

Beating the Heat

RESILIENT HOUSING

Our second edition of the strategic defense guide for building and preparing new and existing properties—to withstand nature's fury.



INSIDE:

- Flood Preparation
- ICF Best Practices
- Defensive Irrigation
- Metal Roofing Tips
- Disaster-Ready Products

A NOTE FROM THE EDITOR

Time to Hunker Down

Next generation homes must be built with worst-case climate scenarios as their baseline.



BY MATT POWER

LAST NIGHT, while attending a Resilience Hub meeting in my home town of Portland, Maine, I was cornered by an anxious friend. She had read some of the latest dire Climate Change reports, and was interested in taking some kind of action to prepare for the changes that are coming, if such preparation is even possible.

It's no longer prudent to put an optimistic spin on the scenarios that lie ahead. Population growth, combined with unsustainable behavior by both industry and individuals make a sudden reversal of greenhouse gas pollution extremely unlikely, if not unthinkable.

That's not to say we lack hopeful technologies and shifts around the corner, such as rapid conversion to a renewable power grid, solar-powered air conditioning, hydrogen cell engines and more, but even

the most optimistic timeline for widespread use of these technologies may not arrest the impending decades of extreme weather strife that we face.

Since we can't compel our neighbors to change their behavior, what's left? Preparation. We can build disaster-resistant housing. A new house that is not built to withstand nature's fury is shortsighted—a disservice to the homeowner. But half measures will not suffice. You need to go all the way. Otherwise, for coastal properties in the mid-atlantic or Florida's gulf coast, you might be wiser to put up a yurt or park an RV than to build a house that's not prepared for a 20-foot storm surge and rising sea levels. When bad weather comes, at least you can run away.

What does a resilient house look like? It may look just like the house next door, but behind the façade the building science is far superior. While the details vary, depending on the most likely hazards, the principal is the same: engineer the structure to stand firm as water and wind pass by.

If coastal or in hurricane-prone areas, such a home may have a shell of insulating concrete forms or structural insulated panels, or, if built with wood, it could be massively strengthened with metal straps and tie-down and anchor systems. If in a flood zone, it's elevated even well beyond the flood plain requirements.

And in every case, net-zero energy performance is the bare minimum. Often the worst storm disaster happens after the event, when homes sit wet and powerless for weeks, without power to help dry out interior spaces. In almost every extreme climate scenario, localized, renewable electricity and heating/cooling will be essential, not to mention fresh water sourcing, filtration and recycling.

The challenges are daunting, but the materials and the building science are sound. And this 2nd annual guide will help you understand both. **GB**



Rock Solid. This Texas home, built with ICFs on a flood plain, survived flooding and hurricane winds as others around it disintegrated.

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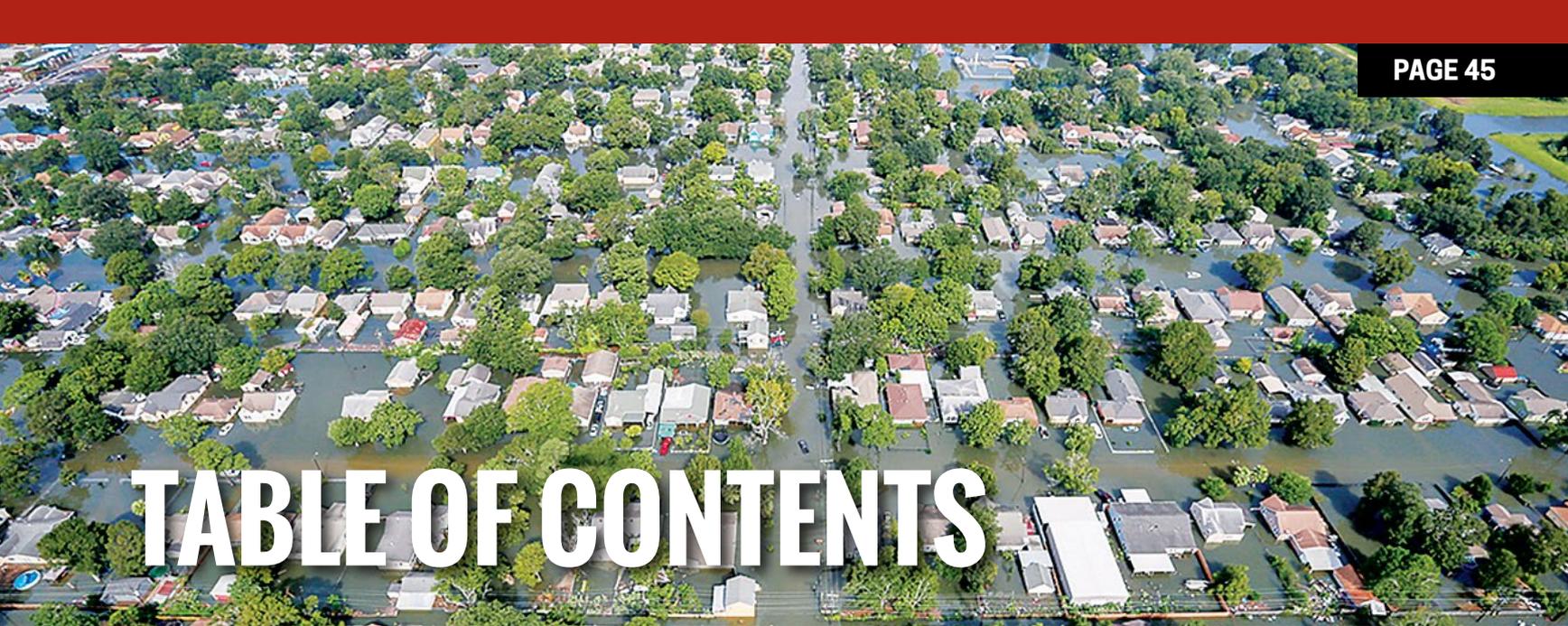
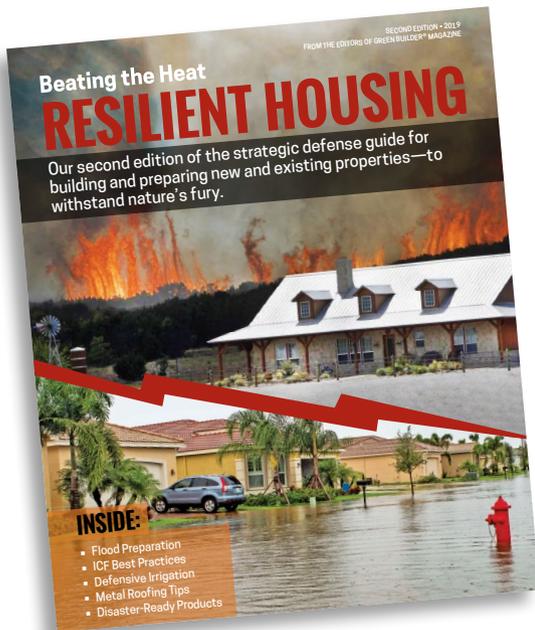


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BRACED FOR NATURE'S FURY

To become resilient, we must build for worst-case scenarios.

ALL BETS ARE OFF with regard to the extreme weather threats of the future. That's more or less what FEMA now says about its "best guess" tools for determining the probability of floods and other major disruptors.

As an example, look at the list of exceptions they make to the inset graph predicting how likely it is that floods will exceed expectations:

"FIRMS (flood insurance rate maps) do not account for the following:

- Shoreline erosion, wetland loss, subsidence and relative sea level rise
- Upland development or topographic changes
- Degradation or settlement of levees and floodwalls
- Changes in storm climatology (frequency and severity)
- The effects of multiple storm events

Thus, what was once an accurate depiction of the 100-year floodplain and flood elevations may no longer be so."

Assuming FEMA, NASA, the Pentagon and thousands of scientists worldwide are right about the side effects of impending climate change, what's the best preemptive strategy for building and designing the homes and cities of the future?

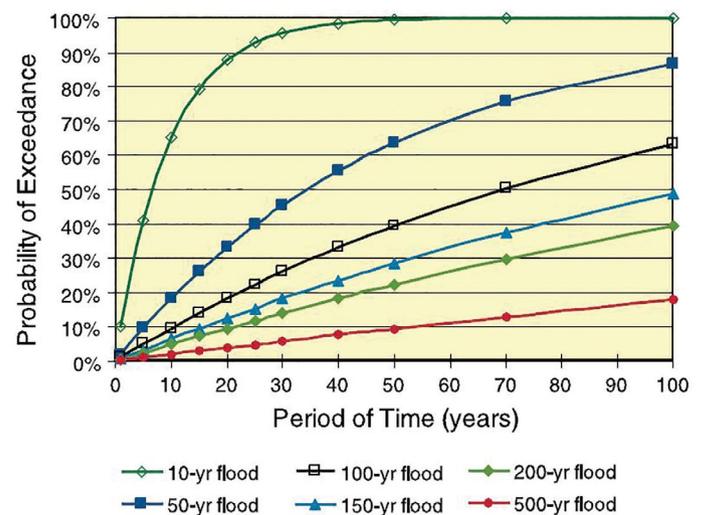
REDUNDANT ENGINEERING

The airline industry considers redundancy one of the best tools for preventing disasters. Hydraulic systems, for example, are often duplicated—or even triplicated—to ensure that if one fails, another takes over. Why can't housing be designed with the same principles in mind?

Some methods and systems in modern construction already rely on redundant systems. Roofing underlayment, for example, plays a backup role to shingles or tiles. In well-built custom homes and factory-built modular panels, fasteners sometimes serve as backup to the adhesive that connects drywall to frame.

The homes and cities of the future will take redundancy for granted,

Probability of a Flood Exceeding the n-Year Flood Level During a Given Period of Time



Note: this analysis assumes no shoreline erosion, and no increase in sea level or storm frequency/severity over time.

as a fail-safe against storms, wildfire, earthquakes and flooding.

Simply elevating a home in a flood zone, for example, won't be the only measure taken against flooding. It may also contain advanced systems for surviving prolonged sea level rise, tsunamis and other threats. And if living spaces are breached, lower floors will be made of materials that can be easily cleaned, perhaps with high-pressure washing equipment that's already part of the home's infrastructure. Future homes will be "ready for anything."



Dome Fortresses

If only we could learn to love domes. With no eaves to catch wind uplift, great flood resistance and even earthquake stability, what's not to love? The trouble is not in these designs, it's in what makes us feel "at home."

Want a tornado-proof home that can stand up to everything, possibly including a nuclear blast? Try a dome home with no windows that's anchored to the ground right through its monolithic walls.

Monolithic domes still represent only a tiny portion of the new home market, but they have arguably the best wind performance of any structural design. Schools in the Midwest are using dome designs to safeguard kids against sudden hurricanes.

WHY WE WILL CHANGE

A lot of the initial spending on resilient building likely will be driven by homeowners looking to retrofit their one-of-a-kind residences in at-risk areas. They'll be looking for a stable, secure setting. They don't want to lose that million-dollar view, nor sacrifice comfort and stability. Some of those dreams will be harder to hold onto than others, however, and owners without deep pockets may find themselves retreating from shorelines, seismic areas and parched wildfire zones sooner rather than later. Here are some of the major reasons why:

1. The End of Subsidized Risk. As we move into a more frugal future, federally backed flood insurance will face increasing scrutiny. It just makes economic sense. At present, just under 6 million homes are now protected by federal flood insurance—a protection NOT offered by most homeowner policies. When this protection ends, all of the risk will transfer to the private sector.

2. Insurance Rollback. Current flood protection policies typically cost about \$600 a year for \$350,000 in residential coverage (\$250,000 for property, \$100,000 for possessions). But what if that subsidized insurance dries up? As extreme weather events increase, private insurers will face whopping bills, which they will pass on to homeowners in higher premiums. Some owners will be unable to handle those costs. And it's not just flood insurance that's likely to become inaccessible—homes in earthquake-prone areas are only slightly better off. A private policy for a \$300,000 single-family home in San Francisco could run about \$650 annually. But what happens if frequency of quakes increases dramatically? (Source: <http://www.earthquakeauthority.com>)

3. Coastal Surrender. About four years ago, the U.K. began abandoning certain seaside areas to nature, because it couldn't afford the billions necessary to keep flooding at bay (<http://tinyurl.com/05khcmm>). The U.S. is feeling similar strain, as civil engineers try to contain eroding beaches and protect homes near the water, especially

"By elevating the buildings on plinths made of mounds of compacted fill, it has been possible to connect HafenCity with the existing city area and develop it step by step from west to east, and from north to south. All new buildings stand on artificial bases eight meters above sea level—out of reach of the most extreme flooding. [...] It is the responsibility of the private developers of buildings to put these artificial compacted bases in place, so their number is growing as the number of buildings increases."



CREDIT: WWW.HTTP://INPLANNING.COM

FLOOD-RESISTANT MATERIAL LIST

Types of Building Materials	Uses of Building Materials		Classes of Building Materials				
	Floors	Walls/Ceilings	Acceptable		Unacceptable		
			5	4	3	2	1
Structural Materials (floor slabs, beams, subfloors, framing, and interior/exterior sheathing)							
Asbestos-cement board		■	■				
Brick							
Face or glazed		■	■				
Common (clay)		■		■			
Cast stone (in waterproof mortar)		■	■				
Cement board/fiber-cement board		■	■				
Cement/latex, formed-in-place	■			■			
Clay tile, structural glazed		■	■				
Concrete, precast or cast-in-place	■	■	■				
Concrete block		■	■				
Gypsum products							
Paper-faced gypsum board		■			■		
Non-paper-faced gypsum board		■		■			
Greenboard		■				■	
Keene's cement or plaster		■			■		
Plaster, otherwise, including acoustical		■				■	
Sheathing panels, exterior grade		■			■		
Water-resistant, fiber-reinforced gypsum exterior sheathing		■		■			
Hardboard (high-density fiberboard)							
Tempered, enamel or plastic coated		■				■	
All other types		■					■
Mineral fiberboard		■					■
Oriented-strand board (OSB)							
Exterior grade	■	■				■	
Edge swell-resistant OSB	■	■				■	
All other types	■	■					■
Particle board	■						■
Plywood							
Marine grade	■	■	■				
Preservative-treated, alkaline copper quaternary (ACQ) or copper azole (C-A)	■	■		■			

Tough Stuff. FEMA classifies building materials based on how well they can handle flooding, with Class 1 and 2 “unacceptable” for flood resistance. Class 5 materials, on the other hand, are “highly resistant to floodwater damage, including damage caused by moving water.” See the full chart at <http://tinyurl.com/qxfb89y>.

along the lower Atlantic coastline. Rising sea levels alone may be enough to stymie the best efforts of civil engineers to protect coastal housing. Add monster storms to that mix, and you can understand the sense of panic that some coastal residents are feeling. The city commission of South Miami, for example, just voted in favor of a resolution calling for dividing Florida into two states, one in the north, the other “South Florida,” in the low-lying southern half of the state.

