While building codes do not specifically apply to manufactured housing, designs contained in prescriptive codes and standards, such as the *International Residential Code* (IRC 2006), contain fastening schedules for wall and roof sheathing that may be appropriate for improving wind performance in manufactured homes. Other connections, such as rafter-to-wall connections, can be designed by registered engineers or architects.

Roofing can be damaged by high winds and windborne debris. During reroofing projects, improvements can be installed to make the roof covering and deck less vulnerable to wind and debris. For homes with asphalt shingled roofing, Technical Fact Sheets No. 19 and 20 in FEMA 499, *Home Builder's Guide to Coastal Construction*[2] (2005), provides guidance on installing asphalt shingles to improve uplift resistance and reduce vulnerability to damage during high-wind events. Asphalt shingles are suitable for roofs with slopes 3:12 or greater.

Attachments and Attached Structures

Homeowners are advised that many homes were not designed or approved by the manufacturer to have attachments connected to the units. Attached structures should not be added to homes not designed to support them. Regardless of whether the added structure is attached to the home or is free-standing next to it, all added structures should be constructed to meet local code requirements using the same standards as those for residential site-built construction. The design of additions should not use reduced wind criteria that is occasionally considered for ancillary structures like agricultural buildings and minor storage facilities. Where no code is adopted, the 2006 *International Residential Code,* the 2006 *International Building Code,* or the 2006 edition of National Fire Protection Association (NFPA) 5000 *Building Construction and Safety Code* should be followed.

Generally, all existing attachments should either be removed or reconfigured so they are supported independently of the home. For best performance, no connections should remain between the manufactured home and the attached structure, other than flashing required for weather-tightness. An attachment may not need to be removed or reconfigured if the home has reinforced structural elements that can support it. The homeowner should refer to the manufacturer's instructions to determine whether the home was designed to accommodate the attached structure. It may be necessary to contact a local engineer for assistance in making this determination.

New attachments or structures should be designed and constructed per the 2006 *International Residential Code,* the 2006 *International Building Code,* or the 2006 edition of NFPA 5000.

Protection from Windborne Debris

Properly installed shutters are effective at preventing broken glazing from windborne missiles and the resulting damage from wind-driven rain infiltration. HUD regulations require that wall framing be provided to

2. FEMA 499 is available online at http://www.fema.gov/rebuild/mat/mat_fema499.shtm. Hardcopies may be obtained at no cost by calling 800-480-2520.

allow the installation of hurricane shutters at all windows and doors in HUD Zone II and Zone III homes, but does not require the installation and use of shutters.

Serious consideration should be given to installing shutters on Zone II and Zone III homes when they are installed in high wind areas where the basic wind speed identified in the local building code requires the use of glazing protection for site-built construction.

Anchorages and Strapping

Anchors and straps should be inspected regularly and all corroded straps or anchors should be removed and replaced. In interior areas (more than 3,000 feet from the coast) anchors and straps should be inspected every 5 years. For homes situated within 3,000 feet of the coast, anchors and straps should be inspected every 2 years. When new anchors and straps are installed, only galvanized materials (with a minimum coating of 0.6 ounce per square foot) should be used. Anchor heads should remain 1 to 2 inches above adjacent grade to help prevent corrosion resulting from water accumulating near the anchor head and strap.

Homes in Special Flood Hazard Areas (SFHAs) and homes located where soils may be saturated should follow anchor spacing and pier construction recommended in FEMA 85, *Multi-Hazard Foundation and Installation Guidance,* due to be completed in 2007.

Ground Anchors

Ground anchors must be properly selected based on the soils present at the site. Loose or poorly consolidated soils require deeper anchors with larger helical plates to provide the strength necessary to resist wind loads. More substantial foundations, like concrete strip footings, may be required in areas with poor soils, with saturated soils, or in areas where a permanent foundation is desired.

