
NATURAL HAZARD MITIGATION INSIGHTS

A publication of the Institute for Business and Home Safety

TORNADOES

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The wind speeds in most tornadoes are at or below design speeds in typical building codes. In other words, a house built to code will stand up to the majority of tornadoes.

There is no need to concede your house and valuables to a tornado. You can build or

retrofit your home, at reasonable cost, to survive most of them. Nevertheless, tornadoes are unpredictable and some of them can be quite dangerous. A person in the vicinity of a tornado should get into a shelter immediately.

This report discusses the dynamics of tornadoes and how you can keep yourself, your family and your property safe and secure.

WHAT IS A TORNADO

Tornadoes are swirling columns of air extending from within a thunderstorm cloud formation and extending down to the ground. Most tornadoes seem to begin when warm,

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humid air along the ground is pushed up rapidly by cooler air and develops into a spinning vortex or funnel. They also may be by-products of hurricanes. Tornado paths average 200 yards wide and several miles long.

Tornado winds typically swirl in a cyclonic direction, meaning they appear to a ground observer to have a counterclockwise spin. On rare occasions they spin in the opposite (clockwise) direction.

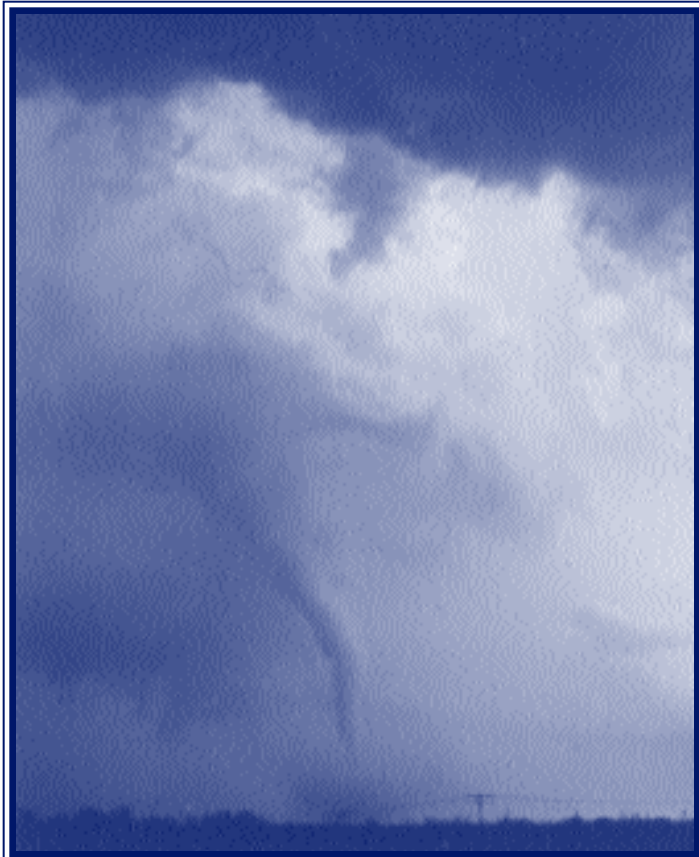
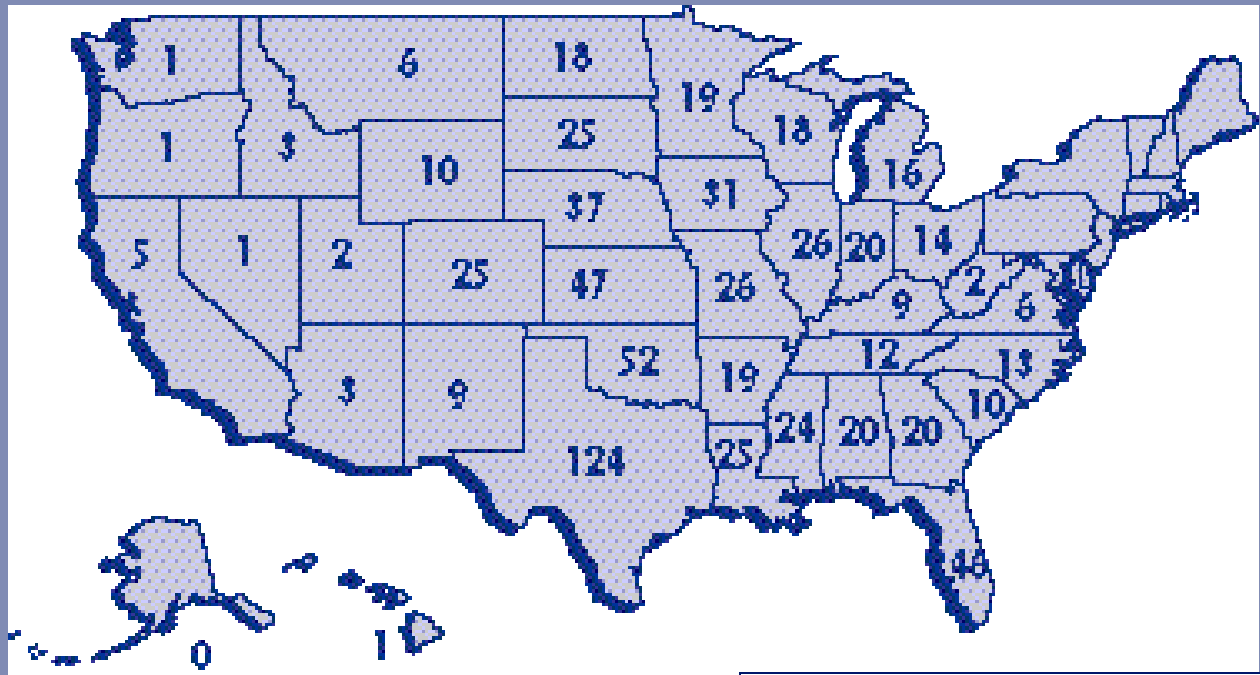