Their concern—and it’s a legitimate one—is that sea level rise is imminent, and the politicians on the high ground in Tallahassee show none of the political will necessary to protect the millions of residents who will be “losing ground” this century.

THE BEST DEFENSE

The term “resilience” gets a bit muddled at times. It’s often used to refer to two different types of future challenges: extreme weather-related events (floods, wildfires, earthquakes, superstorms) and resource scarcity. The latter category include shortages of food, water or breathable air—basic human survival needs.

In previous publications we’ve talked about how to avoid scarcity and achieve food and water abundance over the next century. So our resilience focus is primarily on the weather-ready aspect—ways to survive and mitigate some of the worst-case weather scenarios in the shelter we build and strengthen over coming years.



FLOODS: A SURGE OF IDEAS

We begin the discussion of weather threats with flooding because it’s one of the most destructive—and hardest to build against. It’s generally less costly to retrofit a home or multifamily structure for hurricanes and moderate earthquakes than to withstand a major flood, or repeated flooding.

The Boston Society of Architects just hosted their annual conference, with emphasis on storm-ready, resilient housing. Boston’s city officials are keenly aware of risks related climate change, according to Crystal Aiken of The Boston Harbor Association. She notes that the city has seen four recent storm surges that “have come within hours of striking Boston at high tide.”

Brick Veneer Best Practices

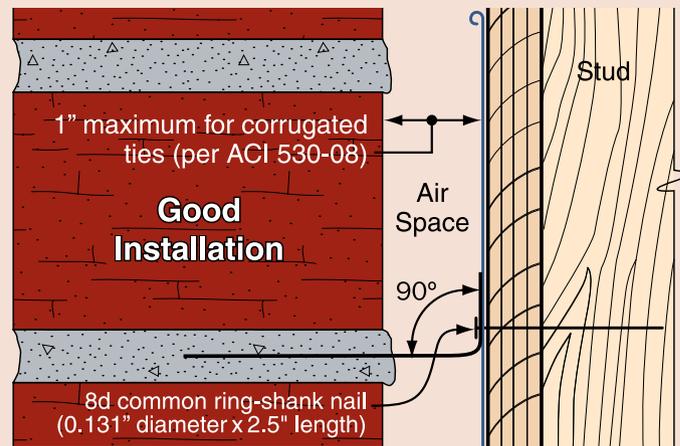
IF INSTALLED PROPERLY, brick veneer can handle hurricane-force winds. Too often, however, they are not attached as the code dictates. Failures can usually be traced back to the metal ties that hold the brick to the wood frame. They can fail if they are corroded (common along coastal areas) or misaligned. Here are some of FEMA's general and specific best practices recommendations for veneer brick, based on post-failure analysis:

Stud Spacing: For new construction, space studs 16" on center, so that ties can be anchored at this spacing.

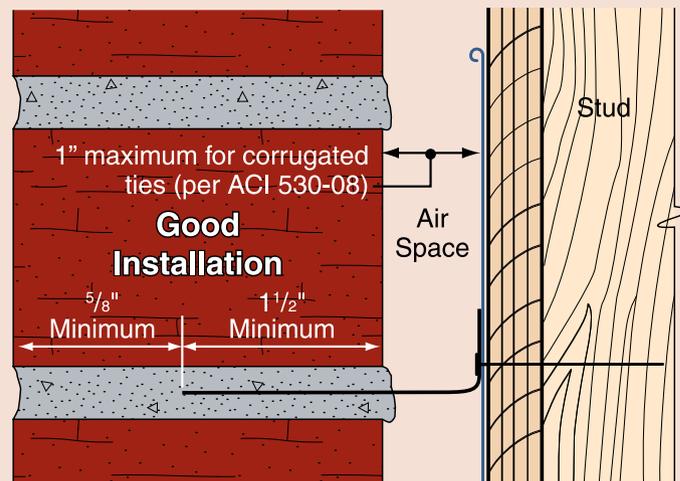
Tie Fasteners: Ring-shank nails are recommended in lieu of smooth-shank nails. A minimum embedment of 2" into framing is suggested.

Ties: For use with wood studs, two-piece adjustable ties are recommended. However, where corrugated steel ties are used, use 22-gauge minimum, 7/8" wide by 6" long, with a zinc coating. Stainless steel ties should be used in areas within 3,000 feet of the coast.

- Install ties as the brick is laid, so that the ties are properly aligned with the mortar joints.
- Install brick ties spaced per Table 1. Studs should be installed at 16" spacing. Veneer tie locations for 24" stud spacing are included for repairing damaged veneer on existing buildings with the wider stud spacing. In areas where the 2006 Editions of the IBC/IRC are adopted, install brick veneer ties spaced no more than 18" vertically to satisfy the requirements of ACI 530-05.
- Locate ties within 8" of door and window openings and within 12" of the top of veneer sections.
- Bend the ties at a 90-degree angle at the nail head in order to minimize tie flexing when the ties are loaded in tension or compression (**See Detail A**).
- Embed ties in joints so that mortar completely encapsulates the ties. Embed a minimum of 1 1/2" into the bed joint, with a minimum mortar cover of 5/8" to the outside face of the wall (**See Detail B**).



Detail A: Bend ties at nail heads.



Detail B: Tie embedment.

IMAGE: FEMA

She and her panel of experts described how other countries such as the Netherlands have adopted a "Live with Water" approach to rising tides. That approach, however, involves storage of huge amounts of excess water during certain months. They have waged an aggressive PR campaign to convince the public to "make room for water" in their communities, in the form of giant seasonal lakes and reservoirs.

Such an approach might work in parts of the U.S., but what about major coastal cities with little undeveloped land to spare? HafenCity, part of Hamburg, Germany, is preparing for storm surge flooding by raising multi-family structures on special "plinths." The technique is described by city planners.

If flood intensity (and depth) increases over the next century, planners will apply new tools. They'll be looking much more closely at materials and active, as opposed to passive, flood resistance.

Raising buildings above flood levels is not a new idea, of course. Even "old school" wooden pilings often outlast the structures they support. The city of Portland, Maine, for example, is debating what

to do with some partially submerged piers on the waterfront that were sunk into the mud about 90 years ago.

But what if sea level rise results in repeated flooding or lengthy submersion? Buildings will need to incorporate not only the usual flood-ready details, such as water inlets, pilings and structural bracing, but also materials (left) that can be cleaned instead of replaced.



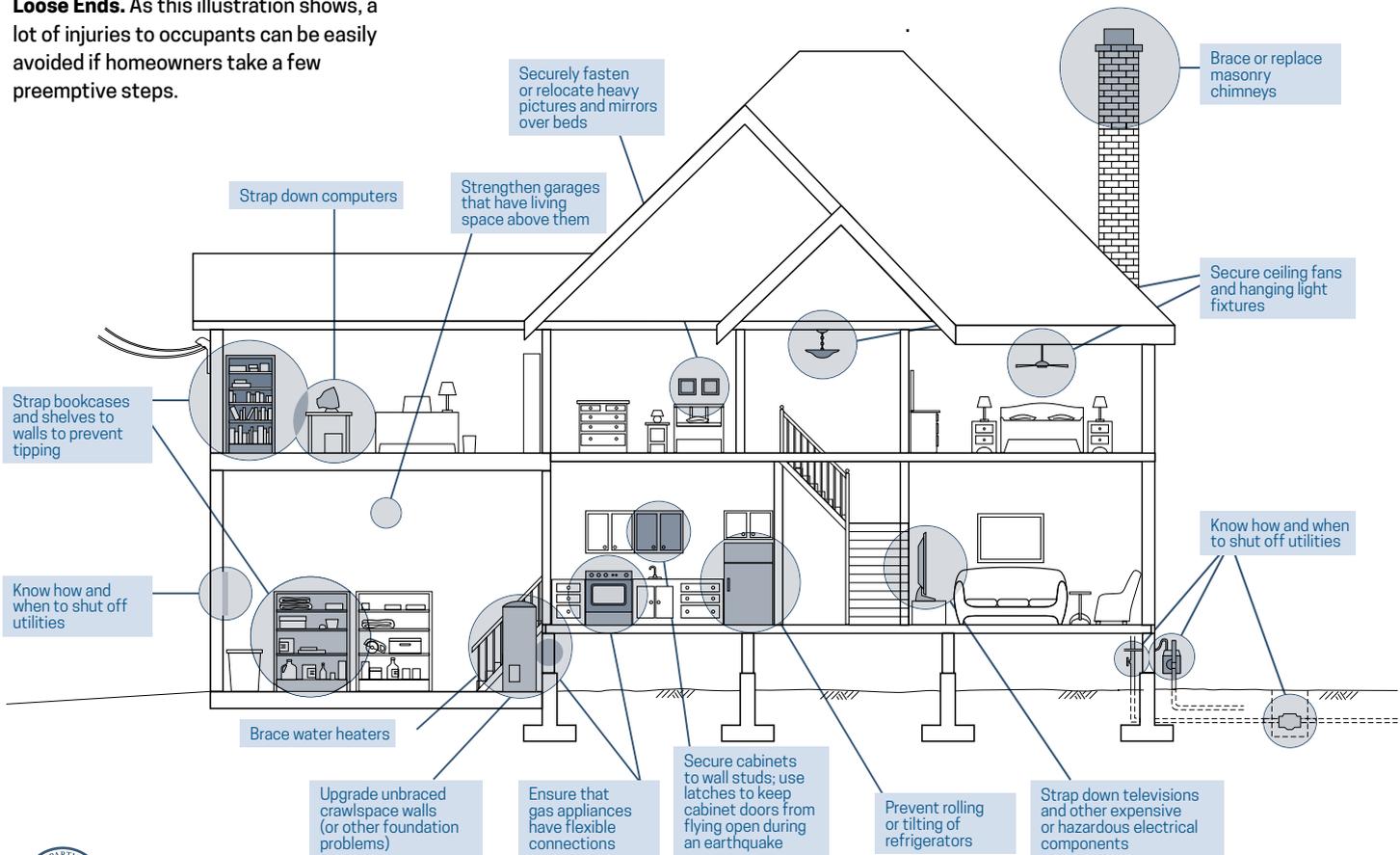
STORM WIND READINESS: THE DETAILS MATTER

Techniques and products for storm-ready construction have advanced over the last 40 years. If you have any doubt, visit the aftermath of a hurricane. The homes that suffer the most damage are usually the ones built prior to modern building codes. Modern U.S. homes, built properly to the code adopted by their local region, tend to perform extremely well in hurricanes and earthquakes.

That being said, however, all it takes is one chink in a home's armor

Quake Readiness: What Homeowners Can Do

Loose Ends. As this illustration shows, a lot of injuries to occupants can be easily avoided if homeowners take a few preemptive steps.



Siding Test. A burning brand applied to a test wall assembly at UC Davis set alight the composite wood siding (left side), but the fiber-cement-covered wall did not ignite.

to turn minor storm damage into a total property loss.

The powerful succession of storms and tornadoes in the last decade have led to a lot better understanding of how and why homes “fail” in storm winds.

A few years back, I visited the sites of both the La Plata, Maryland, tornado and Hurricane Katrina immediately following those storms, so I got a first-hand look at why things fall apart. In extreme winds, homes typically go to rack and ruin because of either wind uplift or pressure differentials as air enters the home.

Oddly enough, homes from the 1920s and '30s sometimes fare better than ones built in the 1950s. Those old homes were overbuilt, mortared to their foundations, and so on, while homes in the age of Levittown subdivisions were built light, with minimal connection to foundations and no added straps or tie-downs.

Lots of recent research offers clear advice on how the homes and multi-family properties of the future can weather severe winds. Here are seven rules to live by:

- 1. Remove or Reinforce Soffits.** Windblown rain entering soffits has

been a major cause of roof blow-offs. If you're not a fan of vent-free attics, look for soffits that are designed to keep out storm winds.

2. Lock Down Roofing. Flying clay roof tiles caused a lot of secondary damage in some of Florida's big hurricanes. Mortar attachment is not enough; they require metal fasteners to stay put. Use extra nails on asphalt shingles and replace any that are old and brittle. Once they lose their grip on the roof, you're inviting trouble.

3. Follow the Code. Don't fudge it on fasteners, tie-downs or other important details. Install impact glass or shutters as required.

4. Build Low. Single-story homes tend to suffer far less damage from wind events than two-story homes. They offer less surface area for wind pressure and a smaller target for projectiles.

5. Strengthen Wall Layers. Wind-flung projectiles have been found to penetrate vinyl siding that's placed directly over a thin-wall sheathing. They can also smash through certain types of garage doors. Adjust accordingly.

6. Reinforce Chimneys. In the La Plata tornado, almost every unreinforced chimney we looked at had broken off and/or collapsed. Brace and repair existing chimneys to make them safer for both wind and seismic pressures. Build new chimneys with reinforcing rebar.

7. Add Sheathing Grip. By using longer fasteners at closer intervals (six inches is good) to attach sheathing to rafters (8d versus standard 6d), you gain significant fastening strength.



SEISMIC SHAKEDOWN

Wood-framed homes tend to handle seismic activity quite well, according to FEMA, due to the fact that systems in wood-framed house tend to be interdependent, not monolithic. Failure of one doesn't automatically lead to failure of others. This might be considered an inherently redundant design feature of wood framing.

And redundancy (through connectivity) is key to any strategy for earthquake-resistant housing. Essentially, what's important is bracing. There's no single right way. The code recognizes multiple ways to achieve the recommended resistance to sliding, overturning or racking.

Fortunately, many of the same principles that apply to hurricane-resistant construction also work for seismic loads. Build (and retrofit) to code, and you've probably achieved most of what is presently possible (and affordable) with regard to earthquake-proofing a home or building. An excellent training series for builder on seismic retrofit is available at <http://tinyurl.com/kv3axy7>. It includes some important but often overlooked details such as how to brace a hot water heater properly so it doesn't become a loose cannon in the basement.

Masonry Construction. The same basic rules of thumb for seismic resistance apply to homes with above-grade masonry walls. The IRC requires an engineering plan for walls more than a story high, but whatever the height, walls, ceilings and foundations have to be connected diligently. Masonry walls are heavier, so they resist more force, but they're also more likely than wood to collapse sideways in the right conditions. A good "best practices" guide for builders is available at <http://tinyurl.com/q6tc8oh>.

Storm Wind Readiness: The Details Matter

Techniques and products for storm-ready construction have advanced over the last 40 years. If you have any doubt, visit the aftermath of a hurricane. The homes that suffer the most damage are usually the ones built prior to modern building codes. Modern U.S. homes, built properly to the code adopted by their local region, tend to perform extremely well in hurricanes and earthquakes.

