

RESILIENT BUILDINGS



Building Tough Nature's not getting any gentler— but builders are getting smarter

BY TED CUSHMAN

The main purpose of a house, it's fair to say, is to protect people from nature. We count on the exterior walls and the roof to keep us comfortable in a natural world—no matter how harsh the conditions outside.

It's a tough job in the best of times. But when nature does its worst, standing up to the elements can be a defining test of a home's performance. In any given year, we know that wind, flood, or fire will strike with fury somewhere in the nation—and that some houses won't survive.

2016 was no exception. Fires burned more than 500,000 acres in drought-stricken California last year, after hoped-for rains from a Pacific Ocean El Niño event proved lighter than promised. One blaze in Kern County destroyed 285 homes in June. In August, fires burned 48 structures in San Luis Obispo County, 189 homes in Lake County, and 105 homes in San Bernardino County.

Then the fire season moved East, and flames punished the parched hill country of Kentucky, Tennessee, Georgia, the Carolinas, and Virginia. Just after Thanksgiving, a raging forest fire damaged or destroyed more than 700 buildings in the Tennessee towns of Gatlinburg and Pigeon Forge. By December, fire had scorched more than 155,000 acres in the South.

In North Carolina, the fall wildfires were the state's second bout with disaster: Flooding associated with Hurricane Matthew inundated parts of the state in early October, when 7 inches fell in a single hour in some locations. Thousands were made homeless as the floods damaged or destroyed houses and washed out roads.

Flooding, unrelated to hurricanes, had already plagued other parts of the South earlier in 2016: Hundreds of homes in Houston were flooded in April, and major floods hit Oklahoma and Texas again at the end of May, damaging more dwellings. But those spring

Photo: Andrea Booher/FEMA

floods paled in significance next to the disaster that befell Louisiana in August, when a stalled weather system brought more than 2 feet of rain to the state. More than 140,000 homes were damaged by the ensuing floods—and only a small fraction of those dwellings were covered by flood insurance. With damage to private and public property pegged at more than \$15 billion, Gov. John Bel Edwards asked Congress for \$4 billion worth of help.

Flooding can be made even worse with hurricane-level winds, and the U.S. has been fortunate that a major hurricane hasn't made landfall since October 2005, when Hurricane Wilma struck south-east Florida. Hurricane Matthew in late 2016 threatened to break that streak: As the storm approached last fall, governors warned of a dangerous storm. But Florida dodged a bullet: Matthew's top winds missed the state with a few miles to spare, and the storm touched South Carolina only briefly, as a Category 1 storm, before curving back out to sea. Wind damage was significant but far less severe than would have been the case had the storm tracked 10 or 20 miles inland up the Florida peninsula.

2016 was still a year of hard lessons. Matthew's near miss was a reminder that only good luck stands between U.S. coastal communities and a killer hurricane. Spring's and summer's deadly floods made it clear that rain is a risk in any low-lying location. And the fall wildfires in the Smoky Mountains were a wake-up call that fire isn't just a Western problem.

Here's the good news: Builders are learning. Every year, we get better at resilient construction. And when it comes to these three major hazards—wind, flood, and fire—a homeowner may be far better off in a new home than in an existing older one. New high-performance materials and components and improved construction methods offer much greater resistance to the forces of natural disasters. Builders who adopt the best technology can help the housing stock of the future stand up far better to nature's fury—and by so doing, can help protect their clients, as well.

This month kicks off *JLC's* new "Climate and Construction" coverage category. In the coming year, stay tuned for a continuing series of technical reports about best-practice disaster-resistant and resilient construction methods.

WIND

No place in this nation is free from wind. Atlantic and Gulf Coast locations are exposed to hurricane winds, Tornado Alley in the South and the Midwest sees tornado risk, and any region can see dangerous straight-line winds from thunderstorms. Codes across the country vary from place to place, in response to the estimated odds of encountering these various degrees of wind hazard.

South Florida is the heart of hurricane country and the place where many wind-resistant structural solutions have been introduced, developed, and proven in the field. After Hurricane Andrew landed in 1992, Florida codes were the first in the nation to toughen up. And in the heavy hurricane years of 2004 and 2005, Florida's tougher building practices paid off: Newer homes in the state





Photos: Ted Cushman (top) and Twister Safe (bottom)

In theory, you could build a house to withstand an EF-5 tornado's 300-mph winds; but it wouldn't really be a house. It would be a bomb shelter.