Photo courtesy of Dr. Joseph H. Golden, NOAA

Average Number of Tornadoes by State 1950 - 1995



Data derived from Storm Prediction Center, NOAA,
U.S. Department of Commerce

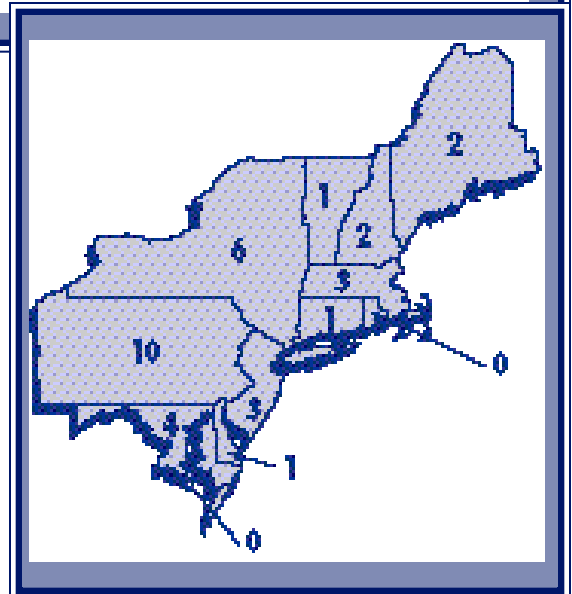
WHEN THEY OCCUR

Tornadoes happen year round. The peak season varies by location, but in general tornadoes are most frequent in the months of April, May and June. That's when warm, humid air from the Gulf of Mexico most often contrasts with cold northern winds over the Great Plains. By July, the temperature contrasts are weaker and the number of tornadoes falls off somewhat.

While they can occur at any time during the day or night, tornadoes tend to form during the late afternoon and into the evening. Approximately 80 percent occur between noon and midnight and 23 percent between 4 and 6 p.m.

WHERE THEY OCCUR

Tornadoes occur in all fifty states, but the majority touch down in an area of the midwest known as "Tornado Alley," which runs from Texas north through east Nebraska and



northeast to Indiana. More tornadoes occur in Texas and Oklahoma than in any other states. The Great Plains are a perfect breeding ground because cold air from the north meets warm air from the south over open terrain.

Hurricanes along the Gulf and Atlantic coasts also spawn tornadoes. Fortunately for Floridians, their tornadoes tend to be less severe than those in the midwest.

HOW OFTEN THEY OCCUR

The “how often” question is not as easy to answer as it may seem. As the population grows and expands into previously undeveloped areas, there are more buildings, more witnesses and therefore more tornado reports. While the number of reported tornadoes has been increasing, it is likely that the actual number of tornadoes has not changed much over the years. A current rough average is 800 to 1,000 per year.