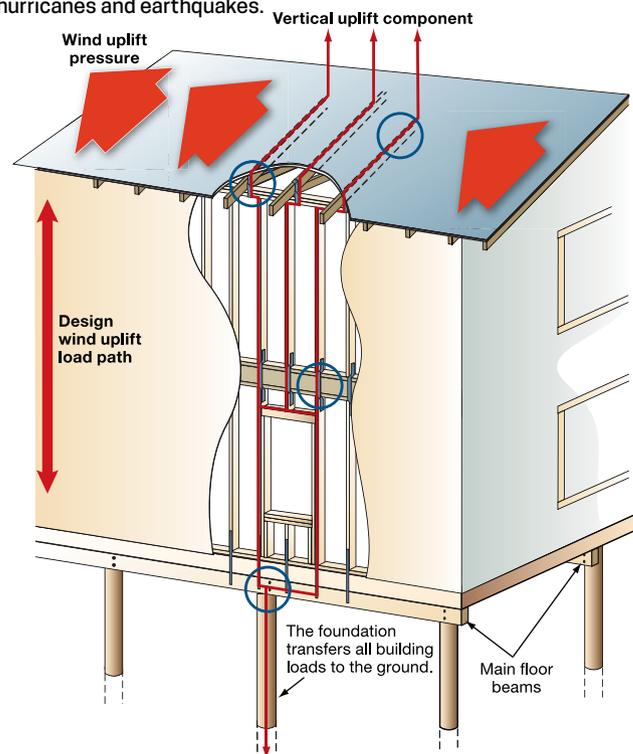


IMAGE: FEMA



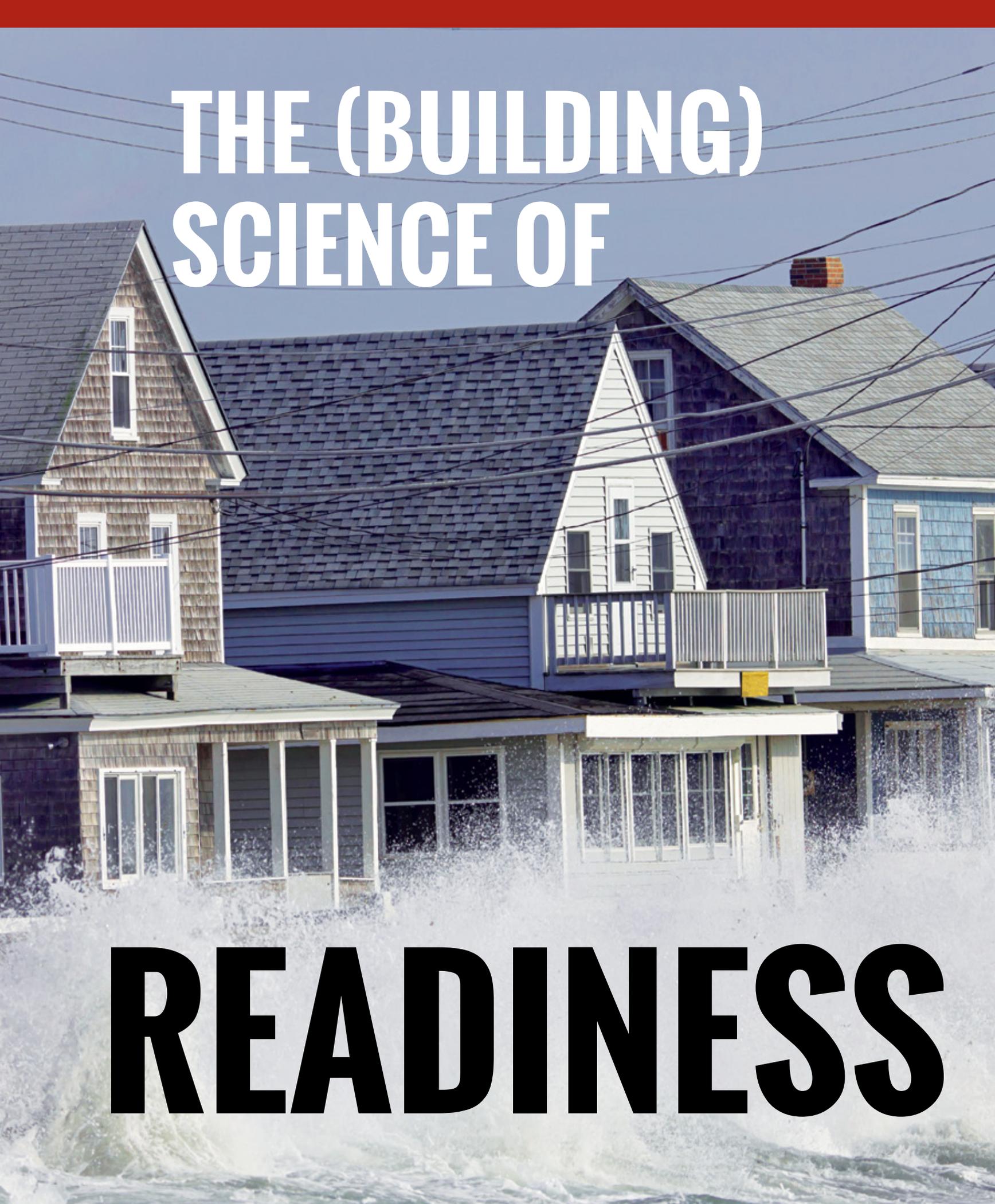
WILDFIRE PREPAREDNESS

Spurred on by record-setting droughts and migrating forest conditions, wildfire often dominates the nightly news. Home losses to fire are rising, in part because we keep pushing deeper into wilderness areas.

But another, sometimes overlooked aspect of fire protection is that water is getting scarce, particularly in the Southwest and West, so water management and accessibility is likely to become a major factor in building or retrofitting a home at risk for wildfire. A resilient, fire-ready home will have a ready supply of local water that can't be compromised.

Over the next century, as in-migration to urban living continues, we expect to see some of the threat to lives and property lessen. But weather extremes are expected to get worse, so the smart money for those who still plan to live "on the edge" will be to create homes and sites that can handle a blaze, and build with fireproof materials.

FEMA publishes the extensive *Home Builder's Guide to Construction in Wildfire Zones*, which is downloadable at <http://tinyurl.com/n35gqa7>. **GB**

A photograph of a row of houses with a large wave crashing against them. The houses are multi-story with gabled roofs and balconies. The wave is white and turbulent, reaching up to the first floor of the houses. The sky is clear and blue. The text 'THE (BUILDING) SCIENCE OF' is overlaid in white, bold, sans-serif font at the top. The text 'READINESS' is overlaid in black, bold, sans-serif font at the bottom.

**THE (BUILDING)
SCIENCE OF**

READINESS



We know how and where buildings fail in hurricanes. Now it's time to prepare for the worst.

BY MATT POWER, EDITOR-IN-CHIEF

AFTER HURRICANE KATRINA IN 2005, I visited New Orleans several times to explore and write about what survived—and what didn't. I also visited the site of the La Plata, Md., F4 tornado back in 2002, and wrote about what happened there—whole houses swept off their foundations, exploding roofs, chimney failures. Back then, those seemed like freak storms. Now, they feel like early warnings of what was to come.

We have entered a new age of weather extremes, at least part of it human induced. That's simply a scientific fact. This year's double whammy of Hurricane Harvey and Hurricane Irma was supercharged by higher-than-normal ocean temperatures. And those temperatures continue to rise each year. Given this situation, how are our Southern friends and families to cope? Will South Florida, Houston, Puerto Rico, the Virgin Islands and other points south simply become unlivable?

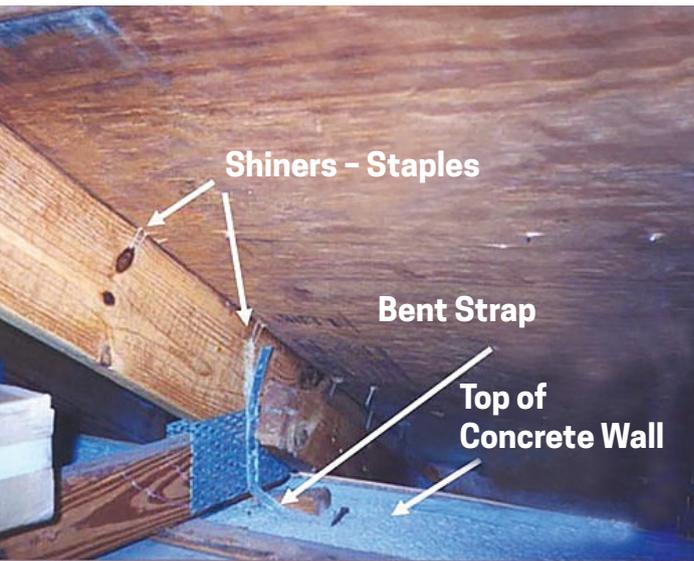
Let's hope not. But we need to take the threat seriously. Builders now have the knowledge AND the products to design and build more-resilient housing. Also, new coastal building codes have proven remarkably effective. After Hurricane Charley, FEMA found that *not one home* built to the 2001 Florida Building Code failed structurally.

FEMA also has done some first-rate research over the past decade. They have published several post-mortem reports on the aftermath of major hurricanes. Sifting through them, it becomes apparent that many aspects of modern homes and multi-family units could be further amended and fortified at a reasonable cost, particularly in the new construction phase.

A key takeaway is that both materials and process matter. If buildings are designed and assembled with extreme weather vulnerabilities in mind, they inevitably perform better when the crisis strikes.

For builders, architects and building designers, there's actually some good news buried in the post-mortem reports from FEMA: Many of the worst failures could have been prevented simply by strictly adhering to the building code.

They identified numerous "weak points" in the building process that were severely damaged by Charley. I would concur, based on personal observation of dozens of ruined homes. To keep this simple and digestible, I've pulled out nine of the most problematic building science flaws and offered solutions.



CREDIT: FLORIDA DIV. OF EMERGENCY MANAGEMENT

Weak link. This thin metal strap is not enough to hold a truss rafter to a masonry wall in a big storm.

1

Design wind loads used were too low, resulting in members and connections too weak for the winds encountered, and roof and framing damage.

THIS IS PRIMARILY A PROBLEM with older homes built before codes were improved, subject to the rigors of corrosion (see page 21) or poor workmanship, especially in homes where two structural systems are combined. A common failure point in high winds, for example, has been the weak linkage between concrete masonry walls and engineered truss roof systems. As Florida's Division of Emergency Management notes, "the vast majority" of older CMU homes simply had a 2 x 8 plate attached to the top of the block, often with only a few widely spaced anchors. Rafters were then toenailed to this face plate. For new and retrofits, this plate must be attached by embedding anchor bolts of a half-inch or larger diameter, spaced no more than 48 inches. The bolt must be installed within a couple of inches of the end of any plate. Also, washers and nuts must fit without gouging out the wood. I would recommend stainless steel anchors (see item No. 6).

2

Degradation of building elements and connections due to material deterioration, insect infestation or lack of proper preventive maintenance resulted in premature building and envelope system failure.

I WOULD CLASSIFY THIS AS THE NO. 1 ISSUE of concern in hurricane-threatened regions. The *Insurance Journal* notes that the age of a home has a direct correspondence to the level of damage inflicted by a hurricane. Homes in Florida built between 1994 and the 2001 code upgrade, for example suffered much more than newer homes. But homes built prior to 1994 fared even more poorly. Hurricane Andrew in 1992 destroyed 125,000 Florida homes.

An important consideration for the future is the intermixing of new and older homes. A 30-year-old property can literally blow to pieces in a storm, and all of its components, such as roof tiles, 2 x 4s and plywood, become airborne projectiles. And that's not even considering the force of a home carried off of its foundation by storm surge flooding. Some areas of Florida are designated as a



Age matters. Older building materials and systems perform much more poorly in high wind than new products built to better codes.

windborne debris region, where new homes requiring impact glass and other features.

The best defense is to build the home as we've suggested here, with corrosion-resistant materials, sufficient high-quality fasteners and straps, with the goal to make future homes much more able to maintain their hurricane resistance than their predecessors.



Frame failure. If fasteners are inadequate, sliding glass doors can be blown completely out of their jambs.

CREDIT: FEMA

3 Structural design that did not account for unprotected glazing, leading to structural failures due to increased internal pressures.

GLAZINGS IN LARGER WINDOWS have been known to blow completely out of their frames, even if the glazing is laminated or otherwise protected. This negates the advantages of impact glass or applied impact window films. However, the solution may be simple: Increase the number of fasteners holding the frame in place. It's too easy to cut corners and apply fewer fasteners than recommended by the manufacturer.

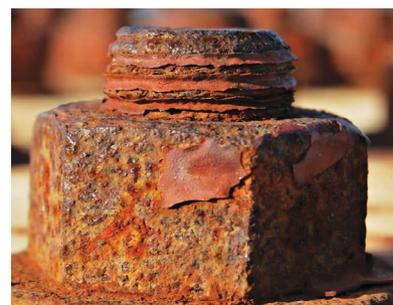
4 Corrosion of anchors or connectors that attach the building to the foundations or tie structural elements together resulted in structural collapse in some instances.

AGAIN, THIS IS a relatively easy issue to address. Assume the worst, when it comes to corrosion. Keep in mind that most concrete at the top of a concrete slab or foundation wall can only dry to about the same level of moisture as the ambient air. So in the Southeast, it will remain wetter than out west. Also, if the concrete was installed without vapor barriers underneath it, its moisture level will follow the ups and downs of the adjacent soil. Metal fasteners will be constantly exposed.

Fortunately, corrosion-resistant versions of foundation anchors are now widely available. For example, Simpson sells 25 stainless steel, half-inch concrete anchors (5-1/2-inch length) for about \$70. That's about twice the cost of galvanized versions, but your clients will probably understand why it's important. Be sure to have an engineer recommend the best size/thickness.



Made to last. Stainless concrete anchors like this one from Simpson Strong-Tie mitigate the problem of corrosion at a home's base.



Danger zone. Rusty anchor bolts of mild steel are almost inevitable in damp soils, and frequently fail under stress.

5

Corrosion of ties or fasteners used to attach siding to the wall structure led to loss of wall cladding and water intrusion.

THIS MAY BE one of the easiest resiliency improvements: upgrading to a better-quality sheathing fastener. The corrosion of fasteners has been heavily researched. We know that galvanized fasteners hold up better than mild steel, and the treated wood accelerates fastener corrosion.

