

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



FEMA

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
- Recommendations¹

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

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)

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.



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.

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



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.

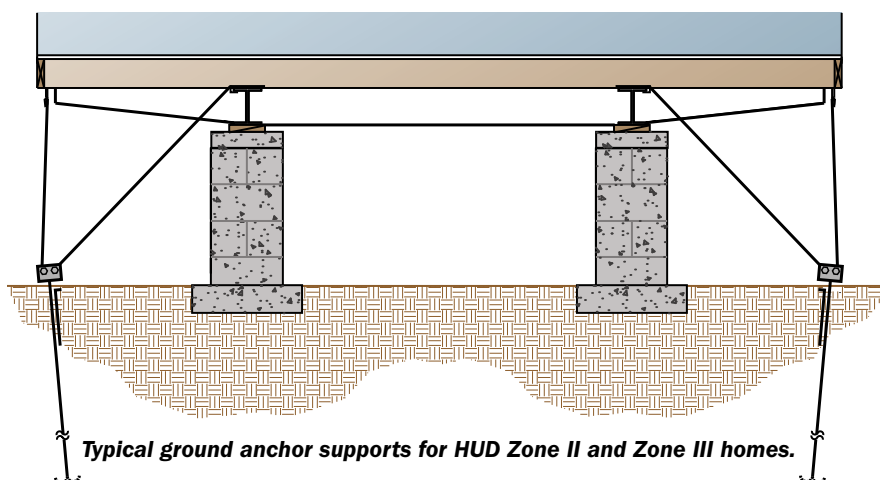
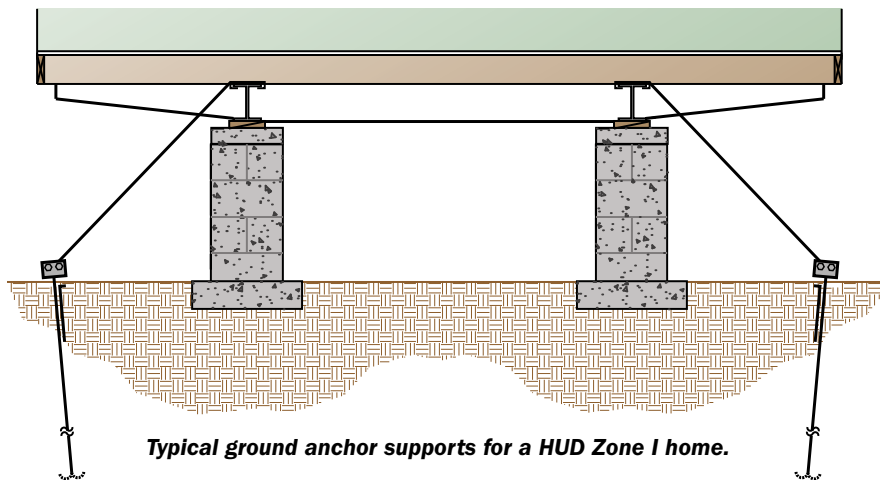
Manufactured Home Anchorage

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.



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.



Fractured ABS stabilizer plate



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.

Anchorage 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.

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

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.

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.

Lateral Ground Anchor Spacing

Design Wind Speed	Single Wide		Double Wide	
	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.

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.

