RESIDENTIAL
Concrete

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On the cover: innovative green building is an urban reality in Orlando, Fla. Photo: James F. Wilson

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Resisting **Wind** and **Seismic** Forces

By Joe Nasvik If global warming predictions for weather come true, there will be a greater frequency of hurricanes, tornadoes, and strong storms throughout the coming years. So designing homes to sustain minimal damage resulting from natural disasters will be increasingly important.

Building codes prescribe a design wind speed for every location in the United States, and for hurricane-prone areas, the codes define in detail how buildings should be constructed. Although wood homes can be modified to resist the prescribed wind and seismic forces, it’s a lot more difficult and costly than building concrete homes. And it’s very difficult to protect the inhabitants of a wood built home from debris carried by high winds. Concrete walls don’t have the debris problem. Just providing the concrete and reinforcement needed to build the walls and decks (ceilings or floors) of a house is usually all that’s needed to provide the strength against wind and seismic forces and to protect from debris. So design issues for concrete homes are more related to connections for doors, windows, roofs, and garage doors locations where different materials meet. This is where some additional costs come into play.

**Defining weather terms**

Hurricanes originate over water and are byproducts of the tropical ocean and the atmosphere. Powered by heat from the sea, Atlantic hurricanes are steered by the easterly trade winds and the temperate westerly, as well as by their own ferocious energy. When the winds reach speeds of 23–39 mph they are referred to as “tropical depressions.” Storms with sustained winds exceeding 39 mph often are referred to as “tropical storms.” When sustained wind speeds reach 74 mph, the storms are called hurricanes, typhoons, or tropical cyclones depending on where they occur in the world in the Gulf of Mexico and along the eastern United States seaboard, they are called hurricanes. In order to provide an estimate of potential damage, a scale was developed to describe hurricanes in categories. The Saffir-Simpson scale places hurricanes in five categories (see Figure 1).

Hurricanes cover large areas and often, in addition to wind damage, involve flood damage due to storm surges.

Relatively small diameter rotating columns of wind are called tornadoes when they occur over land and waterspouts when they occur over water. They extend from a cloud base to the ground and can be either visible or invisible. No place is safe from a tornado, however, there are areas where their frequency is higher. They can last between a few seconds to more than an hour; most commonly lasting about 10 minutes. A scale originally developed by Dr. Ted Fujita and known as the F-scale was modified in 2006 to become
the “Enhanced Fujita Scale” (EF-scale). This is now what we use to describe a tornado’s intensity. The EF-scale rating for a particular event is assigned by looking at the damage from the storm. It’s essentially a damage scale because no one knows what the wind speeds are as it is almost impossible to measure the exact winds inside a funnel. The scale also rates the strength of a tornado in relation to the potential damage it can do. The scale is measured in numbers from 0 to 5 and as you can see in Figure 2, wind speeds can surpass 200 mph, making tornadoes the most formidable wind event.

Though they don’t attain wind speeds even close to a tornado’s, microbursts can be more dangerous than either tornadoes or hurricanes because there is usually no warning of their approach and winds can exceed 100 mph. They result when downdrafts occur during thunderstorms and usually don’t last very long. But they can cause a lot of damage.

The flying debris that results from all the above wind events poses the highest risk to human life. Protecting homes from this kind of damage is difficult and costly, especially for wood constructed walls. Steve Szoke, director of codes and standards for the Portland Cement Association (PCA), Skokie, Ill., says there are no codes written that cover debris impact against the opaque walls of houses or the threat that it represents to human life. “Current codes are written so that buildings will continue to stand up after a wind event,” he says.