Homes should be anchored in both the lateral and longitudinal direction. Manufacturers may also require additional anchorage under shear walls and along the mating (marriage) wall between double-wide homes. Lateral anchorage requirements depend on the design wind speed for the area and on the length and width of the home. The greater the design wind speed, the closer the required anchor spacing. Also, narrow single-wide homes, which are more prone to overturning, require closer anchor spacing than wider double-wide homes and longer homes require more lateral anchors than shorter homes. The type of pads used under the masonry piers that support the home should also be considered. Closer anchor spacing is suggested when ABS (Acrylonitrile Butadiene Styrene) pads are used. ABS pads are a relatively new style of pad that is used in lieu of heavier concrete pads. They are lightweight and typically manufactured from recycled plastics. Closer anchor spacing should limit home movement and should help prevent fracturing of the ABS pads. Lateral ground anchors should also be placed within 2 feet of the ends of the home. Use the table that follows to identify maximum

Lateral Ground Anchor Spacing

	Single Wide		Double Wide	
Design Wind Speed	**ABS Pads**	**Concrete Pads**	**ABS Pads**	**Concrete Pads**
90 mph	5’4”	6’8”	5’4”	6’8”
110 mph	5’4”	6’8”	5’4”	6’8”
130 mph	4’0”	5’4”	4’0”	5’4”

NOTES:

(1) The design wind speed is the 3-second gust wind speed per ASCE 7-05 and the 2006 edition of the International Building Code. The anchor spacing listed above is appropriate for Exposure B and C conditions. A licensed professional engineer should design anchorage for homes placed in Exposure D areas and for homes placed within 1,500 feet of the coast (as required by the MHCSS).

(2) Ground anchor spacing is based on homes weighing an average of 20 pounds per square foot, with steel I-beam frames spaced at intervals of 96 inches or more, with roof slopes between 15 degrees and 20 degrees, and with wall heights up to 8 feet. The spacing is appropriate for homes placed on masonry piers up to 36 inches tall. When the manufacturer’s installation instructions are not available, a licensed professional engineer should design anchor spacing for homes that weigh less, have narrower I-beam frame spacing or taller walls, are placed on taller piers, or have steeper or shallower roofs.

(3) When the manufacturer’s installation instructions or local codes specify ground anchor spacing different than that listed above, anchors should be installed at the closest anchor spacing specified for improved resistance to hurricanes and tornadoes.

The ground anchor spacings shown are greater than Florida 15C-1 requirements. For homes in Florida, locate anchors at 5 feet, 4 inches (maximum).

interval spacing and calculate the number of anchors needed for lateral anchorage. For example, if a double-wide home is sited in a 110 mph wind zone and placed on concrete pads, it should have ground anchors spaced at maximum intervals of 6 feet, 8 inches. Therefore, a 64-foot-long double-wide home would require 20 lateral anchors (10 per side) and a 72-foot-long double-wide home would require 24 anchors. For longitudinal anchorage, 4 ground anchors per section end are recommended. A total of 8 longitudinal ground anchors should be installed for single-wide homes and 16 should be installed for double-wide homes.