Deaths from tornadoes have been decreasing as a result of better warning systems. The National Weather Service has advanced Doppler radar in most parts of the country that can quickly identify tornado conditions as well as the actual funnels.

HOW FAST THEY ARE

An eyewitness observer sees two types of tornado motion: the speed of the wind as it whips around in the vortex or funnel, and the forward motion of the funnel as it travels over the ground.

The forward motion can range anywhere from zero (the tornado is stationary) to 70 miles

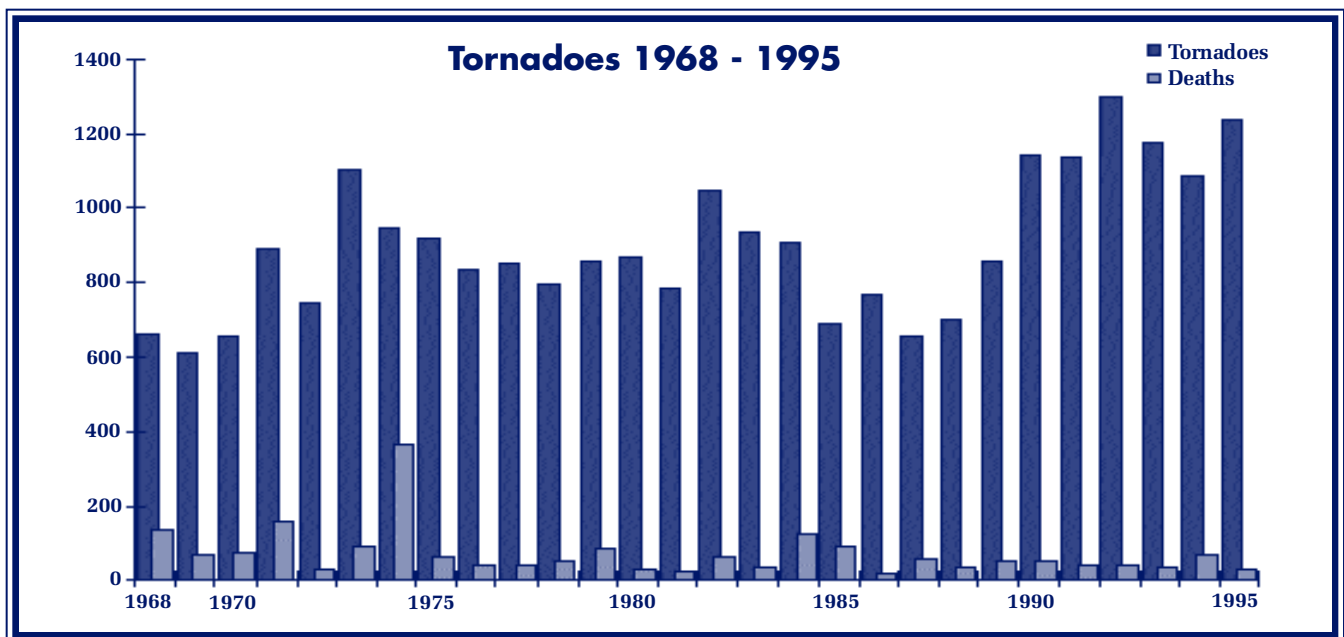
CURRENT DATA INDICATE THAT AROUND 85 PERCENT OF ALL REPORTED TORNADOES HAVE WIND SPEEDS OF 112 MPH OR LESS.

per hour. The average forward speed is about 35 miles per hour. A tornado may pause over a spot, slow down, quickly plow ahead or change direction abruptly.

The winds can be intense and destructive in strong tornadoes, but the majority of tornadoes are not intense and do not cause severe damage.

Current data indicate that around 85 percent of all reported tornadoes have wind speeds of 112 mph or less. It is possible that increased population and a greater emphasis on report gathering have led to the detection of weaker tornadoes that previously would not have been included. The point is that most tornadoes are within the design speeds of building codes.

Ordinary construction methods produce a house that will stand up to 110 mph tornadoes. A builder need only comply with the well-accepted provisions of any of the nation-



Source: National Climatic Data Center, NESDIS, NOAA, U.S. Department of Commerce

ally recognized model building codes. Almost all state building codes, where they exist, are based on these models.

Three organizations promulgate model building codes. All of them incorporate wind speed maps published by the American Society of Civil Engineers (ASCE). ASCE produces maps that show different design speeds for different parts of the country, based upon a constant probability of occurrence. Even though the maps do not consider tornadic winds, the design speeds are high enough

and there is sufficient safety in materials to resist the majority of tornadoes if the building is properly constructed.