But we have to be realistic: Most builders today use nailguns, not hammers, to attach sheathing and roof decking. Fortunately, you can find plenty of corrosion-resistant products, such as type 316 stainless steel fasteners. Here's one online source: <http://bit.ly/2iHpvJO>

Incidentally, the increasingly popular Huber *Zip System R-Sheathing* can be used in coastal zones where basic wind speed is 100 mph, but must be designed by a professional as a shear wall. I would also recommend selecting a siding system with good impact resistance, such as LP SmartSide engineered lumber,



Metal matters. Research (<http://bit.ly/2icPjti>) has shown that traditional mild steel fasteners can corrode quite rapidly in wood. This test include a one-year field exposure of nails in a) treated wood, b) untreated wood, c) galvanized in treated wood and d) galvanized in untreated wood.

CREDIT: ELSEVIER/CORROSION SCIENCE

solid-sawn wood or some brands of fiber cement. FEMA's analysis (<http://bit.ly/2icj9y9>) of post-Katrina damage found that homes with the siding through-nailed directly into wood studs performed best, and that nailing should not exceed a 24-inch gap.



Impact imperfect. Storm shutters can save windows where impact glass may fail, such as in coastal zones.

6

Unprotected glazing led to interior damage from wind and wind-driven rain.

PRESSURIZATION OF HOMES can literally blow the top off a structure. Impact glass tends to meet building code, but it's expensive and not always optimal. My recommendation would be to install impact glass even in high-risk areas such as Florida—whether code mandated or not—but use shutters in the coastal zone. Sure, the glass can slow depressurization. But multiple strikes by debris could compromise it, leading to failure. FEMA can offer examples of storm-shuttered houses that survived Category 4 destruction, located right next to unshuttered ones that did not.



CREDIT: NATIONAL GUARD

Preparing for the worst. Changing weather patterns are making scenes like this Hurricane Harvey-related one all-too-common nationwide. They're also a signal flare for builders, who need to prepare even more for natural disasters.

7 Improper elevation of habitable space and utilities relative to flood risks resulted in structural and contents damage.

ELEVATED HOMES TEND to survive flooding much better than those on low-lying foundations. Flood vents in elevated reinforced block or monolithic foundations can save a home, if flood levels adhere to “normal” levels. But let’s assume future storm surges WILL exceed current height estimates—and focus on the use of pilings.

After Hurricane Fran in 1996, FEMA conducted a study of what happened to stilt homes. The agency found that:

“A significant reduction in building losses was observed in similarly sized oceanfront buildings constructed after the North Carolina Building Code was amended in 1986 to require a minimum embedment to 5 feet National Geodetic Vertical Datum (NGVD), or 16 feet below the original ground elevation, whichever is shallower, for pilings near the ocean.”

Bottom line: The depth is key. It should be noted, however, that pilings do not guarantee an unscathed structure after a storm:

“A study of Topsail Island found that 98 percent of post-1986 oceanfront houses (200 of 205) remained after the hurricane. Ninety-two percent of the total displayed no significant damage to the integrity of the piling foundation. However, 5 percent were found to have leaning.”

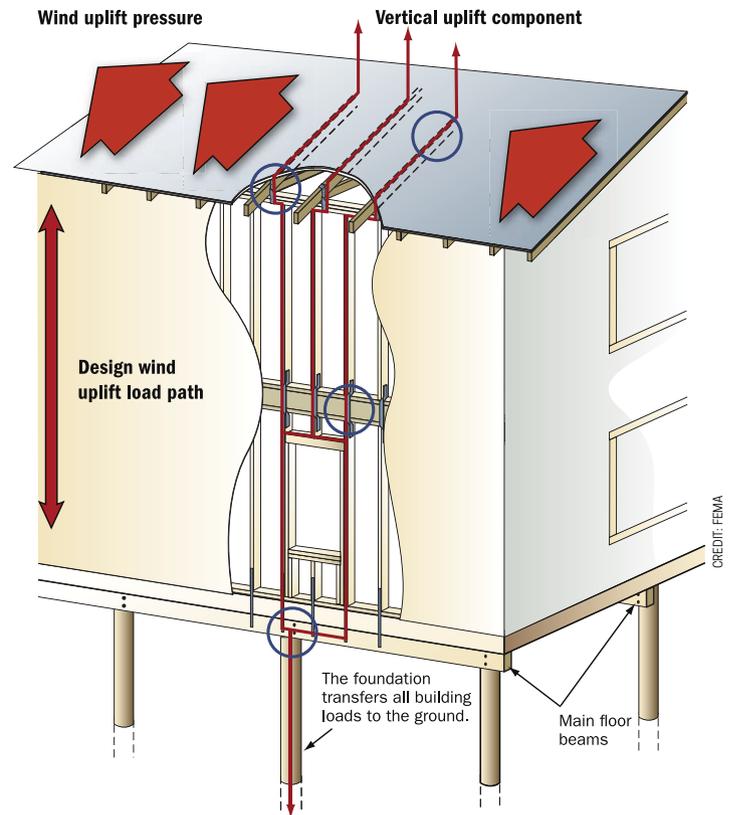
FEMA tested the leaning buildings to find out what happened. They discovered that among the leaning buildings, “none of the leaning pilings tested met the required piling embedment standard. Many were much shorter.”

In other words, the contractors failed. Out of this research, the suggestion was made that pilings be embedded to a minimum depth of 10 feet NGVD, without exception.

8

Small or missing strapping to anchor the roof structure to the walls led to roof framing damage.

A GAIN, THIS PROBLEM applies primarily to older homes. But it's also an important reminder to contractors to check the workmanship of their framing crews. There's no room for skipping rafter straps to save time. Strap size and types should be evaluated with each new building design. Simpson Strong-Tie makes about 20 different types of straps, each designed for a certain uplift. Don't guess. Download the company's *High-Wind-Resistant Construction Application Guide* (<http://bit.ly/1r4DKa0>), and make sure the straps you specify are right for worst-case wind uplift.



Tied down. An integrated, consistent system of fasteners and tie-downs is arguably the best defense to keep the roof on a home in hurricane-force winds.



(Not quite) rock solid.

Hurricanes can be just as dangerous as earthquakes if a masonry-supported house lacks proper reinforcement from a product such as rebar.

9

Unreinforced masonry walls lacked a continuous load path, resulting in wall damage and failure.

IT'S WELL KNOWN that unreinforced masonry can be extremely dangerous in an earthquake. But recent experience shows it also can't be trusted in hurricane winds, not to mention flood surges. The simplest takeaway for builders is: *Don't build masonry homes without rebar and other reinforcement, under ANY circumstances.* I would apply this rule of thumb even to homes

that do not specifically lie in high-wind zones. Any home in Florida, frankly, should be built reinforced. Retrofitting existing buildings with reinforcement is also possible, but obviously quite costly and difficult.

And simply reinforcing the wall itself is not enough to head off cataclysmic damage from a storm. Other systems—windows, shutters, top plates—must be considered as well.

AREAS OF CONCERN

Here are a few other parts of existing homes that have been found to be especially vulnerable during hurricanes:



Vanishing soffits.

Unless they are special, hurricane-resistant types, they are often blown away, allowing water to enter buildings.



Flying vents.

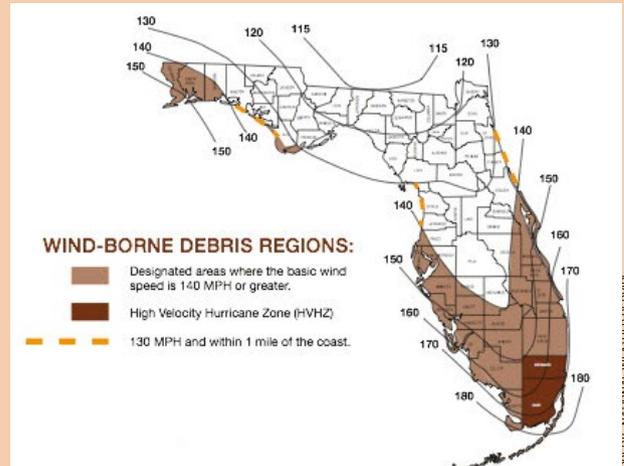
Rooftop-mounted equipment can be blown off roofs or severely damaged.



CREDIT: CLOPAY

Crumpled garage doors.

Unreinforced doors can be penetrated and blown out or simply blown in. Either can cause significant structural damage to the garages.



CREDIT: NATIONAL WEATHER SERVICE

Airborne carpports.

These, along with other accessory structures such as pool houses or screened lanais attached to manufactured homes are frequently blown off, creating additional debris.

LEARN MORE

The Metal Roofing Alliance offers information on specifying and installing metal roofs, an essential component in wildfire resistance. Visit their site to compare styles, find a roofing contractor, or ask questions of an expert: www.metalroofing.com

Risk-Reducing Metal Roofs

The roof is literally the first line of defense in a home's envelope. Faced with fire or wind, it often makes the difference between a total loss and barely a scratch.



BY GREEN BUILDER STAFF

FIRE-RESISTANT HOMES can be built for slightly less than comparable, typical construction, according to recent research Headwaters Economics and the Insurance Institute for Business & Home Safety. And a key component of that construction is a metal roof.

The researchers used a 2,500-sq. ft. Montana home as their prototype for the research. They compared two different approaches to building the same home, one using conventional materials and

systems, the other applying standards developed by the ICC—the International Wildland-Urban Interface Code.

Critical to that Code are the use of fire-resistant roofing such as standing seam metal, along with fire-resistant vents, gutters and doors and windows. Taken together, these fire upgrades added about \$11,000 to the cost of the home.

However, by switching from cedar plank siding to fiber cement siding, the researchers were able to balance the cost with a conventional home, and *make up all of that additional cost in savings.*



Built Tough. Metal roofs on five Habitat homes are clearly visible in this post Michael aerial shot from Florida.

FIVE THAT SURVIVED

The Washington Post reported on five Habitat homes that survived the wrath of Michael last fall. One of the residents, Christina Harding, described how she felt when returning to her home after the storm.

“Harding, an office manager for a loan company, had worked alongside the builders, investing her own sweat equity to construct the house 1.5 miles from the bay. It was topped by a metal roof, but she had no idea how the house would fare in a storm.

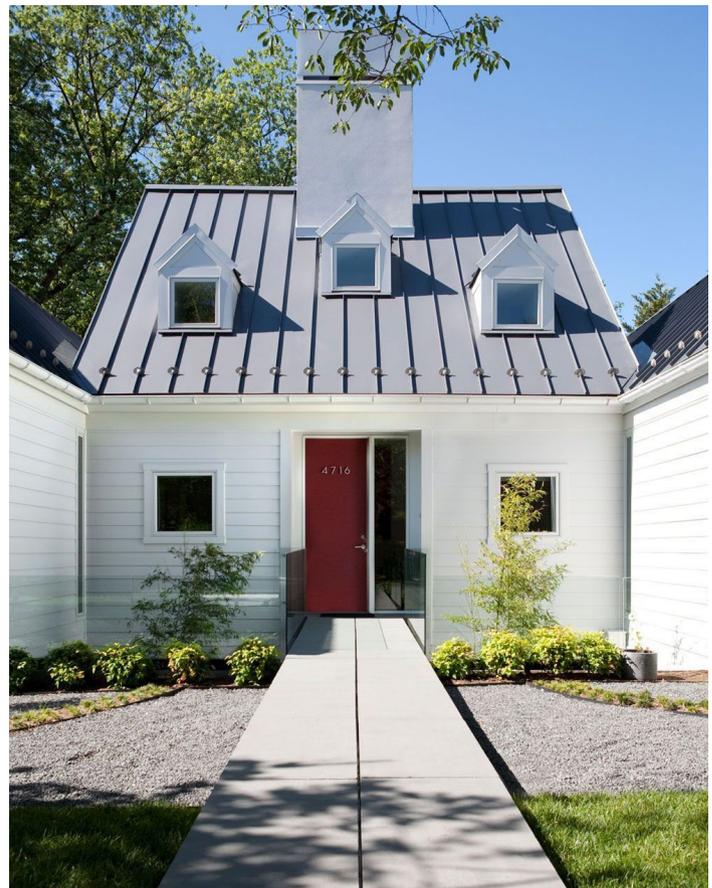
“When I saw those five metal roofs I knew the houses were good and you guys were good,” Harding said her daughter told her. In all, the five Habitat houses lost some siding, an AC unit and one window.”

According to a spokesperson for the Federal Alliance for Safe Homes, the reason these homes survived came down to small but important details: correct nails (not staples), straps and of course, metal roofing.

HARD TO BEAT

Metal roofs vary in thickness, fastening systems and coatings. Roofing experts recommend selecting thicker products for coastal zones especially, but the right product choice will be clearly reflected in its wind and fire ratings.

The other advantages to metal roofing products, of course, are lifespan and recyclability. The product is nearly 100 percent recyclable, and can easily last 50 years, many times that of most modified asphalt products on the market. Perhaps more importantly, in terms of storm resilience, metal roofs do not become brittle or significantly weaken as they age. Research has shown that asphalt based products just a few years age do not perform well in hurricane winds. **GB**





Just Right. A hip roof with a pitch that is neither too shallow nor too steep tends to survive hurricanes best.

Roof Shape, Pitch and Fasteners Matter

For high winds, hips are best, with a 7/12 pitch.

OUR FRIENDS AT ROOF COST ESTIMATOR note that not every aspect of resilient roof design is addressed by Codes. They offer the following design tips to enhance roof survivability. These apply to all roofs, including metal:

Roof shape: There are do's and don'ts. Do not use overhangs of more than 20 inches. Eliminating them altogether is the best practice. Gables, while popular for looks and lower building costs, are susceptible to winds hitting the flat, horizontal side of a home.

A better design is to eliminate gables in favor of a hip roof all around the home, so each side has a slope.

Roof pitch: Civil and structural engineer Rima Taher, PhD, recommends a 30-degree slope as the right pitch to aerodynamically handle high wind. That's a 7/12 pitch – the roof gets 7 inches higher for every 12 inches of run toward the peak.

Steeper slopes increase the “sail effect” that makes them susceptible to wind. Lower slopes don't handle wind-driven rain as well.

The 30-degree, 7/12 roof recommendation is backed up by testing, according to the publication *Science Daily*.

Fasteners: Staples should never be used. Nails and hurricane straps/clips that attach to the wall studs and to the rafters are highly recommended anywhere hurricane or straight-line winds are possible. Hurricane roof bracing and strapping for wind mitigation in Florida Nails and straps are required by the Florida Building Code. Staples are prohibited in Florida and Texas.