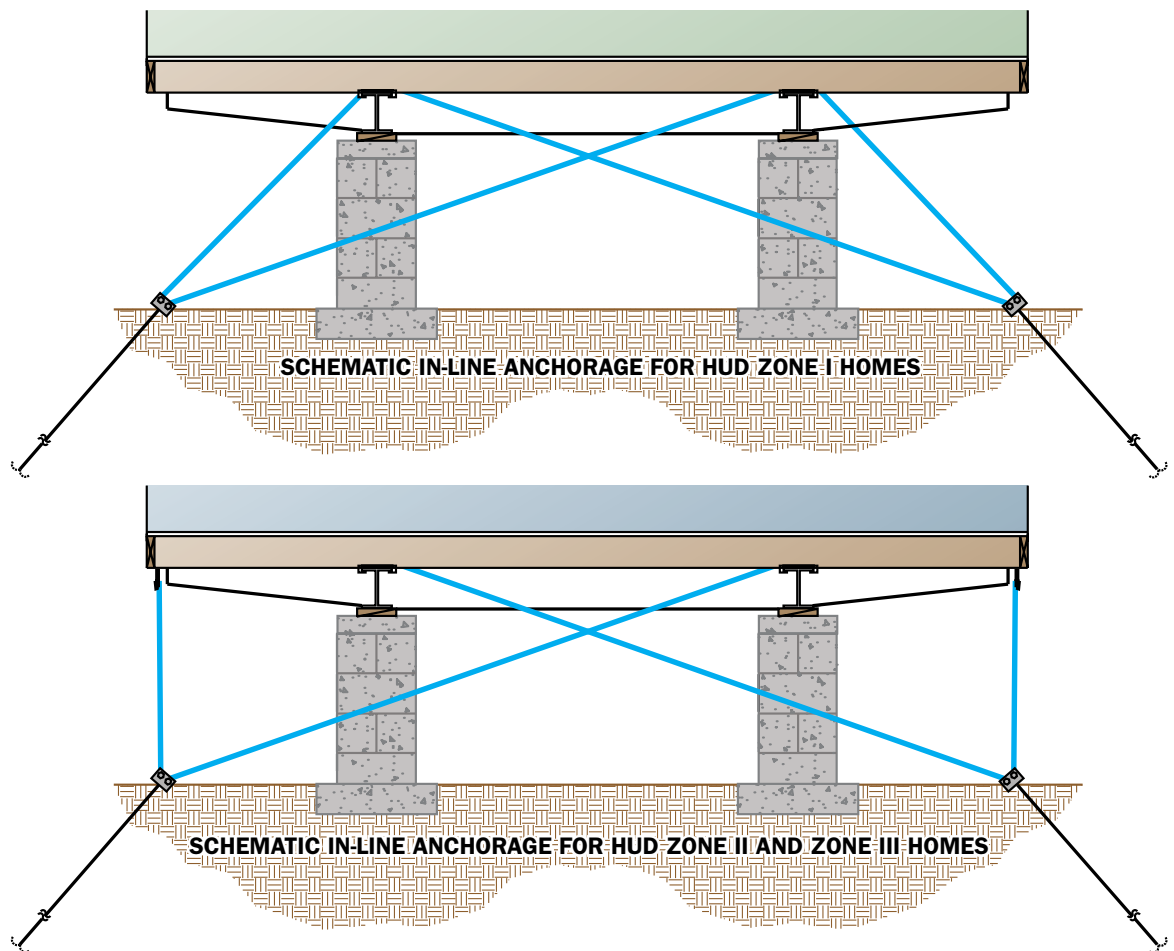
High-wind events can cause homes secured with ground anchors to shift across their piers. This shift increases loads on portions of the footings below the piers which increases the potential for footing damage. Shifting also makes the home more vulnerable to anchorage failures during subsequent events. 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.

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

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.



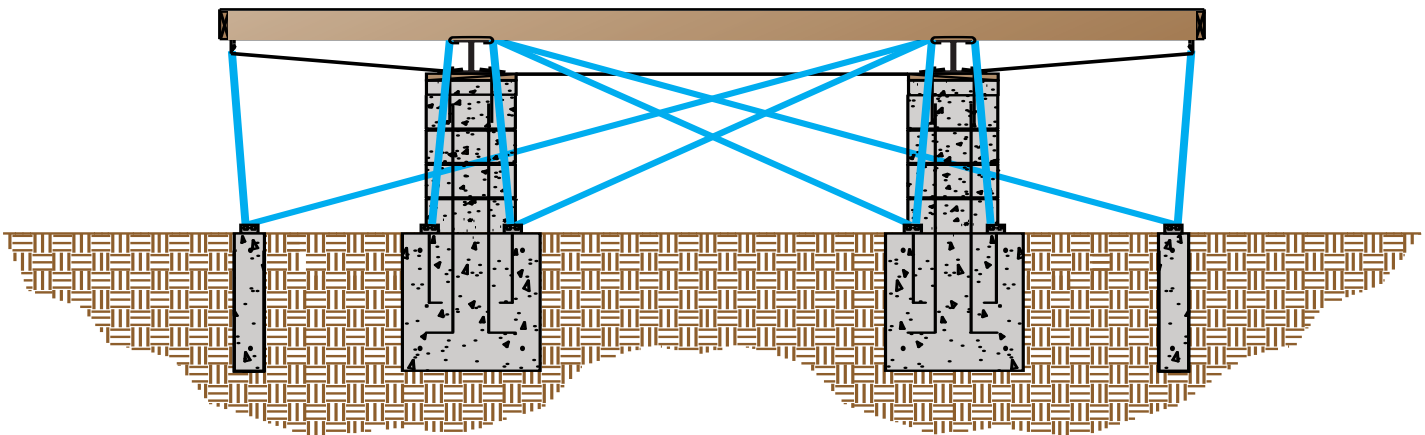
Improved installation using in-line ground anchor installed at a 45 degree angle. The installation reduces the amount a home will move during tornadoes and hurricanes.

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.