Wild Winds and Rolling Waters

Current hurricane research points the way to practical improvements for coastal homes

by Aaron Hoover

When Hurricane Andrew struck South Florida in 1992, it broke through unprotected windows, blew off flimsily built roofs, and turned weakly attached shingles into clouds of damaging flack.

Lessons learned from the 200,000 damaged or destroyed homes or businesses spurred big improvements not only in hurricane-resistant building techniques and materials but also in on-the-ground construction practices and code enforcement intensity. Hurricanes in later years prompted further progress, and though Florida remains the national leader, homes built along much of the Gulf and East Coast today are unquestionably more hurricane-worthy than those built two decades ago.

But large gaps remain.

Despite months of front-page Hurricane Katrina news coverage in 2005, building codes and enforcement practices continue to vary greatly from state to state or municipality to municipality. Moreover, surprisingly little is known about how hurricane winds pull apart and drive rain into homes — and what affordable measures can seal them tight. Plus, existing

Testing real-world conditions: To measure the actual withdrawal strength of sheathing nails, researchers have pulled thousands of individual nails out of existing homes.

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homes, which comprise the majority of the coastal housing stock, may have few (if any) of the hurricane protections standard in new homes.

Fortunately, a small community of building scientists at universities and in the public sector is working to close at least some of these gaps.

According to these experts, when it comes to storm surge flooding, protecting new homes is more a matter of smarter public policy, more conservative building site choices, and better construction quality than new building science. The story, however, is different for wind and wind-driven rain. New insights, from field observations following land-falling hurricanes and laboratory research at universities, are enhancing construction techniques, materials, and building codes, these experts say.

"Twenty years ago, we couldn't do the work we are doing now because it would have been impossible or cost prohibitive," says Forrest Masters, an assistant professor of civil engineering and wind researcher at the University of Florida in Gainesville, who last year designed and built the world's largest portable wind machine. "But technology has reached a point where we can create hurricane conditions in a laboratory."

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To simulate the erratic nature of hurricane-force winds, Dr. Forrest Masters of the University of Florida developed this Portable Hurricane Simulator designed to test the water-intrusion resistance of full-scale building assemblies. Outfitted with a bank of red "rain injectors," the monster bank of eight 5-foot-diameter hydraulic fans can simulate wind-driven rain delivered at a rate of 44 inches per hour under air pressures of more than 35 psf — as close to real-world hurricane conditions as any test apparatus can deliver.

TAMING THE WIND

Wind, the core subject of today's most fast-moving hurricane research, is not the steady force often imagined — a misperception only encouraged by the Saffir-Simpson Hurricane Scale's categorization of hurricanes by maximum wind intensities.

"Wind to me," says Masters, "represents uncertainty."

The Saffir-Simpson scale describes wind speeds over open ocean. But on land, low-level winds arrive in gusts whose forces and directions are influenced by topography and the hurricane's dynamics, Masters explains. What determines whether a house faces a painless puff or a crippling body blow depends as much on intensity as the placement of nearby structures, landscaping, and the presence of micro-bursts, downbursts, or tornadoes, he says.

Getting a handle on wind's complexities is important because most tests for product standards, such as those used by Factory Mutual and ASTM International, consider wind a static, uniform pressure, notes David Prevatt, another wind engineer at UF.

"As anyone who has ever been through a hurricane knows," he says, "wind is anything but static, and anything but uniform."

Accurately portraying wind and its influences on homes is a daunting challenge, in large part because the focus of greatest interest — a real house facing a real hurricane — is also the most dangerous to observe. But Masters, Prevatt, and fellow wind-engineering researcher Kurt Gurley are taking what they call a "wholistic" approach: laboratory experiments, field experiments and observations, and post-hurricane wind-damage assessments.

IMPROVED TESTING

One goal is to improve the testing methodology at the heart of codes and standards.

As part of an initiative called the Florida Coastal Monitoring Program, the researchers measure hurricane wind speeds and other variables using portable towers erected in the path of land-falling storms. They also collect measurements from hurricane-buffeted homes equipped with pressure sensors, among other devices.