Notched frieze board: A frieze board is a board that bridges the gap between roof and wall and is attached to both. Experts recommend a frieze board notched for the rafters for a tighter, more secure fit. The purpose of the board is to keep wind from getting into the gap between wall and roof, potentially lifting the roof structure. **GB**

Reprinted with permission from: *Roofcostestimator.com*. To consult a metal roofing expert or find a roofing contractor, visit the *Metal Roofing Alliance*: www.metalroofing.com

Armchair Firefighting

Proactive owners can save homes from wildfire. But there needs to be a safer way.

A HOME'S RISK is more than the sum of its parts. The level of proaction taken by owners can make or break good material choices. For example, during the devastating Camp Fire in the Sierra Nevada foothills last November, one couple “saved” several home, including their own, with the following approach, according to the *Washington Post*:

“The Moores started their generator and pumped water from their well to sprinklers on the roof of their California home. After retreating for several hours, the couple returned to spend the entire night dousing vegetation and stomping out spot fires on their own and neighboring properties, preventing them from igniting and further fueling the blaze. By the time the fire department showed up the next day, Jeff Moore said, “everything was out.” Not only was their home saved, but so were adjacent buildings in a neighborhood where many burned.”



CREDIT: FOREST SERVICE STAFF

Smoldering Risk. Rather than personally stomping out embers, wifi devices could manage the extinguishing process from afar.

The subtext in the story above is that even with careful preparation of the landscape and home exterior, the home might have been lost without responsive human interaction.

But hanging around during a wildfire is not for the timid, the elderly, or frankly, the wise. Fires are unpredictable, and can explode into “firenado” and other deadly conditions when wind conditions change.

Certain applications for smart technology, applied to wildfire suppression, allow for proactive response without personal risk.

We have heard anecdotally of owners who have combined wifi heat sensors with smart sprinkler systems such as Rachio, to create an automatic perimeter defense of sprinklers for their homes. Even more control could be afforded with a combination of wifi cameras, smart switching, and an off-grid capable solar backup (to keep the gadgets running). One challenge is the need for a self-contained cellular data connection. Our suggestion is to add a low-cost smartphone to a Google Fi plan, and create a \$10-per-month hotspot that will keep working even if the power grid goes down. **GB**

An aerial photograph of a coastal residential area. In the foreground, a house is under construction, showing its wooden roof trusses and blue shingles. A white pickup truck is parked on a paved road that curves through the scene. The road is lined with numerous palm trees. In the background, a large, modern white building with a flat roof stands near the ocean. The sky is clear and blue.

Structure is

Whether you're a homeowner or a builder, you face the same three challenges. You want to create a structure with lasting "wow" factor—but it also has to be tough enough to withstand today's realities of increasingly extreme weather.



Invulnerable? As this photo shows, hurricane force winds damaged every property in the area except the one built with concrete-filled ICF blocks.

Fundamental

CREDIT: PHOTO: AMVIC

On top of that, a modern building—whether it’s a home, school or community center—should require little energy to operate—with minimal maintenance. Fortunately, thanks to new building codes and products, all of these goals are now within reach.



Texas tough. This home, built with Amvic's ICF blocks, survived powerful winds and storm surge, supported by details such as Fiberglass doors and SMART VENT engineered flood vents, which helped clear water when flooding was finished, along with weep holes in stone masonry.

CREDIT: AMVIC

The ICF Advantage

Properly installed, insulated concrete forms (ICFs) demonstrate superior performance when exposed to flood or high winds.

EDITED BY GREEN BUILDER STAFF

IN THE AFTERMATH of a major hurricane or tornado, you'll commonly see images of a neighborhood in total disarray—blown-off roofs, stripped siding, exposed interiors and collapsed foundations. Then you spot a sole residential structure that incurred only minimal damage to its roof, windows, doors and landscaping. That contrast in resiliency often stems from early decisions made in the critical design/build phase.

One of the smartest decisions a home owner can make is to use Insulated Concrete Forms (ICF) as an innovative building envelope alternative to traditional light-wood frame or light-gauge steel. Consider some of the structures that survived the wrath of Hurricane

Katrina. Several ICF buildings not only withstood the tremendous wind gusts, but also the force of the storm surge.

Most builders or home owners, however, do not initially choose ICF systems for disaster resiliency. They use ICFs because of their well-known energy performance. After experiencing extreme weather events with an ICF home, however, their perspective often changes.

Here's what Randy Robbins, a survivor of the Attica, Kansas, tornado of 2004 said about his family's decision to go with ICFs: "Safety was a secondary consideration when we chose to build with ICF. For us, the greatest benefit was its energy efficiency. Yet we're alive today because of these walls."

Best Practices for a Storm-Ready ICF Structure

1. Hire a qualified installer. The installer on your project should be trained and certified in the particular ICF system specified. Some product manufacturers offer site visits at several points throughout the install.

2. Stick to ICFs for exterior envelope. For best storm resilience, avoid transitions to other framing systems such as wood framing on the building exterior. ICF walls perform best when designed and reinforced consistently.

3. Avoid inefficient wall sizes/shapes. Walls with bump-ins or bump-outs result in shorter walls (i.e., less useful living spaces) or shifting of windows. Whenever possible, straighten bump-ins and bump-outs. This will not only add construction efficiency and living space, but reduce the need for more costly corner/specialty blocks.

4. Be aware of the right attachments. When securing items (such as floor ledger boards, brick ties, bracing, etc.) to the ICF, use the method recommended by the ICF supplier.

5. Work efficiently with wall lengths. A strategy for combining multiple ICF blocks and working with cuts/seams will have a major impact on project speed and quality. Select even-inch increments for wall lengths whenever possible, because the connection pattern repeats every inch, thereby making stacking far easier. Work with the block's web spacing increments to ensure that all embedded attachment points are vertically aligned, allowing for smooth application of finishes. Do not take pains to achieve zero cuts in an ICF block—use of a seam (offset joint or standing seam) often eliminates layout problems, speeds up the process, and ensures that the majority of plastic webs are aligned.

6. Brace ICF forms from the inside. Proper bracing is the key to ensuring that walls are straight and plumb, which is critical to structural integrity and also to streamline subcontract finishing work. The higher the wall, the harder it is to reach the exterior with bracing, so brace from the inside. Rather than creating your own bracing system, go with the ICF manufacturer-recommended (OSHA approved) scaffolding/ bracing system that works best with their products.

7. Strategically place a vertical or stack joint. In applications where a vertical or stack joint is required, place the joint over a door or window opening to minimize the required length of the joint and associated labor. Be sure to properly brace and strap the joint at this critical juncture. Importantly, Maintain proper horizontal dimensions above and below openings.



Smaller Vibes. Using a narrow concrete vibrator ensures good wall fill, and reduces risk of form blowouts.

8. Don't compromise the thermal envelope. Maintain continuity of insulation, and avoid cantilevered concrete floors or exposed slab edges to prevent thermal breaks. Insulate broken or damaged areas in the foam panels. Proper detailing of door and window jambs can help maintain the thermal performance of the building envelope.

9. Avoid heavy vibrating during concrete pour. ICF walls should be vibrated to remove voids in the concrete. Consider using a small-diameter mechanical vibrator, to allow concrete to spread evenly and maintain integrity.

10. Make sure the concrete completely fills the form. To avoid holes and gaps in the concrete pour, be familiar with the structural requirements and the design of the webs. It is highly recommended for the structural engineer to know the specific ICF block, thus optimizing the placement of rebar in webs.

11. Choose the proper mechanical system. Because ICF is so energy-efficient, mechanical engineers need to factor this in as they calculate HVAC requirements. In fact, if an HVAC unit is oversized, it can actually create humidity/moisture issues in the interior. Also, plan for “after the storm” drying scenarios. What will work best, given the building's size and layout? **GB**

ANATOMY OF AN ICF SYSTEM

An insulated concrete form (ICF) system offers both the strength and durability of reinforced concrete, and the energy efficiency of expanded polystyrene (EPS) rigid insulation. It's a synergistic partnership, producing a combined effect that is greater than the sum of the separate benefits of each building product.



CREDIT: ANVIC

Special curves. Some ICF systems include a radius corner that allows for continuous concrete flow.

The ICF system serves as a permanent interior and exterior substrate for walls, floors and roofs. To construct an ICF wall, two layers of rigid insulation are separated with recycled polypropylene webs to create an ICF block. These hollow blocks are interlocked (in dry-stack fashion) and the webs locate and hold reinforcing steel (rebar) before the cavities are filled with concrete. The end-result is a reinforced concrete wall in the center, encased in barrier insulation on each side. The materials work as a team, with the concrete and rebar providing an

ideal load-bearing wall that carries vertical loads and resists lateral loads from wind and seismic motions. The entire ICF wall assembly, with all the layers combined, creates a secure, air-tight envelope with good acoustic properties. In the case of ICF roof and floor systems, the EPS functions as a one-sided insulating form on the bottom surface. EPS panels up to 30 feet in span are placed between concrete walls, then fitted with reinforced steel and filled with concrete. Since ICF walls are concrete bearing walls, any traditional flooring or roofing system can be used with them.

REINFORCING ICF RESILIENCE

“Resilience” is an integrative strategy that promotes sustainable building decisions that encompass disaster-mitigation, durability and environmental protection. While energy efficiency has been a huge motivator for selecting ICF materials to date, a building’s disaster mitigation capacities and durability are just as important



CREDIT: ANVIC

All is not lost. Thanks to ICF construction, this Texas home was cleaned and recovered without serious structural damage.

as any LEED-certified standard in achieving a sustainable design.

In fact, all three priorities are so interlinked that a decision made in one sustainability arena positively impacts the others.

For instance, making the decision to select a robust system like insulated concrete forms heightens a building’s durability and longevity in the face of normal wear and tear. If disaster does strike, these durable qualities minimize structural damage, which in turn conserves energy and reduces the need for additional natural resources during the recovery phase.

Adopting a resilient building strategy is not just the responsible thing to do, it’s a sustainable investment which will pay for itself many times over during the short-term build and long-term occupancy phases of a project.



Reinforcements. Careful application of rebar also ranks high on the list of important details for best ICF storm performance.

ICF’S DISASTER MITIGATION ADVANTAGES

Along with energy efficiency, ICF structures bestow the following special strengths to a home:

FIRE RESISTANCE: Because concrete won’t burn like wood, and does not soften or bend like steel, it offers excellent fire resistance. This protects a home’s possessions and structural integrity far longer than wood framing. The EPS insulation of an ICF is also flame-retardant.

WIND LOADS: Thanks to its rugged concrete construction, an ICF building can withstand tornado or hurricane winds reaching 200-300 mph, compared to the 120 mph capacity of most wood frames. In fact, FEMA has recommended that storm shelters be constructed using insulated concrete forms. An important component of wind resistance is the presence of a continuous load path from roof to foundation, as a means for transmitting wind uplift and shear loads safely to the ground. ICF construction addresses this requirement in two ways: First, its wall-to-foundation connection is automatically strengthened by vertical reinforcing steel bars. Second, ICF manufacturers provide specialized hardware for roof and floor connection to walls. Roof trusses can be attached via metal straps to plates embedded in the concrete, or anchored directly to the poured concrete, and ledger systems can be used to reinforce the wall-to-floor connection.

FLOOD PROTECTION: If concrete is submerged in floodwaters, it typically suffers little or no damage. Flood-soaked wood, on the other hand, is subject to rotting and mold. ICFs offer no place for mold to grow. The concrete is inorganic, and the EPS forms of ICFs do not absorb water. The only post-flood cleanup needed for an ICF

wall might be a good pressure washing.

The Roman Pantheon, the medieval cathedrals of Europe, the Hoover Dam—these enduring structures continue to thrive because of their concrete construction. Long after new concrete hardens, it continues to cure, getting progressively stronger as time goes on.

What makes ICF construction even more durable is the method in which the walls and floors are tied together with overlapping reinforced steel, resulting in a monolithic structure that will stand the test of time. The bottom-line benefit for owners: far fewer maintenance headaches and substantial savings over the life span of a building.

ICF DIVIDENDS AFTER A FLOOD

A little known fact about hurricanes and natural disasters is that the worst damage to buildings often takes place after the fact.

That's because as winds and flood waters subside, the power grid may take weeks or months to get working again. During that time, the inside of the structure becomes an ideal environment for mold to form, with extremely high humidity, heat and plenty of bacteria and organic substances.

With ICF walls, however, even a small dehumidification system can reduce moisture levels enough to save the building. ICF homes typically require 32 percent less energy to cool than comparable wood-framed structures, which in normal times means a high return on investment, and in disaster scenarios, can mean the difference between a total loss, and a minor setback.

A small generator, or a solar array with a DC-powered mini split system can take advantage of an ICF building's small energy footprint to reduce humidity and heat levels to a point unfriendly to mold growth.

While others in the neighborhood are wrangling with insurance companies and spending many sleepless nights, the ICF owner can rest easy, knowing that his or her house will soon feel like a home again. **GB**

Source: Original content courtesy of Amvic educational materials, used with permission and edited by Green Builder® Staff

SLAM TEST: ICF walls can take a beating

DIRECT POUNDING OF HIGH WINDS on a building is not nearly as damaging as flying debris driven by those winds. A recent simulation conducted by Texas Tech University's Wind Engineering Research Center compared the impact resistance of residential concrete wall construction to conventional framed walls. A compressed air cannon was used to propel a 15 lb. 2x4 wood stud "missile" traveling at speeds up to 100 mph against four wall types: wood frame, steel frame, concrete and insulated concrete form.

The speed used was calculated as the equivalent of the weight and speed of debris generated during a 250 mph tornado—well above even the most extreme tornado or hurricane wind velocities. All of the concrete test walls were poured at 3000 PSI compressive strength, with aggregate size ¾", 6" slump.

As you might expect, the debris passed completely through the light-wood and light steel framed walls. The concrete walls fared significantly better, with damage only to any exterior finishes, and in some cases, slight dents in the insulation foam. But, most importantly, no cracks in the concrete were observed.

The report summarizes its findings as, "The strength and durability of concrete walls offer unmatched resistance to the devastation of major storms."

