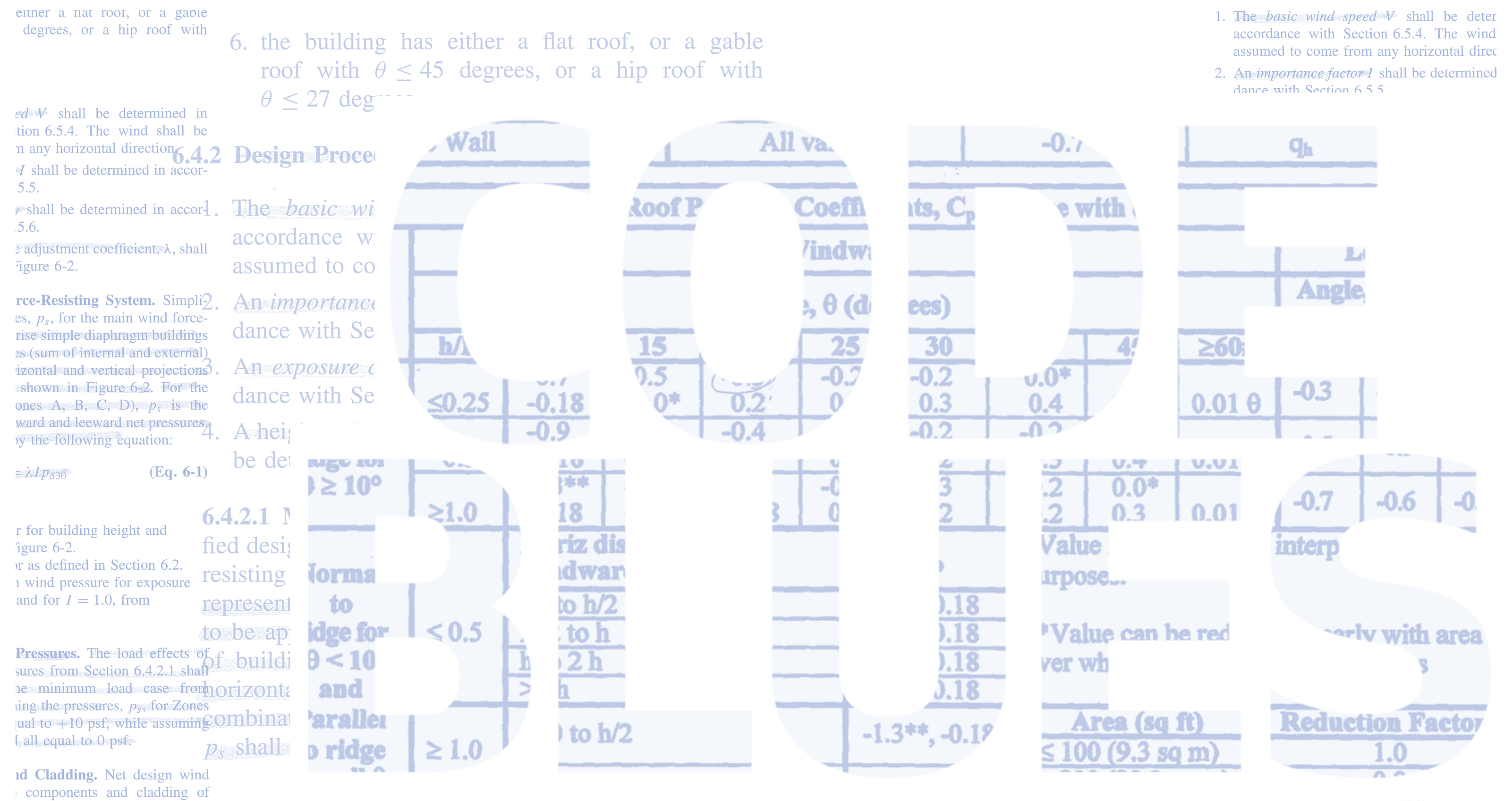

CODE.BLUES

by Christof Spieler

Current measures are limited when designing buildings for **wind** and **water** emergencies

BUILDINGS ARE TYPICALLY ONLY AS HURRICANE RESISTANT AS THE LAW REQUIRES THEM TO BE.

Construction is governed by a patchwork of different codes: Cities like Houston and Sugar Land have adopted the International Building Code (IBC) and enforce it as part of their city ordinances, but those codes don't apply to areas like The Woodlands. The Texas Department of Insurance created its own building code to cover coastal counties, but it's required only for buildings that are seeking hurricane insurance. Similarly, the Federal Emergency Management Administration (FEMA) has its own guidelines that apply only to buildings in designated floodplains insured by federal flood insurance. In sum, one structure might be required to comply with three building codes, while another only blocks away might not need to meet any requirements at all.

To design a building for wind, we have to know how strongly the wind will blow. The building codes are based on a 50-year wind—the strength of wind that has a 2 percent chance of happening at that particular spot in any given year. Obviously, that's not the worst-case scenario. But safety features specified in the code add another 60 percent on top of that, which works out to anticipate a roughly 500-year wind.

The IBC provides a map of 50-year design wind speeds. Galveston is rated at 130 miles per hour, but the speed drops off rapidly inland: Downtown Houston garners a 110 estimate, IAH 100, and College Station 90. Formulas are provided to translate these speeds into pressures, with additional factors taken into account: Buildings in open areas have higher pressures than those surrounded by other buildings; pressures go up farther off the ground; and critical facilities like hospitals, chemical plants, or buildings that could be used as shelters are designed for higher pressures. On tall or unusually shaped buildings, wind tunnel testing is used to get more accurate pressures.