BUILDING A SAFER HOME

The Institute for Business & Home Safety, Tampa, Fla., is a nonprofit organization funded by the insurance industry to promote hazard-resistant buildings. They investigate disasters to gather forensic information about the nature of failures in residential buildings, do laboratory research, and make recommendations. Tim Reinhold, vice president and director of engineering, says they use what they learn to influence code changes at the national level and also for state and local building codes. “We also developed the “Fortified...for safer living” program, which raises the bar about 20% for more robust home...
Figure 1: Hurricane Classification System

<table>
<thead>
<tr>
<th>Category</th>
<th>Wind Speed</th>
<th>Hurricane Class</th>
<th>Damage</th>
<th>Storm Surge</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>74–95 mph</td>
<td>Minimal</td>
<td>Damage to unanchored mobile homes, trees, and signs.</td>
<td>4–5 feet</td>
</tr>
<tr>
<td>2</td>
<td>96–110 mph</td>
<td>Moderate</td>
<td>Some roofing, door, and window damage. Mobile home damage. Trees blown down.</td>
<td>6–8 feet</td>
</tr>
<tr>
<td>3</td>
<td>111–130 mph</td>
<td>Extensive</td>
<td>Structure damage to small residential. Curtain wall failure. Mobile homes destroyed.</td>
<td>9–12 feet</td>
</tr>
<tr>
<td>4</td>
<td>131–155 mph</td>
<td>Extreme</td>
<td>Roof structure failure to houses. Extensive damage to doors and windows.</td>
<td>13–18 feet</td>
</tr>
<tr>
<td>5</td>
<td>&gt;155</td>
<td>Catastrophic</td>
<td>Complete roof failure to houses. Some complete building failures.</td>
<td>&gt;18 feet</td>
</tr>
</tbody>
</table>

Source: NOAA

Figure 2: Enhanced Fujita (EF) Scale for Tornado Damage

<table>
<thead>
<tr>
<th>EF Number</th>
<th>Three-Second Gust (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>65–96</td>
</tr>
<tr>
<td>1</td>
<td>86–110</td>
</tr>
<tr>
<td>2</td>
<td>111–135</td>
</tr>
<tr>
<td>3</td>
<td>136–165</td>
</tr>
<tr>
<td>4</td>
<td>166–200</td>
</tr>
<tr>
<td>5</td>
<td>&gt;200</td>
</tr>
</tbody>
</table>

Source: NOAA, The Enhanced F Scale is a set of wind estimates (not measurements) based on damage caused by a tornado. It uses three-second gusts estimated at the point of damage based on a judgment of 6 levels of damage to 25 different damage indicators, which vary with height and exposure. For a list of the damage indicators, go to www.spc.noaa.gov/tornado/damage_level.html.

and certify that work is being installed properly. Reinhold says that the breaching of any large opening in a house allows the wind to pressurize the interior and can blow off the roof. He also says that the types of failures observed from tornadoes often look similar to those created by extremely high straight-line winds. Tornado wind speeds can be much higher than those in hurricanes, but most of the area affected by tornadoes experience winds lower than those in the eye wall of a strong hurricane. Walls of concrete homes are good at resisting windborne debris, but openings including windows and doors, still present a weak link in debris protection. It’s economically impossible to build homes that will keep people safe from all possible sizes of debris. For that reason, particularly in tornado-prone regions, safe rooms become important for protecting human life.

The Importance of Connections

Creating continuous load paths between roof rafters and footings is very important if a house is to remain intact in a high wind event. It’s more difficult and expensive to do this for a wood-built home than a concrete one. Most concrete homes in the United States have pitched wood truss roofs so the critical connection hardware is between the exterior walls and the roof joists.

Concrete houses are built with either wood block-outs cast into a wall, or concrete edges that windows and doors are connected directly to with concrete screws or anchors. This connection must be strong enough to resist all conceivable wind loads. Szoke says that the anchorage for a garage door is especially important because the opening is so large. “If you lose a garage door, you will probably lose the roof,” he says.