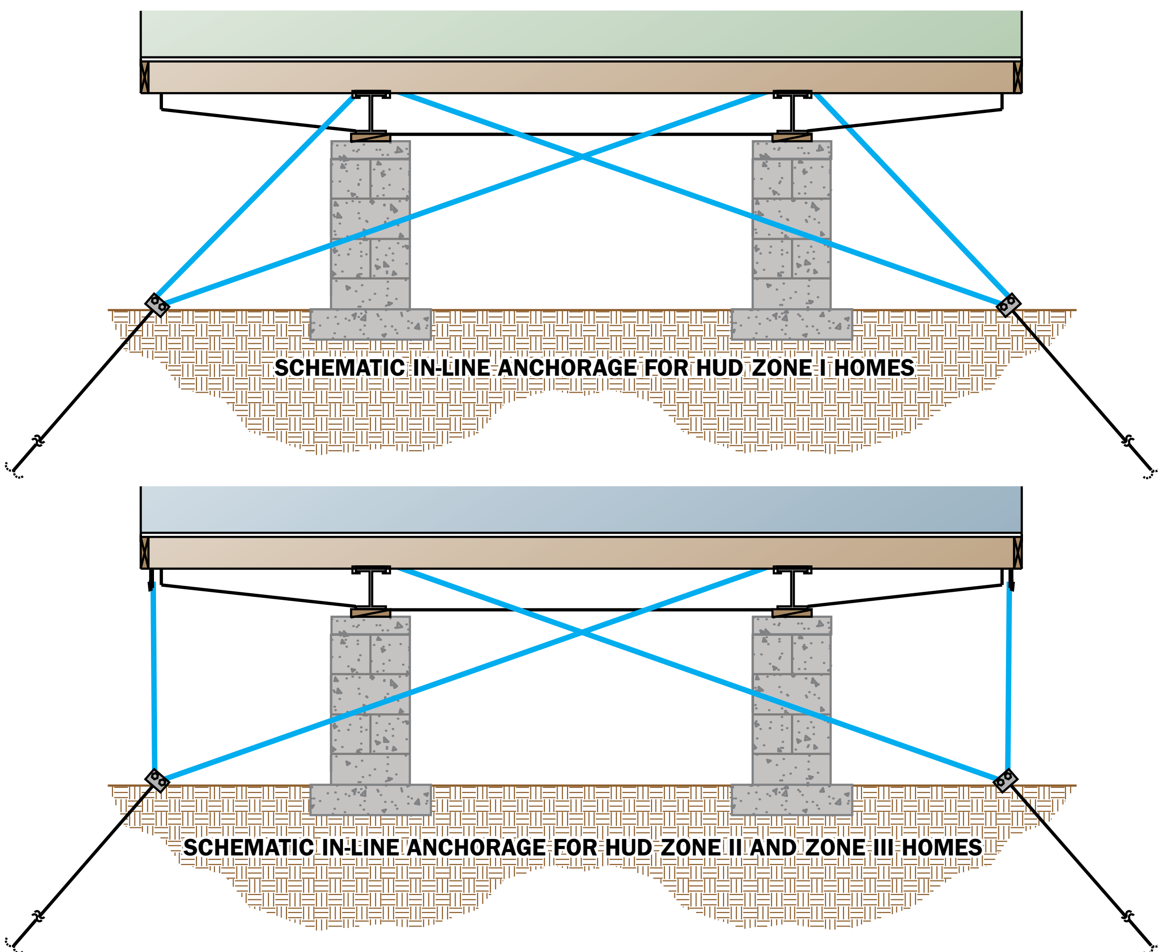
Routine inspection and maintenance should include:

- Inspect anchors and strap tension and tighten when straps are found loose. In interior areas (more than 3,000 feet from the coast), anchors and straps should be inspected every 5 years. In coastal areas, anchors and straps should be inspected every 2 years.
- Replace all corroded straps and anchors.

Maintain Anchors and Straps

When a home is allowed to move, even slightly, anchors and straps can become loose. Loose straps render anchors ineffective at resisting wind. Anchor straps can loosen even without a home being exposed to high winds, particularly if soils are relatively soft or if anchors were inadequately pre-tensioned after their installation. Because of this, manufactured homes secured with ground anchors should have their anchors checked periodically and re-tensioned when straps are found loose.

High-wind events can cause homes secured with ground anchors to shift across their piers. This shift increases loads on portions of the footings below the piers which increases the potential for footing damage. Shifting also makes the home more vulnerable to anchorage failures during subsequent events. When the centerlines of the home's frame are not located within 2½ inches of the centers of the piers, the home should be lifted and re-set to properly center the home's steel frames over the centers of the piers.



Improved installation using in-line ground anchor installed at a 45 degree angle. The installation reduces the amount a home will move during tornadoes and hurricanes.