Tornado wind speeds are measured where they are highest, namely, the fairly narrow band along the funnel wall. Wind speeds drop farther away from the funnel. As a result, a house in the vicinity of a tornado with reported 150 mph winds may experience only 75 mph winds, well below building code design speeds.

WHAT YOU CAN DO

PERSONAL SAFETY

If you live in a tornado-prone area, find out in advance where you can take shelter. The shelter may be a local community building, or your own underground storm cellar or in-residence shelter. When a tornado approaches, get to that shelter safely and quickly.

IF YOUR HOUSE DOES NOT HAVE A STORM CELLAR OR IN-RESIDENCE SHELTER, HEAD FOR THE BASEMENT. IF YOUR HOUSE HAS NO BASEMENT, WAIT OUT THE STORM IN A BATHROOM, HALL OR CLOSET, AWAY FROM THE WINDOWS AND PREFERABLY UNDER SOMETHING STURDY.

Tornadoes can form and move quickly, so if you do not have time to get to a community emergency shelter and do not have your own, keep in mind that:

- 1 **Cars are vulnerable.** A strong tornado can pick up a car, and trying to outrun the storm is not a gamble worth taking. A tornado can speed up and take unpredictable turns. Roads get clogged with downed trees, lines and other traffic. In a 1989 Alabama tornado, 12 of the 21 recorded deaths were in cars. A 1979 Texas tornado resulted in 42

deaths, 25 of which occurred while the people were in their cars. Sixteen victims were trying to outrun the storm.

- 1 **Mobile homes are vulnerable**, including those with tie-downs. Mobile homes have a large surface area relative to their weight, making them good candidates for overturning. They tend to have light frames and thin skins that are vulnerable to wind pressures and wind-blown projectiles. Don't try to ride out a storm in a mobile home.
- 1 **Opening windows in your home is a waste of valuable time.** You may only make the problem worse. At one time it was believed that equalizing the pressure differences between the tornado and the interior of the house would save the house. Houses have enough openings to vent the pressure differentials and flying debris will probably break the windows anyway. Opening windows, especially on the windward side, invites the wind to blow up the house like a balloon.

If your house does not have a storm cellar or in-residence shelter, head for the basement. If your house has no basement, wait out the storm in a bathroom, hall or closet, away from the windows and preferably under

something sturdy like a workbench, pool table or staircase. The more walls between you and the outside, the better.

Don't be fooled into thinking that hills and rivers will divert a tornado. They won't.

You may be caught too far from shelter and away from your home. Here are some safety guidelines:

- | If you are in the open countryside, take shelter in a ditch or ravine or lie flat on the ground upwind of your parked car or mobile home, with your hands covering the back of your head and neck. If an overpass or concrete viaduct is available, take shelter behind the concrete pilings in such a way as to put the concrete between you and the approaching tornado. Watch for flash floods that can accompany tornadoes.
- | In high-rise office buildings, large apartment buildings and shopping malls, go to the lowest floor or the basement. Roofs are more likely to sustain damage. Take shelter in small interior rooms, such as rest rooms, closets and utility rooms, or in interior corridors. Keep away from windows.
- | In schools, if there is no underground shelter area, move into interior hallways or small interior rooms on the lowest level. Avoid auditoriums, gymnasiums and other large rooms with long freestanding roofs, as well as corridors with exposed entrances. Avoid glass display cases, glassed-in stairwells and doorways.
- | In a bus, truck or large van, try to move away from the storm by driving at right angles to its path. If this is not possible or if you experience strong cross winds, park the vehicle pointing into the wind, pull the hand brake and unload your passengers. Leave the vehicle and take shelter in a ditch, ravine or other depression in the ground that is upwind from the truck or bus.

If you have time before the wind picks up, move your lawn furniture and yard equipment inside to keep them from becoming dangerous projectiles in the heavy winds. Move your car into a garage or under a carport to minimize hail damage.

Listen for National Weather Service alerts. A tornado or severe thunderstorm watch means that conditions are favorable for one or the other. A tornado or severe thunderstorm warning means that one or the other is imminent or has already been spotted by sight or by radar in the vicinity. Tornadoes occasionally develop in areas where a severe thunderstorm watch or warning is in effect.

