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

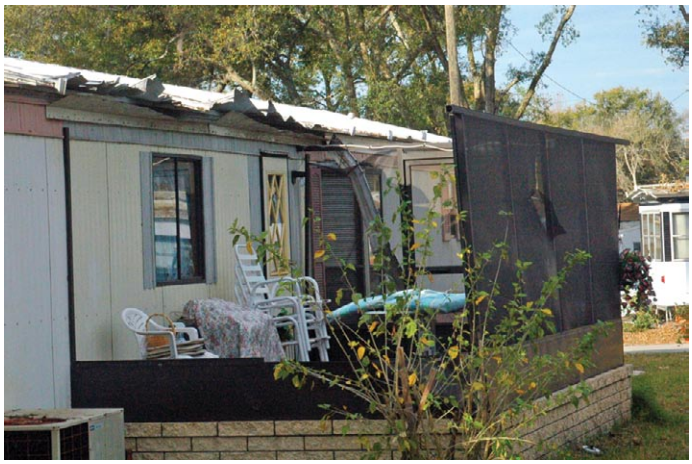
High-wind events such as tornadoes and hurricanes can damage nearly all buildings not specifically designed to resist the strong forces generated by these events. New "engineered buildings," those designed by professionals to meet the latest building codes and standards, have generally performed well 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.

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

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.

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.