Saving lives. A family sheltered in the basement of this shattered building during the 2011 Joplin, Mo., tornado (left). Another Joplin resident survived in a “Twister Safe” shelter (below left).

suffered noticeably less damage from storm winds than older houses did.

A few basic structural upgrades account for the improved performance: a continuous load path to resist wind uplift; strong lateral bracing (or engineered shear walls) to resist the sideways pressure of wind; hardened or protected windows and doors to resist penetration by wind-borne debris; and improved watertight and water-shedding details to resist rain penetration in storms.

As technologies have improved and spread through the market, these methods have become more cost-effective to implement. Then as modern methods are studied and publicized, proven techniques are becoming easier to learn.

Hurricanes. In regions at risk of hurricanes, these practices can make the difference between a house that works and one that fails:

At the foundation stage, place anchors in the concrete footing, stem wall, or basement wall to hold the wood-framed or masonry first story to the foundation.

Next, at the framing stage, design and build walls to resist both uplift and shear forces by using structural panel sheathing and closely spaced nailing. Metal straps nailed to framing members are used to connect upper and lower stories. To complete the continuous load path, metal connectors are also specified to tie roof framing to walls and, in stick-framed roofs, to connect opposing rafters together across the ridge.

Finally, at the roofing and siding stage, rain resistance is upgraded using advanced weatherproof tapes or fluid-applied sealant at sheathing or housewrap joints (a method that also improves house airtightness).

Applying weatherproof tape at the sheathing joints on the roof is a quick, simple step that can significantly boost a home's resilience in a hurricane: If wind blows away the shingle roof and underlayment, the taped sheathing will still keep most rainwater out of the attic, preventing the home's insulation and ceiling from becoming saturated (which can cause a collapse of the interior ceiling drywall). In extreme situations, this step could actually save the whole house: Sometimes, the bracing effect of gypsum board on a house ceiling can be an important structural factor in the building's resistance to wind pressure on the walls, and preventing roof leaks can keep that moisture-sensitive material intact. Depending on the situation, keeping the ceiling stiff could be key to preventing collapse.

And keeping the rain out does more than protect the structure

itself. If a house stands up, but the attic is saturated and the ceilings fail, the home becomes unlivable. That's also true if windows are blown out and the interior floors and furniture are soaked by wind-blown rain. Major repairs can be avoided—and the family can return to their home after the storm—if the house stays dry.

Tornadoes. In tornado country, the rules are a little different. Tornado winds can be much more severe than the worst wind any hurricane can dish out. An “EF-5” tornado (measured on the 0-to-5 Enhanced Fujita Scale) packs winds of 261 mph to 318 mph—about double the wind speed of a top-end Category 5 hurricane and more than twice as destructive.

Winds like that can't practically be measured in the field; instead, scientists classify tornadoes by assessing the damage after the storm has passed. The official verbal description of an EF-5 tornado is “incredible damage.” You have to get down to EF-2 on the scale before you see winds as low as hurricane force (113 mph to 157 mph); in that case, the tornado's effects are termed “considerable damage.” In theory, you could build a house to withstand an EF-5 tornado's 300-mph winds, but it wouldn't really be a house. It would be a bomb shelter.

Still, there's good news. Most tornadoes aren't EF-5 storms; 90% or 95% of them are weaker than EF-3, and three quarters are EF-0, EF-1, or EF-2. The same qualities that a house needs in hurricane country can also stand up to most tornadoes. And while those methods and materials are not typically required in tornado country—because a tornado is such an unlikely event—they're not necessarily prohibitively expensive.

For a production builder who's shaving costs on every house, the bottom-line focus may not accommodate hurricane-resistant construction for an inland house. But for custom builders, the budget might stretch to pay for the few details and design changes it would take to make a house tough enough to withstand a weak tornado or a near miss by a strong one. Either way, you'll want to be careful how you market the upgrade. Given the severity of a tornado, it's not something to make part of your warranty.