THE SHELTER MAY NEVER BE NEEDED, BUT DURING A TORNADO EMERGENCY IT CAN BE WORTH MANY TIMES THE EFFORT AND COST OF PREPARING IT.

A tornado warning will indicate the location of the tornado and the area in its path. Anyone in that area should find shelter immediately. You should consider purchasing a weather-alert radio with a battery backup. These radios sound an alarm that is activated by the National Weather Service.

Finally, assemble a safety kit containing first-aid supplies, a battery-powered radio and flashlight, bottled water and instructions on shutting off your home's utilities.

YOUR PROPERTY

It is economically impractical to build houses that are tornado-proof. It makes sense, however, to build storm cellars and in-residence shelters and to make sure your roof and walls are properly constructed.

Constructing an Underground Storm Cellar

In parts of the country where tornadoes are relatively frequent, some form of tornado shelter is vital. The shelter may never be needed, but during a tornado emergency it

can be worth many times the effort and cost of preparing it. One of the safest tornado shelters is an underground excavation, known as a storm cellar.

- | **Location:** Locate the storm cellar inside your house or so close that you can get to it in seconds without exposing yourself to wind-borne debris. Do not connect the cellar to house drains, cesspools, or sewer and gas pipes.
- | **Size:** The size of the shelter depends on the number of persons to be accommodated and the storage needs. A structure eight feet long by six feet wide and seven feet high will protect eight people for a short time, and provide limited storage space.
- | **Material:** Reinforced concrete is the best material for a tornado shelter. Cover the roof with earth, sloped to divert surface water and of sufficient depth to support ground-cover plants. The entrance door should be of heavy construction, with sturdy interior latches to hold the door down in high winds.
- | **Drainage:** For drainage and easy cleaning, the floor should slope to a drainage outlet, if the terrain permits.
- | **Ventilation:** A vertical ventilating shaft about 1 foot square can extend from near the floor through the ceiling. This can be converted into an emergency escape hatch if the opening through the ceiling is made 2 feet square and the 1 foot shaft below is made easily removable. Gratings of heavy wood on the floor will improve air circulation.
- | **Emergency Equipment: Store a lantern and tools** - crowbar, pick, shovel, hammer, pliers, screwdriver - in the cellar to help you get out if the cellar exit is blocked by debris. Grease stored metal tools to prevent rust.

THE IN-RESIDENCE SHELTER LETS YOUR FAMILY CONTINUE ITS NORMAL LIVING PATTERN DURING A WEATHER ALERT.

Constructing an In-Residence Shelter

Wind engineers have noticed that even in cases of severe tornado damage to houses, an interior bathroom or closet was often left standing. This observation led to the idea of building a “safe room” in a new house or retrofitting an existing house to include one. The work can be done without a major investment of time or expense.

Building an in-residence shelter into a house under construction can add approximately \$3,000 to the total cost, depending on the size and severity of the storms for which it is designed. Retrofitting a bathroom or closet in an existing house will cost about \$2,000 or more, based upon accessibility and other conditions. Basements offer relatively safe shelters from tornadoes, providing the basement has a stout ceiling, but homes in many areas of the country do not have basements. The cost of an in-residence shelter is substantially less than the cost a basement.

A shelter near the center of a residence makes sense because it eliminates the danger you will be struck by flying debris while attempting to reach an outside cellar or community shelter. The in-residence shelter also lets your family continue its normal living pattern during a weather alert, with the peace of mind knowing that a place of safety from extreme winds is only a few seconds away.

One of the greatest threats in severe winds is wind-borne debris, which is capable of penetrating conventional walls and roofs. In order to provide a high degree of protection, the shelter must be designed to prevent perforation by missiles on all surfaces — roof, walls and doors.

In general, in-residence shelters are most easily and economically constructed with a cast-

in-place reinforced concrete roof slab with one of the following:

1. reinforced concrete walls;
2. reinforced brick (concrete masonry) walls;
3. stud walls filled with concrete and expanded steel reinforcement; or
4. layered plywood at least three inches thick.

In-residence shelters like these, built according to guidelines published by the Institute for Disaster Research at Texas Tech University, provide near-absolute protection from 99 percent of all recorded tornadoes. They are designed to resist windspeeds of 260 mph, are vented to equalize atmospheric pressure changes, and will resist an end-on impact of a 15 pound 2 x 4 timber traveling at 100 mph. The shelter can be used for other purposes when not needed for storm protection.

