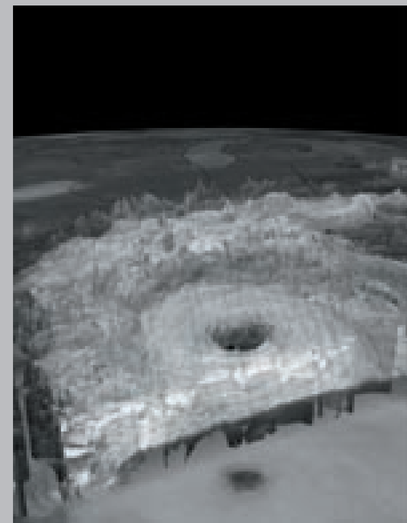
HUFFING AND PUFFING AND BLOWING IT DOWN: HOW TO MAKE HOUSES THAT WILL SURVIVE A KATRINA



Gregory A. Kopp and F. Michael Bartlett

Disaster aftermath coverage inevitably shows houses and other buildings that appear to be damaged according to some random, arbitrary calculus: a house reduced to toothpicks right next to one that seems untouched. As Gregory Kopp and Michael Bartlett write, this effect has less to do with the whims of the elements than with construction codes and design standards. Using real examples from Hurricanes Katrina and Dennis, they make a case for better building codes and provide a preview of what will go on at a unique University of Western Ontario testing facility named after a nursery rhyme.

Les reportages sur les catastrophes naturelles montrent inévitablement des habitations qui semblent ravagées selon une sorte de mathématique arbitraire, certaines maisons anéanties en avoisinant d'autres qui paraissent intactes. Or cette impression relève moins des caprices des éléments, écrivent Gregory Kopp et Michael Bartlett, que des normes de conception des bâtiments. À l'aide de véritables exemples étudiés dans le sillage des ouragans Katrina et Dennis, ils préconisent l'élaboration de codes de construction plus rigoureux et offrent un aperçu des travaux prévus à l'Université Western Ontario, dans des installations d'essais uniques.

Although Katrina was a major hurricane, her maximum wind speeds do not appear to have exceeded those used for structural design guidelines in the region. The storm surge was estimated to be as high as 30 ft, with probabilities of occurrence greater than once in 500 years in many areas along the coast. The surge and high winds devastated the coastal cities of Biloxi and Gulfport, Mississippi. There was also extensive wind damage in New Orleans, most notably the loss of office tower and hotel windows, as well as the roof panels on the Superdome, where thousands of people were taking refuge from the storm. Worst of all, the storm surge also caused the levees surrounding the city to burst, leading to massive flooding. Tens of thousands of homes were destroyed in New Orleans and along the Mississippi coast.

All levels of government were slow to respond to the crisis and have since been widely criticized. This was truly both a natural disaster, due to the hurricane itself, and a management disaster, due to the slow response of those responsible for emergency preparedness.

It is enlightening to compare what happened during Katrina with a more positive example: the 1997 Red River flood in Manitoba. Following the 1950 flood, which destroyed over 10,500 homes in Winnipeg, a 47-km floodway to bypass the city was built for $63 million. "Duff's Ditch," named for Manitoba premier Duff Roblin, who was its leading proponent, was mocked at the time, but it protected Winnipeg four decades later when similar flood levels occurred.

Other factors prevented disaster in 1997 as well. Accurate forecasting predicted the actual flood levels. In particular, after the flooding of Grand Forks, North Dakota, proved the forecasters correct, the residents of Manitoba worked together with military personnel to raise the dykes south of Winnipeg so that the river could not do an "end run" around the floodway. The capacity of the Winnipeg floodway is currently being expanded.

Natural disasters are the interaction of naturally occurring hazards with human populations. We can do nothing about the actual natural hazards, so to minimize their risks and consequences, we must manage the other half of the equation — the human population and infrastructure. Wind, snow and rain hazards are different than floods. Flood damage is controlled by limiting development in high-risk areas or providing large-scale diversion infrastructure like floodways (an effective strategy for Winnipeg) or levees (an ineffective strategy for New Orleans).