FLOOD

In the U.S., there's one provider of flood insurance for homes—the National Flood Insurance Program (NFIP) administered by the Federal Emergency Management Agency (FEMA) and the U.S. Army Corps of Engineers (USACE). Just one flood insurance program for the whole country—but the country has more than one kind of flood. As with wind, there's the coastal version (hurricane storm surge flooding), and there's the inland version (rising water from rain). Their physical causes are very different and, to some extent, so are their damaging effects.

Having one flood insurance program for two very different types of natural disaster weather events complicates the risk calculation in the flood insurance program and contributes to the many problems that the NFIP faces. But that's outside our topic here. More to the point, there are measures that builders can take to manage the risk of flood when they build a house—and the ones

Whether the concern is coastal surge or a rainstorm, elevation is the key to avoiding the risk of flood.

a builder chooses to implement should reflect the type of flood event the building could face.

One smart move, obviously, would be to build the house someplace where there won't be a flood. But that's not as easy as it sounds. FEMA provides flood-plain maps, created by the USACE, that define the boundaries of what's called the “hundred-year flood plain.” The term is a little misleading: A house in a 100-year flood plain might easily flood more than once every 100 years. More accurately, the flood plain is defined as the location where the risk of flood in any given year is at least 1%.

But that “at least” hides a lot of variability. Some places in the flood plain are likely to flood more often. And the boundaries of the flood plain are based on complicated assessments that involve many uncertainties. Suppose your house is outside the flood plain but only a short distance away from the line and a few inches above it? How much safer are you than your neighbor, really? It's an impossible question to answer.

The flood map suggests discrete zones, but flood risk is a moving target. Natural changes in rivers and bottom lands, development upstream, soil subsidence, erosion, and other factors all can upset the odds. So even if you're not officially inside the flood plain, that doesn't mean you shouldn't build as if you were.

In practice, whether you're concerned about storm surge or rising water from rain, elevation of a home is the root strategy for avoiding risk. The higher you build a home's occupied space, the less likely it is to flood. And the way you elevate varies, depending on the type of flood you expect.





Elevation works.

Above, a concrete house on pilings survives amid bare slabs in Pass Christian, Miss., after Hurricane Katrina. Right, "Fortified" wood houses on pilings stand alone on the beach in Gilchrist, Texas, after Hurricane Ike.



Photos: Marty Bahamonde/FEMA (top); Paisy Lynch/FEMA (bottom)

In the coastal velocity zone (“V zone”), where hurricane storm surge is the risk and wave action is the driving force, you need an “open foundation” on pilings, which allows waves to pass harmlessly below the home’s occupied space. Waves pack an enormous punch—measured in thousands of pounds per square foot compared with tens of pounds per square foot for wind. Because water is so much more massive than air, a 2-foot or 3-foot wave is far more destructive than any hurricane wind pushing against a structure. That’s why a 30-foot surge with high battering waves, like Hurricane Katrina brought in 2005, was able to scrape entire shorelines clean of buildings, including a total of 7,500 homes around Pass Christian, Miss.

River lowlands, where waves aren’t expected, are in the “A zone.” There, a foundation doesn’t have to be open; an enclosed concrete or block foundation is OK, as long as it has flood vents to let water in and out, equalizing pressure on the foundation wall.

In either kind of flood plain, official maps will supply a “base flood elevation,” or BFE. That’s the elevation that the 100-year flood is predicted to reach, if it happens. Depending on your local code, you may have to build above the BFE level by a foot, 2 feet, or even 3 feet—a safety factor known as “freeboard.” If the property has to carry NFIP coverage (which typically is required only if the house is mortgaged), freeboard can reduce the insurance premiums. The opposite, of course, is also true—homes that are below the BFE get smacked with steeper premiums.

In Louisiana’s historic August floods, barely 21% of flooded homes were insured against flood. Some homes weren’t mortgaged, so insurance wasn’t required. But many were outside the official flood plain—proof, if any were needed, that no line on the map can guarantee safety in the real world.

Elevating houses is expensive and is hard to justify if the flood risk is uncertain. For low-lying inland locations, where destructive ocean waves aren’t the big risk, there’s another option—called “wet floodproofing.” The idea is to design and build the lowest parts of the structure to be drainable and dryable, so they can withstand an occasional soaking. Usually, wet floodproofing doesn’t meet code for construction within the official flood plain. But for homes near the flood plain, it can be a wise precaution. And for homes that have already been flooded, it may be the most sensible way to repair them.