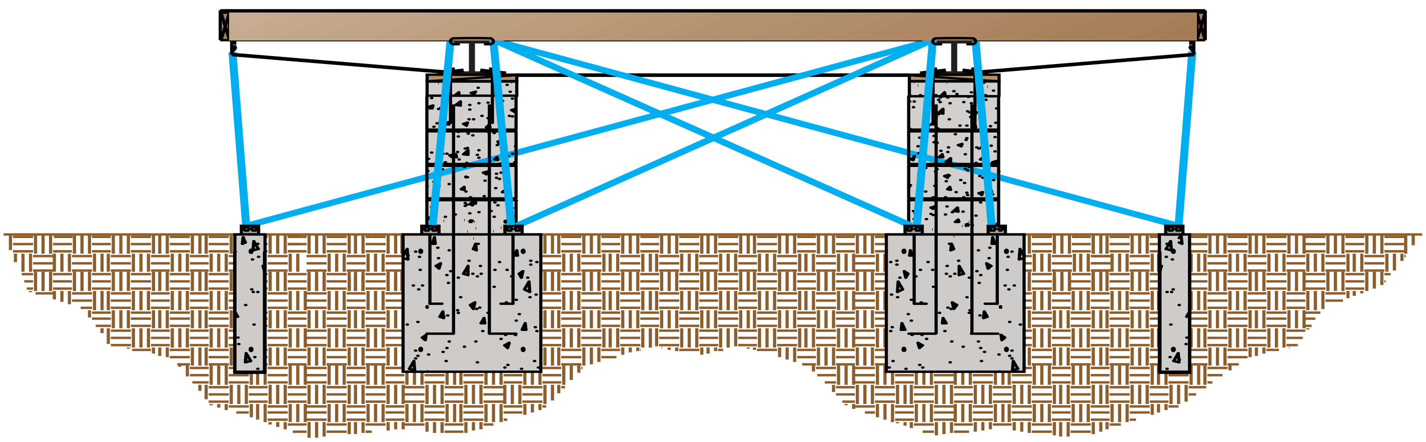
Improve Anchorage by Using In-Line Anchors

Homeowners should consider replacing vertically installed anchors used with stabilizer plates with anchors installed at a 45-degree angle. When exposed to wind loads anchors installed at a 45-degree angle (also called in-line anchors) move less than vertically installed anchors used with stabilizer plates. FEMA-funded ground anchor tests conducted in Florida in 2001 revealed the superior performance of anchors commonly used in Florida when they were installed at a 45-degree angle. In dry soils, 5-foot-long anchors installed at a 45-degree angle moved 30 percent less than vertically installed anchors used with stabilizer plates. In saturated soils, the differences were more pronounced. Five-foot-long anchors installed at a 45-degree angle moved 60 percent less than vertically installed anchors used with stabilizer plates. Installing anchors at a 45-degree angle requires more clearance under a home than the clearance required for vertically installed anchors used with stabilizer plates. Pre-drilling holes for the anchor helixes allows anchors to be installed at a 45-degree angle when lower clearances exist. Pre-drilling up to one third the length of an anchor is allowed by most anchor manufacturers, provided the excavated soils are compacted after the anchor is installed.

Conventional Foundations

When selecting a foundation, owners of manufactured homes should consider foundations such as those used for site-built homes. These types of foundations can be used to support manufactured homes and require less maintenance than ground anchor foundations. Conventional foundations also perform better than ground anchor foundations during high-wind events.

Perimeter foundations, like those used to support site-built homes, are one option. Those foundations are typically considered permanent and, in addition to improved stability and performance, they may also allow homeowners to benefit from lower mortgage interest rates. Perimeter foundations typically require the use of a crane to lift the manufactured home and place it on the perimeter foundation, thereby increasing the cost of installation.



Example of concrete strip footing foundation.

A second foundation option is to place the manufactured home on concrete strip footings and masonry piers like those shown below. Concrete strip footings and piers offer the advantage of not requiring a crane to place a manufactured home; if properly designed, these foundations can provide improved stability and performance that approaches that of a perimeter foundation.

For homes located in Zones I, II, and III, continuous concrete strip footings are placed under the steel frames of the home. The footings need to be placed on firm soils at an adequate depth to meet local building code requirements. Reinforced piers are then constructed and strapped to the frames and anchored to the footings. Cross-straps connecting footings to opposite frames provide rigidity. For homes located in Zones II and III, perimeter strip footings are needed for connections to wall ties.

Homes located in Special Flood Hazard Areas (SFHAs) should follow installation recommendations contained in the revised FEMA 85, *Manufactured Homes in Flood Hazard Areas – A Multi-Hazard Foundation and Installation Guide.* The revised FEMA 85 is due to be completed in 2007. The ground anchor spacing table included in this Recovery Advisory was developed from FEMA 85.