Installing Windows and Doors

Steve Burke, technical marketing manager for Andersen Windows, Bayport, Minn., says there are several criteria that must be met for
windows and doors installed in coastal and hurricane areas. They must resist wind speeds as high as 174 mph, be able to handle large pressure differences between the interior and exterior, and have good impact resistance. To meet the requirements, manufacturers reinforce both their frames and sashes. Anderson adds screws to the connection and their windows often have two or three for additional security. They also use galvanized "jamb clips" instead of plastic strips to anchor doors and windows to walls. These clips are either screwed into the wood bucks or anchored to the walls with concrete screws. Burke says that the test procedure is referred to as "The Large Missile Test." A 9-pound wood 2x4 is fired through an air cannon at 34 mph at windows and doors. "It will break them but it must not pass through," he says.

**Building to resist debris**

To simulate debris striking buildings at the wind speeds present in hurricanes and tornadoes, the Wind Engineering Research Center at Texas Tech University was the first to design an air cannon that could shoot 2x4s and other objects to duplicate flying debris conditions during hurricanes and tornadoes. Debris flying at 100 mph can pass right through a standard wood-framed wall leaving inhabitants at risk. The standard "double-wall" concrete panel (each concrete wythe is 2½ inches thick with a 3½ inch separation in the middle) shown here wasn't damaged. But for buildings in tornadoes more than EF 3, openings are the problem. Installing windows and doors that can survive winds above 165 mph is too expensive. Constructing safe rooms inside homes becomes the best way to save lives.

**Safe rooms**

The Federal Emergency Management Agency (FEMA) provides plans for safe rooms. Referred to as "FEMA 320," information is available on the FEMA Web site (http://www.fema.gov/plan/prevent/saferoom/fema320.shtml). A safe room provides a space where residents can take refuge to prevent injury during a severe wind event. Concrete homes with concrete decks easily meet safe room requirements in rooms with no windows and an entrance that debris can't reach. But however you build them they should be designed to resist the highest conceivable loads, including all flying debris. In addition to the FEMA document, a consensus standard on storm shelters is being developed by the International Code Council and the National Storm Shelter Association. The draft standard is available free on the NSSA Web site (www.nssa.cc).

**Seismic considerations**

The Richter scale, the most familiar rating system, originally was developed to measure the magnitude of earthquakes in California. It is not a predictive tool—you only know the magnitude after the event. For many years, U.S. building codes divided the country into Seismic Zones 0 through 4, with 0 indicating the weakest expected ground motion and 4 the strongest. Structures in Zone 4 had a high likelihood of being subjected to a significant seismic event while those in Zone 0 were unlikely to see an earthquake. Building codes required structures in Zone 4 to be designed and built to resist most anticipated earthquakes.

When the International Building Code (IBC) was published in 2000, new provisions were established based on information developed by the Building Seismic Safety Council through the National Earthquake Hazard Reduction Program. This established a new system called the Seismic Performance Category (SPC), defining categories A, B, C, D, and E. E" represents the least seismically active area and "E" is the most. Design for a specific SPC takes into account the

(continued on page 30)
Building a Safe House
Safety doesn't have to come at a high price

When the Joseph Corp., Aurora, Ill.—a non-profit organization that helps people with limited means find housing—was demolishing some homes that involved through their “Safe Home Illinois” initiative. The IBHS is involved through its “Fortified... for safer living” program.

Together, their goal was to build a reasonably priced 1,500-square-foot home that would keep its new owners safe in the event of a natural disaster, significantly reduce heating and cooling bills, ensure low maintenance cost, and be fire resistant.

Life safety, sustainability, and energy efficiency
Life safety issues focus on construction methods and materials that will prevent the collapse of a building in the event of a disaster.

The fundamental concept of sustainability is simple: to use products made with recycled materials, and build structures with long-service lives that also can withstand disasters.

Energy-efficiency goals are achieved when there are few air leaks in a building envelope and when insulation with high R-values is installed. Sometimes the ability of a structure to store energy in its thermal mass, which concrete does well, and to release it at times when it is needed, can reduce energy bills.