The team started chasing hurricanes in 1988 and has gathered data from 18 storms so far. According to Prevatt, the researchers are now checking this data against the equivalent measurements obtained with scale-model homes in wind tunnels — measurements that have long been the basis for the American Society

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The Florida Coastal Monitoring Program, run by a consortium of wind research universities, has set up portable weather towers (left) in advance of every hurricane and tropical storm that has made landfall in the southeastern U.S. since 2001. Combined with data from sensors installed on houses near the predicted landfall site (below), researchers have evolved a much more accurate profile of the wind-pressure characteristics that buildings must survive than was available from previous data collected from ocean buoys and airplanes.

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of Civil Engineers (ASCE) wind-load provisions underlying the International Building Code (IBC) and International Residential Code (IRC) and have been widely adopted by cities, states, and municipalities.

Prevatt says the mean pressure coefficients in the field observations and wind-tunnel experiments match, but that the wind tunnel may underestimate peak loads on roofs.

"The fact that the means are tracking fairly well is a sign that we are modeling the macro, overall loads appropriately," he says. "However, there is a question of whether we are actually capturing the peaks."

Prevatt stresses that more research is needed before drawing conclusions, but confirmation could encourage revisions of the ASCE provisions.

The researchers also examine the performance of building components, such as windows, doors, and soffits.

In a project headed by Gurley, the team scrutinized how 200 homes held up against the four 2004 Florida hurricanes. Among its conclusions: While homes built to Florida's then-most-recent 2002 code sustained less damage than earlier homes, soffits were a major point of failure. Wind damaged or blew out soffits, allowing wind-driven rain to enter the attic, soaking insulation, collapsing ceilings, and ruining interiors.

The 2007 Florida Building Code, the most recent version, requires soffits designed to withstand the same wind pressures as walls, Masters says. At this point there are no prescriptive measures for how soffits should be detailed. However, the UF research has helped builders develop better soffit-building methods, which relies on strong blocking behind soffits rather than just J-bead (see "Securing Soffits," January/February 2007; www.coastalcontractor.net).

The UF team is also seeking to identify the most important upgrades for existing homes built with no or few hurricane protections. They use the hurricane wind machine, pressure-measuring nail-pullers, and load sensors suspended from cranes to assess the performance of homes built before Florida's first Andrew-inspired codes in 1994. Prevatt says findings confirm that many such homes have extremely weak roof-to-wall connections. Metal connections that transfer the load path from truss to plate to studs to ground are essential. However, retrofitting these connections, as any remodeling contractor knows, is usually easier said than done.

"One needs to find a way in which you can attach [connectors] on the interior and exterior faces without removing things, but it's not easy," Prevatt notes.

KEEPING ATTICS DRY

The improvements that followed Andrew — shutters or impact-resistant windows, for example, and nailed rather than stapled shingles — took care of the most glaring home-construction deficiencies in new homes.

Since then, engineers and building scientists have been focused on the "next weak link," in the words of Tim Reinhold, director of engineering and vice president for the Tampa-based Institute for Business & Home Safety. After the 2004 Florida storms, that weakness was a home's ability to resist water intrusion.

Many homeowners complained of soaked carpet or moist drywall despite roofs and walls remaining intact. The water not only seeped through soffits, windows, and doors: it entered through gable-end vents as well. When enough shingles disappeared, rain also poured through gaps in intact roof sheathing.

What's needed, Reinhold says, is a moderately priced "backup system" — a modification that would keep most of the rain out, for a long enough period, to allow homeowners to repair the roof or to cover it securely. Otherwise, he says, even with little apparent exterior damage, homeowners may face complete renovations of interiors.

One potential solution is to cover the joints in the plywood roofing sheets with water-shielding tape during reroofing jobs. A second is to spray closed-cell foam on the underside of the roof, Reinhold says.

As for attics, Reinhold says the 2004 Florida storms also showed wind could blow off ridge vents, leaving "a nice big place for water to pour into the attic."

Florida's code now requires the vents to withstand the same design pressure as the walls. But Reinhold says installing vents — and soffits — per the manufacturers' guidelines is critical. Most manufacturers recommend that workers install soffits against wood backing strips, but installers sometimes ignore the recommendation because the work requires a carpenter, he says.