Wet floodproofing involves constructing the lower parts of a first-floor wall using water-tolerant materials, so that if the wall is soaked by a foot or two of water, it can be quickly drained, dried, and repaired before damaging mold can get a foothold. Well-known building scientist Joseph Lstiburek and his colleagues at Building Science Corp. developed guidance for water-tolerant wall assemblies suitable for Louisiana and Mississippi following the disaster caused by Hurricane Katrina. The Louisiana State University extension program has also issued wet floodproofing guidance, which has found its way into FEMA construction manuals as well.

In brief, the idea is to frame and sheathe, if possible, with treated wood (already required in some Southern jurisdictions because





Keeping fire at bay. Fire spread from house to house after entering the California neighborhood above. But the development at left, designed with resilient landscaping and construction features, survived a similar type of fire with no homes lost.

of termites) and insulate with waterproof exterior foam instead of cavity fiber insulation. Then on the lower portion of the wall, use cement board or an equivalent water-tolerant material instead of drywall. In the event of a flood, the baseboard and a strip of wall-board can be removed at the base of the wall, the water can drain out, and fans can quickly dry the open wall cavity. After that, only the base of the wall will need repair. (Wiring, by the way, is run high up on the wall, and outlets are located feet up instead of at the usual 16-inch height.)

FIRE

The risk of wildfire waxes and wanes with the weather. Prolonged droughts create extreme risks, and in recent years, Alaska and western Canada have seen unprecedented incidence of major wildland fire. This past fall's catastrophic Smoky Mountain wildfires followed many months of deep drought in the Southeast, and winter rainfall was a welcome relief for the region.

But human activity is a complementary risk factor. As residential development pushes deeper and deeper into formerly wild areas,

more and more homes are placed in locations where wildfire is a common natural occurrence, though one that, just like the cold, the snow, and the rain, we humans would prefer not to experience.

Preventing or extinguishing major wildfires isn't something builders can do. That requires a major community effort, involving governments at all levels. But wildfire's danger to homes can be controlled, or at least limited, house by house and neighborhood by neighborhood—and here, builders have an important role. The design and construction of developments and homes can make the difference between survival and destruction.

The basic principles of wildfire resilience are built into several flavors of Wildland Urban Interface (WUI) code. The National Fire Protection Association (NFPA) and the International Code Council (ICC) each publish a model WUI code, which states and localities can adopt. The state of California, where the risk is extreme, has its own WUI code and has led the nation in the application of the code to neighborhoods and homes.

All the codes take the same fundamental approach. Fire protection starts with the landscape, and the mantra “lean, clean, and green” applies: Vegetation should be kept away from the house and be kept trimmed, pruned, and watered.

Then there's the house itself: There are ways to harden homes against being ignited by wildfires. Research has shown that the most intense phase of a high-intensity wildfire, the “crown fire,” passes through an area in a matter of just a few minutes. Keeping the surrounding area well-groomed will prevent the intense fires from approaching the house. The crown fire itself applies intense radiant heat to a house, but only briefly, as it passes through. So if a house exterior can resist a few minutes of intense heat, it won't catch fire. The state of California maintains a database that includes products that have been tested for ignition resistance, as well as fire-resistive assemblies.

But the heat of a crown fire isn't the only risk. Windblown embers, which can travel for a mile or more on a windy day, are a major source of ignition. They pile against the house, land on roofs, or blow into the home through open windows. So fire resistance on the lower edge of the house is key; fire-rated roofing is vital; and windows that won't shatter from heat during the brief high-intensity crown-fire exposure can be a home-saver.

Ironically, other houses, not the dry wildland, can be the biggest source of fuel for an out-of-control wildfire. In an ordinary house fire, firefighters can concentrate on putting out one house so it won't ignite its neighbors. But once embers blow into a development and set several homes on fire—while the woods nearby are also burning—firefighting resources can be overwhelmed. Houses on fire send large volumes of hot embers up into the wind, which carries them into the surrounding wildlands and onto nearby homes. That's why fire resistance is a community concern. Carefully detailing every house to resist ignition is the key to preserving a whole community from a runaway wildfire.

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