More Information: The following publication and video are available from the Portland Cement Association. To order call PCA Publications at 1.800.868.6733. Ask about VC511 "Concrete Homes- Built In Safety". Source: Portland Cement Association

CONCRETE WALL TEST RESULTS

WALL TYPE:	TEST WALL DESCRIPTION:	SPEED OF DEBRIS:	RESULTS:
Concrete:	<ul style="list-style-type: none"> 6" thick reinforced concrete wall, #4 vert. reinforcing bars, 12" o.c. No finishes 	109.0 mph	No cracking, front face scabbing or back face spalling of concrete observed.
	<ul style="list-style-type: none"> 6" thick reinforced concrete wall, #4 vert. reinforcing bars, 24" o.c. No finishes 	102.4 mph	No cracking, front face scabbing or back face spalling of concrete observed.
ICF:	<ul style="list-style-type: none"> Block ICF foam forms 6" thick flat concrete wall #4 vert. reinforcing bars, 12" o.c. Vinyl siding (Tested a second time with similar results.) 	103.8 mph	Debris penetrated vinyl siding and foam form. No cracking, front face scabbing or back face spalling of concrete wall observed.
	<ul style="list-style-type: none"> Block ICF foam forms, 6" thick flat concrete wall, #4 vert. reinforcing bars, 24" o.c. 3" brick veneer with ties spaced 1'-0" ea.way. 	99.0 mph	Debris penetrated and cracked brick veneer. Foam form dented. No cracking, front face scabbing or back face spalling of concrete wall observed.
	<ul style="list-style-type: none"> Panel ICF foam forms, 4" thick flat concrete wall, #4 vert. reinforcing bars, 24" o.c. Vinyl siding 	96.7 mph	Debris penetrated vinyl siding and foam form. No cracking, front face scabbing or back face spalling of concrete wall observed.
	<ul style="list-style-type: none"> Block ICF foam forms, Variable thickness "waffle" concrete wall, 6" max. thickness, and 2" min. thickness. #4 vert. reinforcing bars in each 6" vertical core at 24" o.c. Synthetic stucco finish. (Tested a second time with similar results.) 	100.2 mph	Debris penetrated synthetic stucco finish, and foam form. Impact of wall at 2" thick section. No cracking, front face scabbing or back face spalling of concrete wall observed.

SOURCE: WIND ENGINEERING RESEARCH CENTER, TEXAS TECH UNIVERSITY

Storm Front

This high-performance home in the Florida Keys, built with structural insulated panels, weathered Hurricane Irma virtually unscathed.

BY GREEN BUILDER STAFF

WE HAD A LITTLE TROUBLE GETTING up-to-date photos for this 1,350-sq.-ft home, completed in June 2017. That's because shortly after completion, Ramrod Key, where it stands on Mariposa Road, was smashed by Category 4 winds from Hurricane Irma—almost at the storm's center.

Local homes took a beating. In fact, three months later, the *Miami Herald* reported that many residents of nearby Big Pine were still living in tents, their homes wiped out.

Not so this SIP house. In fact, according to Innova Eco Building System, it took no damage from the monster storm. The only challenge has been reaching it by vehicle. The roads and infrastructure, even at this writing in early 2018, have been blocked with debris.

The home's extreme resilience is one reason it just won a Building Excellence award from SIPA.

Jerry Gilman of Innova, the panel maker, notes that the SIPs were chosen because of the region's high risk for hurricanes, along with energy efficiency and good moisture resistance. Panels on the walls were 2¾" thick High Impact magnesium cement SIPs. On the roof were similar 8½" MgO and plywood SIPs. The home cost about \$300,000 to build, not including land, but saved considerably on labor costs over comparable construction with concrete blocks.

"Although the surrounding homes and neighborhood were severely damaged," Gilman says, "this home received no damage from the storm. Hurricane Irma damages incurred at Ground Zero for this home was \$0." **GB**



PROJECT TEAM

Builder:

Pedro Falcon Contractors
and Christian Brisson (Owner)
Big Pine Key, Florida Keys

Designer:

Innova Eco Building System
Miami, Florida

Standing tall. This home on Ramrod Key in the Florida Keys withstood extreme winds virtually unscathed, while older and less resilient homes around it were thrashed or washed away.



“Although the surrounding homes and neighborhood were severely damaged, this home received no damage from the storm. Hurricane Irma damages incurred at Ground Zero for this home was \$0.”
– Jerry Gilman, Innova

PRODUCT SHOWCASE

New products and systems that address flooding, wildfire and wind provide ready-made solutions to design and engineering challenges.

BY GREEN BUILDER STAFF



CREDIT: ATAS METAL ROOFING

Atas Metal Roofing

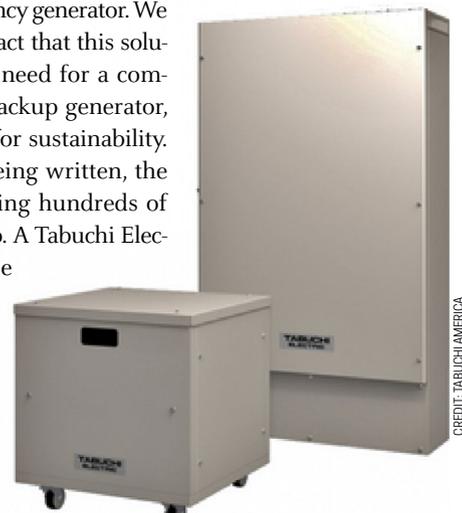
ATAS OFFERS A wide range of residential roofing materials that are storm- and wildfire-ready. The award-winning project shown featured “Dutch” seams that overlap and interlock, making them especially wind resistant. They offer aluminum, metallic coated steel, aluminum-zinc alloy coated steel with acrylic coating and copper products. Specific detailing to maximize wind resistance will vary somewhat but the same general rules of thumb apply.

Demand for metal roofing is expected to increase dramatically as extreme weather events intensify in coming years. In fact, the Metal Roofing Alliance this year sponsored a competition called *Top Survivor Home of the Year*, honoring homes with extreme resilience (and metal roofs) that survived major natural disasters. MRA can help you find a qualified installer (www.metalroofing.com/professionals/contractors)

Learn more about Atas roofing at www.atas.com/project-of-the-year

Tabuchi Electric Solar + Storage

UTILITY RULES IN MANY STATES dictate that solar inverters automatically shut down and stop backfeeding power to the grid. This has been a source of frustration to many solar owners system: in an outage, even on a sunny day, they can’t use their systems. Tabuchi Electric, an innovative Japanese company, has solved the issue with a smarter inverter that redirects solar power to a small battery bank, essentially acting as an emergency generator. We especially like the fact that this solution precludes the need for a combustion-powered backup generator, so it’s a “win-win” for sustainability. As this article is being written, the company is installing hundreds of units in Puerto Rico. A Tabuchi Electric system will be displayed in our Flex House project at the Consumer Electronics Show (CES) in Las Vegas in January.



CREDIT: TABUCHI AMERICA

extremegreen Wallboard

THIS INNOVATIVE WALLBOARD defies easy categorization. It's made with magnesium oxide with no organic fillers or resins, and comes in quarter-inch, half-inch and 5/8-inch thicknesses. The company also sells tile backer and other products of the same material.

We talked with extremegreen CEO Sam Catling at Greenbuild. He says the product is currently imported from China. GB: "Do you have plans to open a U.S. manufacturing plant?" Catling: "No comment." We're hoping that means we'll one day see U.S.-made versions of this product, which has a Class A1 fire rating, with zero flame spread and zero smoke developed rating.

After a flooding event, Catling says the product can just be washed off with a mild bleach solution and will continue to perform. Perhaps the best feature, however, is that the wallboard can be used in place of interior drywall. Seams would still need to be taped, of course, and this might require some clever product choices to keep up with the wall's strong performance in the face of mold, water and fire.

Another perk is that fixtures, art and other heavy objects can be hung directly from this material, without blocking. The product is more suited to nailing than screws when attaching to studs.



CREDIT: EXTREMEGREEN



James Hardie Fiber Cement Siding

SIDING IS A KEY component of a home's ability to survive Wildfires. It also adds to the projectile resistance of wood-framed homes in hurricane and tornado events.

James Hardie's siding will not ignite or add fuel to a fire. It complies with ASTM E136, as a noncombustible cladding and is recognized by fire departments across the U.S.

As an alternative to other claddings, such as wood or vinyl, fiber cement offers superior fire resistance. The Hardie product also has a flame spread index of zero and a smoke developed index of < 5, offering additional peace of mind to homeowners.

RESILIENT PRODUCT SHOWCASE

continued on next page

RESILIENT PRODUCT SHOWCASE

continued from previous page

Amvic ICF System

DESIGNED AS A complete structural system, Amvic insulated concrete forms (ICFs) maximize strength, performance and storm survivability.

With convenient 90 degree corner blocks, and an embedded, 100 percent recycled polypropylene web, they are designed to fit together and interlock precisely and quickly. Small details such as built in rebar holders reduce labor even more.

Amvic takes sustainability seriously. Their products are made without harmful chemicals such as CFC's, HCFC's or formaldehyde. Because the webs are recycled, the system consist of 60 percent recycled content. They also contribute 25 to 35 points to LEED certification. You can browse the Amvic brochure at www.amvicsystem.com/products/icf/#specs-guides, or visit their website at www.amvicsystem.com.



CREDIT: CLOPAY

Clopay WindCode Garage Doors

WHEN HURRICANES THREATEN, one way to reinforce garage doors is to insert posts behind the door until after the storm has passed. But Clopay has developed some doors specifically with high winds and flying debris in mind.

The company's *WindCode* line of garage doors are tested under ASTM E330 for uniform static air pressure. Doors are assigned to specific homes in different regions, based on the response to several questions. Clopay assigns a *WindCode* "W" rating to their doors, based on code requirements determined by wind speed in miles per hour (MPH), home exposure and home structural type. W1, for example is good for winds up to 85 mph, while W7 can handle 150 mph winds.

RESOURCES

- | | | |
|---|--|--|
| ▪ Atas Metal Roofing
www.atas.com | ▪ James Hardie Fiber Cement Siding
www.jameshardiepros.com | ▪ Amvic ICF System
www.amvicsystem.com |
| ▪ Tabuchi Electric <i>Solar</i> + Storage
www.tabuchiamerica.com | ▪ extremegreen Wallboard
www.extremegreenbp.com | ▪ Clopay <i>WindCode</i> Garage Doors
http://bit.ly/2icanAq |

Learn how to make homes resilient to wildfire!

Get the only national standardized training that offers science-based solutions to home wildfire risk. The two-day Assessing Structure Ignition Potential from Wildfire class is based on research including post-fire investigations. Learn how to identify techniques to reduce ignition potential and make homes and communities more resilient to this growing threat.

NFPA's expert-led classroom training gives you the science behind wildfire disasters and home survival. Learn to better protect your homes from wildfire!

Visit www.nfpa.org/hiz for more information. Contact us at **1.877.336.3280** or **wildfiretraining@nfpa.org**.



NATIONAL FIRE PROTECTION ASSOCIATION

The leading information and knowledge resource on fire, electrical and related hazards

Safe Havens

Adding elevation, adaptability and passive systems to buildings helps them survive nature's fury – but also offer solace to the greater community.





Flow on the go. Grand Bay Discovery Center's 12-foot-high trusses allow flood waters to move below unimpeded, reducing impact on the natural hydrology.

BY JOSHUA GASSMAN

THE 2017 ATLANTIC HURRICANE SEASON has drawn to a close, but we still remember related names—Harvey, Irma, Maria—which are now synonymous with devastation that upended millions of people's lives. It will take years of work and untold resources to ameliorate the damage. Additionally, memories still linger of Katrina, Hugo and Andrew from previous years.

Increasing development in coastal cities combined with sea level rise make natural disaster mitigation and management ever more urgent.

It is no longer enough for architects to merely reduce the negative environmental impacts of building. We must begin to ask, "What does it take for our projects to survive the storm?" and more importantly, "How can the built environment contribute to the greater good after a disaster?"

The first step is designing projects that don't just survive storms but provide critical shelter and services in their wake. We must create buildings that are *passively survivable*. The concept of *Passive Survivability* was introduced by *Environmental Building News* (now *Building Green*) in a December 2005 article published shortly after Katrina struck the Gulf Coast.

The concept posits that buildings should be designed to meet some basic needs of occupants, such as light, drinking water and ventilation in the face of disaster-induced utility interruptions. At one point, more than 90 percent of the island of Puerto Rico was without power due to Hurricane Maria. Imagine what might have happened with a few construction modifications.

SERVICE WITH STYLE

Designers must find ways to make structures more habitable in the face of such interruptions. Many of the planning and design strategies that can make buildings passively survivable have been around for a long time, but we have ceased to incorporate them as we increasingly rely on air conditioning, artificial lighting and other active systems for human comfort.

These strategies can include design for extensive daylighting to reduce the need for artificial lighting, operable windows to allow for natural ventilation, passive solar design to allow (or avoid) solar gain based on location and climate, orienting the building to take advantage of prevailing breezes—especially in coastal areas—and, finally, not building in flood-prone locations (while this may seem obvious, flooding in Houston after Harvey and in New Orleans after Katrina were exacerbated greatly due to building in low-lying areas).

One example that implemented many of these strategies is the Blue Ridge Parkway Visitor Center, located just outside of Asheville, N.C. In the Asheville climate, daylighting and natural ventilation are keys to creating a comfortable building in summer, but the winter conditions required a more complete passive solution.

As a result of climate analysis coupled with a study of the vernacular architecture of western North Carolina, the team designed a series of Trombe walls along the south façade to passively heat the building. A Trombe wall is a high-mass wall (typically concrete or stone) with a glass wall in front of it, creating an air space. The sun heats this gap like a greenhouse, and this energy is then transferred to the inside of the building through the mass wall, via venting, or both.



CREDIT: LORD AECK SARGENT IN COLLABORATION WITH THE MILLER HULL PARTNERSHIP

Disaster safeguard. When construction is completed, Georgia Tech’s Kendeda Building for Innovative Sustainable Design will include emergency potable water collection services, a backup battery system if the solar array is damaged, and an edible landscape in case of urgent food needs.

This strategy, in conjunction with others mentioned, yielded a building with energy performance nearly 80 percent better than a code-compliant building, while passively providing heat for an indefinite period of time without the use of any fossil fuels or power.

ADAPTIVE DESIGN

While passive survivability is increasingly relevant, we need to add more deliberate intent and action to the thought process to be truly holistic and helpful. Enter the idea of *Resilient Design*: “The capacity to adapt to changing conditions, and to maintain or regain functionality and vitality in the face of stress or disturbance. It is the capacity to bounce back after a disturbance or interruption.”

At the Grand Bay Discovery Center in Moss Point, Miss., many passive survivability strategies come together to deliver a resilient project able to bounce back after interruptions in a remote, storm-prone region subject to frequent, extended power outages.

A marine research and education center, the project takes advantage of passive survivability strategies and creates resiliency for its occupants. It is elevated 12 feet on trusses that allow flood waters to move below unimpeded, reducing impact on the natural hydrology. The windows are hurricane impact resistant and oriented to optimize daylighting and reduce solar heat gain, as well as being operable with insect screens to allow for natural cross ventilation.

A research porch was designed to function in the event of a long disruption. Screened-in with large overhangs and emergency power for research refrigerators, the building helps prevent interruption of critical research activities. A large, elevated exterior gathering space can function as a classroom and public gathering space should the need arise. Providing living quarters for visiting scientists, the building can serve a safe harbor for those working or visiting. An off-grid toilet system was designed to use collected rainwater for flushing and treats all water on site with a biofiltration system for infiltration back into the ground.