The door to the shelter must be capable of stopping wind-driven missiles without excessive deforming. One that performs ade-

quately has two layers of 3/4-inch plywood glued together and covered on the outside with 14-gauge sheet metal. The door must be supported on both sides. This can be built as a pocket door (one that slides into a wall recess) and used only when the room is occupied as a shelter. A conventional door with the usual finishes and accessories can be installed for normal use.

Standard designs are available from the Institute for Disaster Research at Texas Tech University, Box 41023, Lubbock, Texas 79409-1023, for the cost of reproduction and shipping. Send any requests by mail. The Texas Tech plans are for shelters measuring eight feet by eight feet. If you need a larger one, consult an engineer or an architect with special training in wind-resistant design.

Making Your Home More Secure

All up-to-date building codes call for features that will hold your house together in the face of the ASCE design wind speeds.

Winds will try to lift off the roof and blow out the walls. To help a house resist those pressures, a contractor complying with building codes will build in such a way that the pressures to lift the roof are transferred from the roof frame through connectors down to the wall frame and from there down to the foundation. In effect, the entire house is strapped securely together all the way to the ground.

Here is what to look for:

- 1 Roof sheathing that is securely nailed to its support frame (the rafters or truss). As a builder lays sheathing on top of the rafters and nails it from above, he or she cannot see the rafter. Sloppy work may result in nails that completely miss the rafters and that are therefore useless. Go up to our attic and look at the ceiling if it is unfinished. Check for lines of nails that punch through the sheathing but miss the rafters.

The author expresses his appreciation to the following for their assistance and insights:

- 1 Joseph H. Golden, Ph.D., Senior Meteorologist, National Oceanic and Atmospheric Administration
- 1 Ahsan Kareem, Ph.D., Civil Engineering and Geological Sciences Department, University of Notre Dame
- 1 Kishor C. Mehta, Ph.D., Wind Engineering Research Center Texas Tech University, The National Severe Storms Laboratory

This paper also had the benefit of review by and comments from members of the Institute for Business and Home Safety Wind Damage Mitigation Committee, consisting of Drs. Kareem and Mehta and:

- 1 Ronald H. Cheshire, CPCU, CLU, WDM Associates
- 1 John Waring, PE, Wausau Insurance Cos.
- 1 Richard P. Hughey, PE, ISO Commercial Risk Services, Inc.
- 1 Larry McKean, CPCU, State Farm Fire & Casualty Co.
- 1 James Merva, CPCU, Northbrook Property & Casualty Insurance Co.
- 1 Elaine O'Rourke, CPCU, AIM, ARP, AIAF, TIG Insurance Group

- | Rafters that are fastened tightly to the top plates or beams along the top of the wall studs. This is commonly done with metal hurricane clips or straps. The studs should be anchored to the base or sill plate, which is the piece running atop the foundation walls.
- | A base plate that is bolted securely to the foundation. In some houses, the frame of the house sits on the foundation walls with nothing more to hold it there but the force of gravity. Strong uplift pressures from a tornado will pick up the frame and sweep it away.

If your house has gable ends in the roof, make sure they are cross-braced. Gable ends present a high profile to winds and

therefore are vulnerable. Winds pushing against them from the outside have a lesser chance if there is interior framing pushing back.

Windows and garage doors are weak points. If the wind pushes through an opening in a window or garage door, pressures inside the house climb dramatically and the house is far more likely to fail.

Install impact-resistant shutters or glass in window openings. You can also hang 3/4-inch plywood, but you run the risk of being outside as the wind from the storm whips projectiles around at dangerously high speed.

Garage doors are just as important. Many people assume garage doors are relatively strong, but the fact is these doors are flexible and tend to sit in lightweight frames. As a result, they can deflect and give way easily. One study of a 1982 Nebraska tornado revealed that 49 percent of observed roof damage could be traced to the failure of the garage door, which led to a buildup of internal pressures and stressing of the roof from within.

Install sturdy cross-bracing on the frame to help hold the garage door in place when the wind pushes at it from the outside. Also, anchor the door frame to the wall. You can find guidelines in the booklet *Building Performance: Hurricane Andrew in Florida (FIA-22; 2/93)* available from the Federal Emergency Management Agency, 500 C Street SW, Washington, DC 20472, or by calling FEMA at 1-800-480-2520.

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*This report was written by **Paul A. Devlin** of the Institute for Business and Home Safety.*

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