Building a disaster-resistant home
Bock says this house was originally going to be a wood-frame house. For the student's educational and training purposes, it was decided to keep the breezeway and the garage as wood-frame structures with brick as the finished surface.

To more easily achieve the fortified designation and provide an energy-efficient sustainable home, Dukane decided to make their precast concrete double-wall panels with a brick formliner pattern the same size as the bricks.

The house has cast-in-place footings and foundation walls except for one wall. “We left the foundation wall out for the area closest to the street for curb access to the back of the house,” says Bock. “Afterward, we installed a precast foundation wall and then placed the first story wall on top of that.”

The 6000 psi precast panels are made with 38% recycled material including fly ash, ground granulated blast furnace slag (GGBFS), and expanded slag lightweight aggregate. The lightweight aggregate is backfilled dry to reduce transportation costs and then saturated with water in a vacuum saturation tank just before it is used. A typical wall panel is 8 inches thick consisting of two concrete panels joined together by a wire truss. Each concrete panel is 2½ inches thick with the 3-inch section in the center used for insulation, rough electrical, and plumbing. Bock says they use a biobased foam insulation product made from soybean and castor oil that provides R-19 insulation per inch of foam or R-21 for the panel. Though they still place steel rebar in the panels, Dukane also uses prestressing strands set every 2 feet.

This project uses Dukane’s concrete floor panels consisting of 3-inch-thick concrete slabs with steel trusses below the concrete. The top chord of the trusses is embedded into the concrete floor panels. The open truss area on the bottom of the floor panels will make it easy for the high school workers to install heating and cooling ducts and lighting. Clips on the bottom of the trusses will serve...
type of soil and rock and the anticipated ground motions. For design and detailing requirements, the SPC also considers the type of building, recognizing that some buildings, such as hospitals, must be able to continue operation after an earthquake while others, such as an office building, are not as critical.

Szoke says that the more massive a building is, the more the energy from an earthquake will influence the structure. Concrete homes have high mass but are low in profile so there aren’t many relevant seismic issues. Dave Gowers, Dave Gowers Engineering, Selma, Ore., designs insulating concrete form (ICF) homes in California, Oregon, Washington, Arizona, and Nevada. He says he normally works with 6-inch-thick core walls.

“With this amount of concrete and the ACI 318 minimum reinforcement guidelines, the wall is frequently stronger than structural analysis requires,” he says. The most he has been required to design for so far is a Zone 4, SPC D2 seismic force. “The minimum requirement is typically rebars on 12- or 16-inch centers. Using #5 bars adequately covers it,” he adds.

Wind and seismic events both apply lateral loads to a home. Seismic design usually is based on forces that are related to some fraction of the weight of the building or its components. “For wind, the major complicating factor is that the roof uplift forces may be several times the weight of the roof,” says Reinhold. For seismic design, though, the dead loads, live loads, and wind loads are only a fraction of the maximum expected earthquake loads, so detailing the connections is critical to prevent collapse during a seismic event.

**MASONRY WALLS**

Most concrete homes built in the United States are constructed with concrete masonry blocks. According to Nick Lang, a research engineer for the National Concrete Masonry Association (NCMA), Herndon, Va., the typical residential exterior wall is constructed with 8-inch concrete block. Walls include bond beams at the bottom and top of the wall plus additional bond beams above and below each opening. The block cores are reinforced and grouted according to the engineering requirements for either wind or seismic at the location of the building. NCMA’s Web site (www.ncma.org, click on Resources) provides an extensive set of technical briefs (c-TEK) on the subject. Lang says that you also can call the NCMA hotline at 703-713-1900 for expert help.

**BUILDING WITH CONCRETE**

Concrete is the best building material for protection from wind and seismic events. Most new home construction in the southern part of Florida today uses either concrete or masonry block. Damage to reinforced masonry and concrete walls from wind events is less than with other building material and they provide life protection from wind driven debris.