BUILDING RESILIENCE

Grand Bay does create a community resource, but its impact is limited due to its remote location. Having greater social impact and serving non-direct occupants of the building can help create more-resilient communities—especially if these projects are in urban areas. Resilient projects can become refuge and community gathering spaces in the event of disasters, potentially exporting needed energy, water or other resources.

The Kendeda Building for Innovative Sustainable Design, currently in design in the heart of Atlanta on Georgia Tech’s campus, is incorporating community resilience considerations in its design. Seeking full Living Building Certification, the project builds on passive survivability concepts to become nearly self-sufficient.

In addition to incorporating many of the passive design strategies highlighted previously, this project includes collection and provision of potable water, potentially offering a life-saving resource if the city source should go down. Power generation via solar panels will generate 105 percent of the project’s projected power use, as well as a battery system for use at night or if the photovoltaic array is damaged.

The Kendeda Building also offers a possible food source in its edible landscape, which is fully accessible to the public. All of these features allow the building to survive, but more importantly, allow the community to recover more quickly in the event of disaster.

As we consider the future of survival and sustainability, let’s continue to think of buildings as an opportunity to impact more than just that building’s occupants. Buildings can give back in terms of environmental impact upon construction and resource use, but also withstand storms and other disruptions, and can provide shelter and safe harbor within their communities. **GB**

Joshua Gassman is a senior associate at Lord Aeck Sargent (<http://lordaecksargent.com>), with more than 15 years of experience in sustainable design and project management.

These Incentives Improve Community Safety and Provide Developer Savings

In exchange for installing home fire sprinklers in entire developments, authorities having jurisdiction can offer locally negotiated trade-ups as incentives to developers. These incentives may include:



- Street-Width Reduction
- Longer Dead-End Streets
- Tee Turnarounds Permitted
- Increased Street Grades and Building Setbacks
- Additional Units Permitted
- Expansion of Existing Water Supply May Not Be Needed
- Increased Hydrant Spacing
- Subdivision Single Access Point
- Gated Communities

HOME FIRE SPRINKLERS PROTECT THE ENVIRONMENT*

Reduce greenhouse gas emissions by 98%

Reduce fire damage by up to 97%

Reduce water usage to fight a home fire by as much as 91%

Reduce water pollution

* Environmental Impact of Automatic Fire Sprinklers, FM Global, 2010



For more information about home fire sprinkler incentives, including case studies, video testimonials, fact sheets and NFPA 13D information, visit our website at HomeFireSprinkler.org/crr.

Home Fire Sprinklers: A Win-Win for Your Entire Community

Home fire sprinkler incentives can reduce construction costs, while protecting residents and firefighters, and help to protect the environment.

Pillars of Society

Efforts like RMI's Islands Energy Program can turn nature's fury into tomorrow's powerhouse.

BY CHRISTOPHER BURGESS, STEPHEN DOIG AND JUSTIN LOCKE

MAJOR STORMS TAKE TERRIBLE personal and societal tolls on the small economies of the Caribbean, setting these countries back decades overnight. For example, Hurricane Ivan cost Grenada \$900 million in 2004, more than twice the country's GDP. Last fall, Hurricane Irma caused an estimated \$10 billion in damages to Barbuda, the British Virgin Islands, St. Bart's, Anguilla, Puerto Rico, Cuba, the Dominican Republic, Turks and Caicos, the Bahamas and the U.S. Virgin Islands, and overall economic losses could be tenfold higher.

Equally important, these disaster events highlight how vulnerable Caribbean countries are to disruption. Nowhere is this more evident than in their electricity grids, which are exposed, centralized and powered by fossil fuels. If a storm shuts down an island's power plant, the entire island goes dark. Damage to vulnerable seaports also cuts off the delivery of desperately needed fuel. And the many miles of power lines are highly vulnerable and expensive to rebuild.

Rebuilding for Resilience

The crucial first response to this latest disaster, of course, is tackling the humanitarian crisis. That means bringing in water, food and other essential supplies; ensuring the safety of residents; reestablishing basic services; and helping businesses get back on their feet. But even as we rally to help the region now, there is an opportunity to rebuild better, cleaner and stronger. Instead of reconstructing the existing 20th-century electricity grid, we can leapfrog ahead with 21st-century technologies that make the Caribbean far less vulnerable to future storms.

The key step is replacing or retrofitting the centralized electricity grid with decentralized resilient renewable power, combined with energy efficiency measures. This will bring many benefits. Thanks to plunging costs for solar, wind and battery storage, small distributed renewable energy systems and increased efficiency actually would lower the electricity costs on the islands, which now are some of the highest in the world at 20 to 50 cents/kWh.

They also would reduce the countries' vulnerability to major storms, because some individual microgrids are likely to continue functioning even if the grid or other microgrids are knocked out. Remarkably, the solar installation that powers the majority of Sir Richard Branson's Necker Island survived the brunt of Irma. And reports from Fortis TCI, the utility on Turks and Caicos, confirm the uninterrupted operation of its solar assets on the island of Providenciales after Irma whipped over 155 mph winds through the popular British Overseas Territory.

The islands are not the only places that decentralized, resilient and renewable grids are being targeted. In the U.S., the National Electrical Manufacturers Association (NEMA) envisions that a resilient and robust utility infrastructure of the future can be built out of interconnected microgrids at universities,

hospitals, industrial parks and neighborhoods. Individual microgrids would be nominally connected to form a single utility grid, but could also isolate from the grid and operate independently in case of disruptions.

In addition to resiliency, renewables would insulate the islands from spikes in fossil fuel prices, which along with hurricanes have shocked the region's economies and put significant burdens on one of the most economically challenged parts of the world. More importantly, they would reduce dependence on fossil fuel imports, keeping millions of dollars at home instead of shipping them off island to buy foreign fuel—while also making it possible to slash those imports far more by switching to an electrified transportation system.

Seizing this opportunity to rebuild smarter would be eminently worth doing, even in a world without climate change. But with the certainty of rising seas and stronger and more-frequent storms, the task becomes even more vital. It offers the Caribbean islands their very best hope for surviving the next challenges while also cutting costs, boosting their economies and improving the entire region's competitiveness.

Pillars of Transformation

The approach to transforming the Caribbean builds on our experience from running the Islands Energy Program with the Clinton Climate Initiative (CCI) over the past few years. Specifically, the approach consists of three mutually reinforcing components.

The first step is rapid-integrated resource planning, a whole-systems approach that will create an integrated plan for the energy and transportation sector that reduces costs, catalyzes private-sector investment, improves reliability, increases resiliency (to extreme weather events and other disasters) and reduces emissions (ideally to net zero). The plan identifies the optimal projects for transforming the energy sector with high levels of renewable energy and energy efficiency and converting the transportation sector to electric vehicles. This process includes:

- Aligning stakeholders on a shared vision of what they want their society to look like;
- Forecasting the change in electricity demand and determining the need for new resources to meet that demand;
- Identifying the available resources such as solar, wind, hydro, biomass, geothermal, waste-to-energy (WTE), diesel and natural gas;

“Seizing this opportunity to rebuild smarter would be eminently worth doing, even in a world without climate change. But with the certainty of rising seas and stronger and more-frequent storms, the task becomes even more vital.”

Wipeout. Scenes like this on the Caribbean island of Jost Van Dyke northwest of Tortola were all too common following Hurricane Irma's passage in September 2017.



- Analyzing combinations of energy efficiency and centralized and distributed energy generation options and their impacts on the existing grid, along with their costs;
- Identifying existing vulnerabilities in the grid (from disasters, overloads or other issues), and the opportunities to strengthen the grid.

The second step is project identification and resilient development. Once the planning process identifies the possible investment projects, the next phase of the effort focuses on increasing the investment opportunity in targeted Caribbean islands by creating more-detailed plans and reducing the overall risks. The process includes:

- Identifying the mix of resources that will meet a specific island country's needs at least cost and determining the best place to install those resources;
- Performing a detailed financial and economic analysis;
- Preparing the sites for development and commercialization.

The third step is project financing and construction. Once resilient, renewable projects are developed and considered investment ready, affected countries need support in mobilizing concessionary and grant financing and private sector capital to turn those proposed projects into steel in the ground. They also need support in supervising construction to ensure safety and building standards are met. This support includes:

- Determining the right financial structures such as power purchase agreements (PPAs); build, own, operate, transfer (BOOT); public-private

- partnerships (PPPs); or typical capital improvement loans;
- Supporting the contract negotiation process;
- Supervising construction to ensure that best practices and safety standards are implemented;
- Commissioning the system with the local island utility, the contractor and a third-party engineer.

The efforts in all three components are mutually reinforcing. The rapid integrated resource planning work identifies optimal climate resilient projects to pursue. Project derisking ensures high quality and attractive investment-ready projects. Meanwhile, project financing and construction oversight support ensures the rapid quality deployment of these projects—enabling beneficiaries to see the myriad benefits, including lower costs and increased reliability and resiliency.

This, in turn, reinforces the value of the integrated plan and the iterative process continues. Moving forward with this process yields faster, higher-quality and lower-cost projects, making it possible to accelerate the transition to a stronger, cleaner, more sustainable future. **GB**

The Rocky Mountain Institute (RMI) engages businesses, communities, institutions and entrepreneurs to accelerate adoption of market-based solutions that cost-effectively shift from fossil fuels to efficiency and renewables. Christopher Burgess is director of projects for RMI's Islands Energy Program (IEP). Justin Locke is the IEP's director. Stephen Doig is RMI's managing director.



Positive flow. Strange as it may seem, the Houston floods were not as bad as past years—at least, not in Caroline Kostak's neighborhood.

Thoughts From Ground Zero

Ten ways to make your home more resilient to disaster.

BY CAROLINE KOSTAK

After spending significant time last fall tearing out wet drywall and insulation in Houston, I have some thoughts on building homes with an eye toward resiliency:

1. Build homes higher. Elevate homes that are within the 500-year-flood plain, or at least the 100-year. The difference in our neighborhood between the elevated house, such as ours, and the non-elevated houses was “no problem” vs. “total loss.” Some of this may be covered in local codes, but it is no joke—it’s the best thing you can do to protect your home.

2. Find better drywall. There has got to be some material better for the bottom three feet of a house than drywall. Maybe beadboard or some other wood-based material? Just put it up a few feet, and then drywall to your

heart's content. Or switch to a magnesium-based wallboard.

3. Rethink insulation for flood-prone areas. Both blown-in cellulose and fiberglass insulation get wet inside walls and are hard to dry out...Could these and other insulation systems be modified for flood zones, so that with removal of wallboard, they could be dried more efficiently?

4. Build escape hatches into attics. I'm not kidding. If it's a vented attic, make the vent removable. If it's an unvented attic, build in a removable door, especially in one-story homes. Or at least have an axe holder on the wall or ceiling, and include the axe.

5. Make pavers and driveways permeable. This would greatly increase a site's ability to absorb water. We've paved over a significant portion of the west side of Houston, and I think it's not a coincidence that we've had three major flood events since. What was prairie is now neighborhood. All that stormwater runs off into the Houston bayous, which flood Houston.

6. Expect more floods. Thank God for first responders and boats.



Washout. Hurricane Harvey's hammering of Houston left many residents' homes under water, and has builders wondering how to keep it from happening again.

Of course, if we take the above steps, there's also some psychology we need to employ:

1. Have less stuff. The people with the greatest need are the hoarders (or whatever nicer term you want to use for people with a lot of stuff). A house volumetrically full of stuff is WAY harder to clean up than a house with a reasonable amount of stuff. And it turns out there are a LOT of people with a LOT of stuff. Even nice people, like your friends.

2. Be educated ahead of time about what to do in case of a flood. Floods are going to be a reality for a lot of people in the coming years. Why not prepare ahead of time? Know what FEMA and your flood insurance policy recommend: Should we sort materials on the curb? How high up should we cut the drywall? These things are easy to figure out ahead of time, and save a lot of consternation and phone calls to your insurance agent in an emergency. They can also keep you from doing things wrong while in emergency mode.

3. Don't panic. It creates more waste. They're not thinking about things through clearly. They're throwing out some perfectly fine things—stuff that just needs some cleaning—simply because they got wet and people can't handle the emotional trauma of having wet stuff around them. This is becoming an opportunity to have your neighbors and friends clean out the craft drawers you haven't touched for years, even if they didn't get wet. Solid wood furniture isn't ruined if it gets wet.

4. Become resilient people. Be prepared to handle things when things go wrong (i.e., learn how to not freak out when things go wrong). Life throws us challenges sometimes. If we crumble, we won't be able to help ourselves or those around us. Toughness is a requirement in life, not an option.

Surviving this has been another amazing experience. Neighbors and friends

coming together to help recovery; people from all over the country donating materials and money to get other people back on their feet...

Unfortunately, I said "another." Hurricane Ike was similar, except our neighborhood had far more damage. Really, despite having kayaked through the streets, there are not huge amounts of trash on the curb this time. After Ike, most of the houses in our neighborhood were raised if they weren't already elevated (anything built after 1977 had to be built on stilts). I think that made a huge difference. And maybe, just maybe, people learned the lesson from Ike that they shouldn't have so much stuff under their house.

And actually, I ask myself: Why wasn't the damage worse? I know there were a lot of displaced people. And I know there are a LOT of damaged houses. And there were some people who unfortunately perished in the water. But a lot of people didn't have damage, and a lot of people didn't drown. Why not?

If this happened in some other country, or maybe in another city, I think things could have been way worse. Fifty inches of rain is a LOT. I believe that the infrastructure improvements that we've made in the last eight years have significantly improved Houston's drainage. The bayou and reservoir systems work pretty well. Some improvements can be made, of course—especially in helping inland bayous drain toward the Gulf—but really it handled a huge test fairly well. There are a lot of people who do not have damage. **GB**

Caroline Kostak is a green building consultant with GreenHouse Integration LLC (www.greenhouseintegration.us) in Clear Lake Shores, Texas, and owner of RePurpose Depot (www.repurposedepot.org). She also chairs the U.S. Green Building Council's Green Homes and Green Schools committees.

Floods and Folly

Cities, such as Houston, must learn from natural disasters to prevent being hit even harder the next time.

BY DIANE TOOMEY

Note: This article originally appeared in *Yale Environment 360* (<http://e360.yale.edu/>), a publication of Yale School of Forestry & Environmental Studies and Yale University.

FOR DECADES, HOUSTON AND its surrounding region has been one of the fastest growing metropolitan centers in the United States, with the population of Harris County rising from 1.75 million in 1970 to more than 4.5 million today. But as population soared, developers in southeast Texas were allowed to build on whatever land they could find, including wide swaths of drained wetlands, with little thought of flood risk.