Some typical pressures: A two-story building in Houston would be designed for 25 to 30 pounds per square foot of sideways load on the walls and 20 to 55 on the roof. A Galveston highrise may be designed for pressures as high as 90. These are big numbers: By comparison, the design load for a residential floor—enough to include all the people and furniture—is 40 pounds per square foot.

In our first and most simplistic view of wind loads, the big bad wolf blows over the pig's shack like a house of cards. In reality, that almost never happens in hurricanes—not because it's impossible, but rather because this is the aspect of wind design that's best understood and most thoroughly designed for. In wood construction, plywood panels nailed to the wall studs and tied to the foundation keep the building from leaning. Without the plywood, wood buildings do behave like houses of cards: In 1999, a three-story wood-framed hotel under construction in Houston collapsed in thunderstorm winds.

In commercial buildings, steel X-braces, block walls, or concrete walls brace the building. These systems are strong, small, and reliably built. They must be designed not only to hold the building up but to limit its movement, so finishes don't crack and occupants don't get seasick.

The strongest forces on a typical building in a hurricane act not on the walls but on the roof. To make design more complicated, winds suck upward on a roof, opposite to the direction of gravity loads. And once a roof fails, wind and rain get inside the building, damaging contents and often ripping off other parts of the structure. A wood roof has a myriad of potential failure points: Shingles can lift off the roof, plywood can rip off the rafters, the rafters can flex upwards, and the ends of the rafters can lift off the walls. The code prescribes measures for all of these: nailing patterns for shingles and plywood, blocking to stiffen rafters, ties at the ridge, and sheet metal hurricane clips at the eaves.

Though the materials are different, the basic wind issues with steel and concrete roofs are the same. Proprietary systems for flat roofs are lab tested and rated for uplift resistance. Welds are specified to keep roof deck and joists in place, and extra bracing is required to keep the roof from flexing upwards. Despite the code requirements, roofs remain one of the most fragile parts of a building. The basic issue is workmanship: There are hundreds of connections that can be done incorrectly, and while carpenters have a gut feel for how gravity works, they don't have that same sense for the equally strong loads that can act upward.

The most common damage to buildings in hurricanes is broken windows. Like a hole in a roof, a single broken window can lead to the complete destruction of a building as wind and rain work their way in. (Doors, especially large garage doors, are also vulnerable to being blown out). Unlike roofs, though, windows are not usually damaged by wind pressure alone. Windows break because of flying objects. Perhaps the easiest way to prevent this is with shutters or sheets of plywood. But not all building owners will be that diligent, and the usual masking-tape expedient does no good whatsoever. Window damage is also a major issue on highrises, where neither shutters nor plywood are economical. Building codes now require that all windows within one mile of the coast in hurricane-prone areas be equipped with permanent shutters or be designed to withstand impacts from flying objects. Manufacturers certify their windows for these criteria by shooting objects at them in testing labs.

The codes also address the problem of smaller amounts of debris that can break windows. During Hurricane Alicia, in1983, the Allied Bank and Interfirst Bank buildings in downtown Houston suffered considerable window damage from gravel blown off the roof of the Tenneco Building; gravel roofs are no longer permitted in hurricane zones.

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There's no easier way to destroy a building than to drop a big object on it: a tree, a part of another house, even a vehicle. The resulting hole weakens the entire building. It's almost impossible to build for such an impact, and the codes do not consider it.

The greatest destruction from Hurricane Katrina wasn't from wind; it was from water. Along the Mississippi coast, the storm surge rose to the second floor of houses, with battering waves on top, and entire communities were leveled. In New Orleans, the water came more slowly, leaving buildings standing; but a building that is submerged in standing water for days will require major reconstruction.

It is essentially impossible to design a building for being submerged. No wood framing will withstand the pressure of several feet of water, let alone the pounding of waves. Neither will doors or windows. The only solution is to elevate the building on piles, with any walls between the piles designed to break away in a storm, a requirement by FEMA in flood areas. But FEMA's floodplain maps don't represent anything like the maximum possible storm surge, and they don't take waves into account. If a worst-case storm surge hits the Houston area, any building built at grade within its reach will likely be destroyed or significantly damaged. But many buildings built on piles will probably be damaged, too, from wave action. Codes offer little protection. But then, the only way to successfully resist a storm surge is probably a concrete bunker with solid steel hatches instead of doors.

Building codes have gotten significantly better as we've gained experience with each major hurricane. A building built to code will likely survive the winds of even a major storm intact, if no storm surge or falling tree is involved. Of course, not all buildings are built to code: Builders have many incentives to cut corners, and even in those places where building inspections are required, inspectors can miss things.

The biggest shortcoming in the codes, however, do not relate to new buildings at all. Older buildings were not built to current codes and lack many features we now consider essential. The first building code to consider debris impacts on windows was South Florida's in 1994, in response to Hurricane Andrew; that provision was not adopted widely until 2000. Hurricane clips were uncommon before the 1980s; in the 1960s and 1970s, engineers often did not consider wind design in one- or two-story commercial buildings.

No code requires older buildings—even essential facilities—to meet its standards, except when they are significantly modified. Thus, most of the buildings in any hurricane-prone city do not meet current codes. Of course, that does not mean they will fail. But in every storm, the greatest number of building failures tends to be in older structures. At present, the codes are sound, but they're limited.