Reinhold adds that homeowners can avoid worrying about vents and soffits entirely by building sealed attics, with no vents or other penetrations. While unusual in the past, sealed attics are becoming more common, thanks in part to closed-cell foam insulation and better understanding of the need to seal thermal bypasses (see "Insulation That Works," January/February 2008; www.coastalcontractor.net).

ENCOURAGING ELEVATION

No matter how well homes may be fortified against wind and wind-driven rain, all are essentially defenseless against another hurricane danger: storm surge.

"Wind, we build buildings to resist," says Chris Jones, a Durham, N.C.–based engineer and consultant who co-wrote the current edition of the Federal Emergency Management Agency's *Coastal Construction Manual*. "Flood, we build them to avoid."

Storm surges flood structures in their path, batter them with waves, tug at them with currents, and slam them with floating debris. Their awesome destructive power was obvious in the aftermath of Hurricane Katrina, which destroyed an estimated 300,000 single-family homes in Louisiana and Mississippi.

Katrina's surge topped base flood elevations by as much as 15 feet in coastal Louisiana and Mississippi and produced the highest storm surge recorded in U.S. history (27.8 feet in Pass Christian, Mississippi). Below-sea-level New Orleans was a special case, but in Mississippi, the result was "tens of thousands" of homes lost to surge alone, Jones reports.

Unlike the case with wind, Jones says, few new materials or research-inspired design advances will change the traditional approach to surge: elevating homes, or placing them

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Using sensors to measure the uplift force, researchers test the resistance of framing connections in houses slated for demolitions. The results will help determine the real-world performance of retrofit connections needed to strengthen older homes.

atop ground high enough to remain clear of flooding.

"I think we've known for decades what to do," he says. "We just don't always do it."

That said, there is growing recognition in some coastal regions that homes may be exposed to harsher flood conditions than long thought, he notes.

As a result, there is some possibility that more "A Zone" homes may be built to tougher "V Zone" standards. "V" zones are threatened by fast-moving waves 3 feet or higher, while "A" zones are areas where such waves are not expected or are less than 3 feet.

The National Flood Insurance Program, which underwrites all coastal flood insurance policies, is trying to toughen coastal homes by providing discounts to communities who switch to V zone standards in A zones, Jones notes. New flood insurance rate maps, meanwhile, make it easier for builders to locate the most vulnerable region of the "A Zone," ending one source of past difficulty, he explains.

Whether or not those inducements work, Jones says he always encourages builders to be conservative, building higher and stronger than the code allows.

MICHELLE MILLER-FREECK/FEMA

"Raise it or lose it" summarizes the basic tenet of new home construction along the Gulf Coast in the aftermath of Hurricane Katrina.

ANDREA BOOHER/FEMA

Slab after slab was wiped clean, as the surge of Hurricane Katrina advanced along the Mississippi coast near Gulfport. According to a December 2005 report by the National Hurricane Service, the maximum high-water mark was 27.8 feet at Pass Christian, just west of the area shown (above). The surge penetrated at least 6 miles inland in many portions of coastal Mississippi and up to 12 miles inland along bays and rivers.

MITIGATION MATTERS

It's an admonition with relevance for the coastal building industry and construction related public policy in general. That's because the research and recommendations of building scientists like Reinhold, Masters, and Prevatt represent only part of the solution to fortifying homes. Responsibility also rests with the elected officials, regulators, builders, and inspectors, who control everything from where homes are built to quality of workmanship to maximizing compliance with codes.

Before Katrina, Alabama, Louisiana, and Mississippi lacked statewide building codes for residential structures. Three years later, Reinhold notes, Alabama has yet to adopt a statewide residential building code. Mississippi, which lost 68,729 homes to Katrina, now requires coastal counties to enforce the 2003 IBC and IRC, but enforcement is questionable, Reinhold says. Louisiana, where 283,838 homes were destroyed, today requires the latest codes "but they are struggling trying to get up to speed on getting building departments in place and enforcing the code," Reinhold explains.

Says Reinhold, the only solution to protecting coastal homes "is through mitigation and making sure we build as smartly as we can. We need to give these buildings the best chance we can of going through these storms." ~

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