[Hurricane, later Tropical Storm] Harvey reclaimed much of that land, dumping more than 40 inches of rain in a matter of days and flooding as much as 30 percent of Harris County in August 2017. In the wake of the storm's catastrophic damage, flood expert Philip Bedient says business-as-usual building practices in the Houston area must change.

Bedient is a civil and environmental engineer at Rice University, where he directs the Severe Storm Prediction, Education and Evacuation from Disasters (SSPEED) Center. He has advised the city of Houston on low-impact development practices that help to mitigate flooding. In an interview with *Yale Environment 360*, he discusses southeast Texas' haphazard development boom, how communities should approach rebuilding after Harvey, and how the region needs a network of flood mitigation policies and technologies to protect it from future climate change-fueled storms.

Yale Environment 360 (e360): Harris County, which includes the city of Houston, has experienced phenomenal population growth in the last few years. You've described the building practices in the area as "the Wild West." How so, and how did that contribute to the current disaster?

Philip Bedient: Most of that Wild West [building] was years ago. We have a lot of legacy areas around that were built in the 1960s, '70s, and the '80s, in the fast boom-or-bust era. It was also a time where our flood control policies were not very strong at all. A lot of those areas were built with a lot of high density, with not a whole lot of green space, with not a whole lot of good practice. Very little attention went into it. That's all changed, but it didn't change until the '90s, and it was a day late and a dollar short, because so much of the area



CREDIT: WORDLUNKY/FELICKR

Rework-ready. Houston-area contractors and homeowners will be kept busy as they repair flood-caused damage from Harvey and future storms. The city is considering a variety of projects to protect against flooding.

had already been developed.

e360: Are there zoning regulations now that, say, prohibit building in a 100-year flood plain?

Bedient: No, they [local officials] still allow building in the flood plain, but I have a feeling that a lot of this is getting ready to go through a change. I do know that they're starting to think seriously about putting some additional [water] storage out on the west side, in the Katy Prairie area, and try to do a better job with the reservoirs that are out there now. But don't forget, we just had the largest flood in U.S. history spread out over an entire county. There's no way we could've come out of this without some flooding. But it would've been a lesser amount, if we had had some of these policies in place.

e360: Were there any surprises for you regarding the pattern of flooding in the Houston area?

Bedient: No real surprises, other than it's the largest amount of rainfall to ever befall an urban area in the history of the United States. When you get 3 feet of rainfall, pretty much spread uniformly over a 1,700-square-mile area, it's pretty daunting.

e360: You've worked with the City of Houston to evaluate different types of low-impact development. What does this look like?



CREDIT: DANIEL MARTINEZ/AIR NATIONAL GUARD

Flood watch. By the time Harvey had subsided, an estimated 30 percent of Harris County—about 444 square miles—was submerged.

Bedient: You can do everything from an individual green roof, or a small green area associated with a building, all the way to what I call green infrastructure, which would be using a greenway or green belt, and adding [water] retention wherever you can, and minimizing impervious surfaces. We've recommended that at all different levels.

When I came to Houston originally, I worked on the Woodlands, up on the Northside, which is one of the best-designed flood-protected communities anywhere. We did that in the '70s. There are other areas around Harris County, out in Fort Bend County and in the Sugar Land area, where these are practiced, and they actually worked well during this flood. But unfortunately, we need to do a lot more of that in Houston. I do think that they are going to begin to turn in that direction. This is the third year in a row of major flooding. They're really going to have no choice but to turn in that direction.

e360: You've also worked on flood resiliency with the Texas Medical Center, which fared pretty well during Harvey. Tell me about how you advised that facility.

Bedient: We helped rebuild the Med Center and redesigned the whole infrastructure post-Allison. We have a flood warning system that they rely upon. All of that worked really, really well during this storm. This was the highest recorded levels ever on the bayou next to the Medical Center, by probably more than a couple of feet. The Med Center actually saw a little bit of flooding, but it was absolutely minor

compared to everything else we're seeing in the city of Houston. The system worked perfectly.

e360: They've got submarine doors, I understand, in their underground tunnels.

Bedient: They brought in shipbuilders from the Northeast the day after Allison, and they started designing these gates and doors to be completely waterproof. They work very well.

e360: There is an ongoing federal and county project known as Project Brays, which is trying to reduce the risk of flooding along the Brays Bayou with channel widening and storm water retention basins. Is this an effective approach? If so, is more of the same needed?

Bedient: I would say that Project Brays is the only hope those people had, but we just saw about a 500-year flood, and that is far beyond anything that Project Brays was ever designed to do. It will still help the next time we get the 100-year [flood]. But those people in Meyerland have been flooded now three years in a row. I think we're going to probably end up looking at a massive buyout. There's going to have to be some sort of a major shift in policy. There's got to be an infusion of money to really make this happen and get those people out of harm's way.

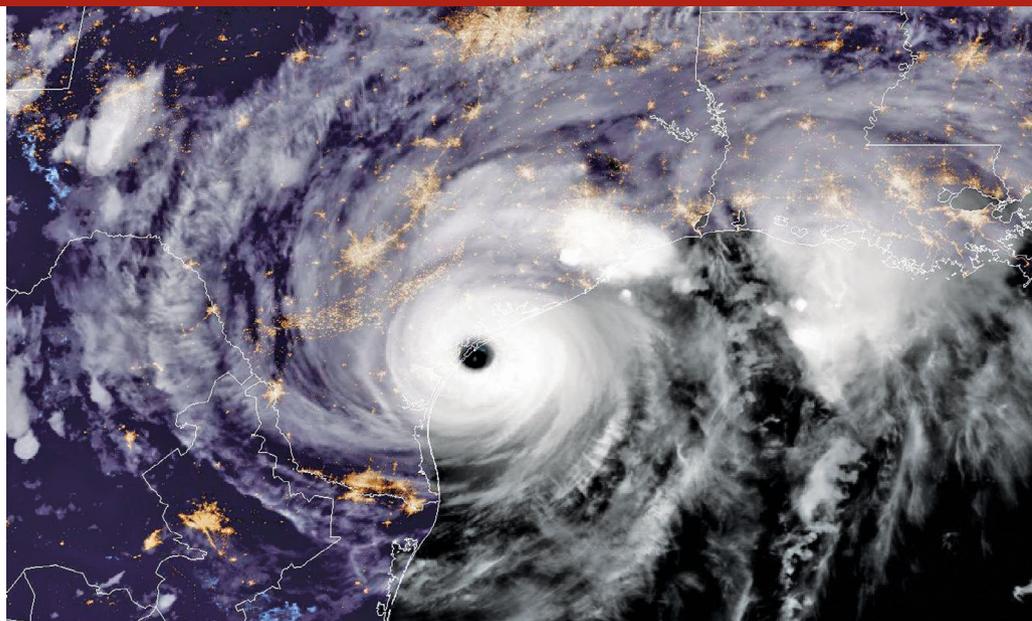
e360: If this is Houston's Katrina, is there receptivity now to major shifts in the way this region thinks about development?

Bedient: I think if there weren't a major shift now, I would be very surprised. Unfortunately, there are a bunch of developers who just try

to meet the bare bones minimum, and we're going to have to turn that thinking around. We cannot continue to develop just for the bottom line. We're going to have to develop in smart, resilient ways. Otherwise, Houston is going to be forever known as the flood capital of the United States.

e360: Your center and Texas A&M at Galveston have put forth various proposals to protect the region from storm surge. The Texas state legislature and local officials are now supporting the so-called coastal spine, or "Ike Dike," a series of floodgates along the coast that can be closed when needed. In April, Texas land commissioner, George P. Bush, asked President Trump for \$15 billion to build the project. If that money doesn't come through, then what?

Bedient: I hope it does. I hope that we begin to do something. It's been nine years since Ike. We'll see. But I'm also [not] going to be surprised to see... a competition for money for inland flood defense, which is what just happened here. This wasn't a surge event. We had no surge at all. It was all inland flooding. Monies are going to begin to flow, but the question is, what are they going to be used for? And what is their best purpose?



Eye of fury. When it hit land in late August 2017, Hurricane Harvey became the most destructive natural disaster in U.S. history, causing \$199 billion in property damage.

I'm not in any position to try to make those political decisions, but hopefully, the right decisions get made about how to spread the money around appropriately to protect all of the critical facilities, all these neighborhoods, as well as the coastline.

e360: What does the SSPEED Center's modeling tell us about a worst-

The Foam Factor

After the big one hits, here's how to keep residential flood and water damage to a minimum.

A CROSS THE U.S.A. and Canada, heavy rainfall and flooding have caused millions of dollars in damage, lost revenue, damaged crops and homes. Hurricane Harvey ravaged southern Texas and the nation's fourth largest city, Houston, flooding vast areas of the region—and Hurricane Irma pounded Florida, Puerto Rico and much of the Caribbean with high winds and downpour. In British Columbia, a tough spell of raging wildfires over the summer made heavy rainfalls a greater threat in fall.

Water ingress resulting from storm surges, high rainfalls and flooding can cause massive damage to the typical home. When water ingress occurs from extreme weather events, it becomes necessary to assess extent of damage and contamination, debris removal requirements, and how to reconstruct or repair to reduce probability of similar damage in the future.



The dry look. Closed-cell spray foam such as Icynene ProSeal can act as a water-resistant barrier and provide additional "racking" strength vs. high-powered winds.

Power cells

When seeking methods to reduce the risk of water ingress, spray foam insulation is often overlooked as a comprehensive solution that can help play a role to keep out moisture and deter flood damage. However, spray foam insulation can be a key component in the design of building assemblies against future disaster-driven damage. Both open-cell and closed-cell spray foam insulation can be used throughout a residential or commercial structure to manage and minimize moisture ingress.

When it comes to addressing moisture, open-cell foam is better suited for use against building materials that can be damaged by water buildup. When applied against these types of materials (e.g., exterior wood sheathing), particularly in hot or humid climates, insulation should allow just enough moisture diffusion to occur to let adjacent building materials breathe, preventing moisture entrapment. Open-cell foam delivers this "breathability" and allows building materials to dry, minimizing moisture buildup and related problems, such as mold.

case scenario hurricane hitting the area?

Bedient: The SSPEED Center scenario says that even if a coastal spine [were built], you would really still need even some in-bay elements. We've advocated for the mid-bay solution, particularly to protect the Houston Ship Channel.

e360: That's the solution that your center has put forward. What does it entail?

Bedient: Our mid-bay is basically a dike that runs down alongside the Houston Ship Channel, all the way out toward Galveston Bay. But about midway down, it cuts over and connects with the existing Texas City dike. It protects a big bay area, including all of the Clear Lake area, and in particular, provides an extra level of protection for the Houston Ship Channel. It involves a coastal spine. We think that actually all of it, all the elements together, really need to be built—both a coastal spine, as well as mid-bay elements—because just the coastal spine will not be fully protective.

This storm hit Corpus. It hit Rockport. But it very easily could've come in and hit Houston. If it had come into Houston with a direct hit, we would've seen massive damage within the Houston Ship Channel area—spills, environmental impacts—because there's nothing out there to protect it right now. They're sitting ducks. You can't trust just a single line of defense.

For example, in scenarios where the foam is applied to the underside of a roof deck, in the event of a roof leak water drains straight through the insulation by gravity rather than being trapped against the roof sheathing where it could contribute to roof rot. Upon drying, some open-cell spray foam insulation products return to their original state without warping or distortion, and the effectiveness of the insulation is restored to its original performance potential.

The Federal Emergency Management Agency (FEMA) has identified closed-cell spray foam as a flood-resistant material due to its resilience and strength. According to the government agency, flood-resistant material is any building material capable of withstanding direct and prolonged contact with floodwaters without sustaining significant damage. Closed-cell spray foam, like Icynene ProSeal, can be used as a water-resistant barrier to help deflect moisture and provide additional "racking" strength to help resist the high winds of a storm or hurricane.

Dealing with flooding's aftermath

When assessing flood damage, one must almost always assume that the water contains contaminants, such as decaying organic matter and debris, raw sewage, fuel, solvents, microbes and mold. Through wicking, moisture and contaminants can be drawn into areas above the actual flood level. Even after cleanup, homeowners may still notice problems with housing elements, since mold and other contaminants can be present due to wicking and therefore may render homes unlivable.

Cleaning up after a flood should involve an assessment of the extent of removals required, necessary cleaning, drying and disinfecting of surfaces by

e360: Given the reality of climate change, the Houston region will face even more powerful hurricanes, more heavy rain events, higher storm surges. Will a place like Houston even be habitable in a century?

Bedient: That's a really good question, but then we've learned to live with big storms over the years. If indeed they're going to start to get bigger and more intense—which I think they are—I think we're seeing it now, and I think we've seen it in the last three years. If that's going to happen, then we've got to take flood protection a lot more seriously than we have in the past. It needs to become No. 1 priority.

Houston helped put a man on the moon. Houston is the leader in the medical field. It could also begin to be a smart, resilient city if it puts its mind to it. That's all it's got to do. **GB**

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- Yale School of Forestry & Environmental Studies, <http://environment.yale.edu/>
- Rice University Severe Storm Prediction, Education and Evacuation from Disasters Center, <http://sspeed.rice.edu/sspeed/mission.html>
- Project Brays, www.projectbrays.org



CREDIT: BART EVERSON/FLICKR

Unpleasant surprise. Mold, which can take hold in as little as two days once a structure has become saturated, may appear in obvious places like ceilings, or, in this case, on a wall behind a hanging picture.

a qualified contractor. Some porous materials may take days or even weeks to carry out. Mold can begin to thrive in as little as 48 hours when contaminated water floods an assembly. This makes it likely that many porous materials will, in fact, require removal after an extreme weather event.

Repair work following water ingress or flooding will often involve raising older buildings and constructing new ones on piers or platforms above the Base Flood Elevation (BFE). Construction below the BFE must be done with flood-resistant materials. Closed-cell spray foam insulation is suitable for application below the BFE.

Above the BFE, both open-cell and closed-cell spray foams can be used, but consideration has to be given to avoiding other porous materials that can absorb contaminated water. The choice of materials should be made based on sound building science

principles. For instance, in a floor above a damp crawlspace, it may be desirable to use closed-cell foam because of its vapor retarding, compressive strength and water-resistant characteristics. A qualified and experienced insulation contractor is able to help work through the best approach.

Most of all, building materials exposed to flooding must be resilient enough to sustain a certain amount of water exposure to avoid the need for complete replacement. A "repair and prepare" approach using spray foam insulation can help reduce risk of water ingress and damage, as weather patterns across North America continue to change and challenge our approach in designing and building sound, solid structures to live, work and play in. **GB**

Source: Icynene (www.icynene.com), a developer of high-performance spray foam insulation solutions.