Wind, snow or rain damage is controlled through design, construction and maintenance of each individual structure by builders and individual homeowners. Houses and other light-frame structures, in spite of their widespread use and apparent simplicity, are among the most complex structural assemblies used by Canadians. The complexity comes from the highly redundant yet vaguely defined system of structural elements that are not truly “engineered” based on scientific principles, but rather “proportioned” using prescriptive rules derived from traditional practices that specify, for example, the maximum spacing of 2-by-4 studs in a wall or the minimum number of nails in a connection. Prescriptive rules ensure that house collapses are infrequent while keeping construction affordable. This does not necessarily ensure that they are optimal in an engineering sense.

The environmental protection systems in houses are also complex. Insulation keeps the heat in, but may alter the moisture movement necessary to keep interior walls dry. Moisture arises within a house because of human activity, rain and humidity. Rain is a particular problem because the pressure gradients that generate significant forces on the structure also propel rain through cladding materials, such as brick or siding. Trapped water can allow mould to grow, leading to a health hazard that is also an eyesore. Thus, there need to be built-in mechanisms to allow the walls to dry out, a particular challenge in Canada since they may conflict with our need to retain heat. Because houses are not engineered, but designed and built largely based on experience through prescriptive rules, damage surveys following significant environmental (e.g., wind, snow, rain, hail) events and laboratory testing under realistic yet extreme conditions are critical. Post-disaster investigations of damage to housing due to extreme winds and rain do not always uncover the causes of a progressive structural failure or water entry, so laboratory-based experiments are also necessary.

Figure 1 shows a relatively new house with significant structural damage sustained from Katrina. At first glance, these may not be surprising images. What actually makes the image surprising is what is not shown — the 100 or so other houses in the neighbourhood, of the same age and style, without any significant structural damage. This was the only house in this neighbourhood that sustained major structural damage. Many houses had shingle and/or siding loss (like those in the background of the photograph). Many more had no visible damage. Clearly, most the roof shown in figure 1 has been torn off by wind uplift loads, with the left end probably secured by the chimney. Did the missing roof go as a single unit, or was it torn away in pieces? Was the failure due to internal pressurization caused by the breakage of the second floor window (shown circled in the figure)? Was some element or connector improperly installed? What components or connections actually need to be strengthened to prevent this type of failure from occurring in the next windstorm? Efforts to rescue anyone buried in the collapsed structure and to return the structure to some degree of functionality can hamper forensic investigations, as can the clean-up by the homeowner (notice the clean lawns around the houses at the time of the photograph, three weeks after the storm).

Flood and ruin: The Mississippi River and downtown New Orleans, with entire residential neighbourhoods under water. Stronger building codes wouldn’t have prevented the flooding after the levees broke, but they might have helped the Gulf Coast better withstand the battering of the perfect storms, Katrina and Rita.

While Canada does not have the same hurricane risk as coastal Florida and the Gulf states, we do occasionally experience them, as Hurricanes Hazel in 1954 and Juan in 2003 illustrate. We also have significant wind events associated with tornadoes and other thunderstorm winds that can be accompanied by large amounts of rainfall. Building codes play a crucial role in the safety of our homes. Timothy Reinhold, vice-president of research for the Institute for Business and Home Safety in Tampa, observed after the 2004 Florida hurricane season that "building codes make a huge difference. If we can get better codes in place, then we can reduce the amount of post-disaster assistance that the government is going to have to provide." Reports from the United States Federal Emergency Management Agency (FEMA), based on observations from the 2004 hurricanes, indicated that the performance of housing was dependent on which code it was built to. Newer homes built to the newer Florida codes performed well, with only a few failures due to errors in construction or the incorrect installation of structural features and materials. Improved codes also have the potential to reduce insurance claims and the resulting rates homeowners must pay. Risk optimization is possible: stronger structures have higher first costs but require fewer repairs after extreme events.

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The question of "how safe is safe enough" is not one that interests the average homebuyer, so at least minimum safety levels must be assured by governments through building codes. Sufficient resources are necessary for education and enforcement to ensure that code provisions are successfully implemented. Professor Paul Gauvreau of the University of Toronto observes that "building codes freeze technology and innovation" by at best providing prescriptive rules for existing or recently discovered solutions. New editions are published at five- or 10-year intervals. Code development has an inherent inertia as changes must be learned by the design profession and the various stakeholders in the construction industry. For example, a recent study by the American Concrete Institute identified a ten-year interval between the publication of new information in scientific journals and the adoption of the information in the Institute's Building Code Requirements for Structural Concrete. Recognizing this, the 2005 edition of the National Building Code of Canada will initiate the replacement of prescriptive design criteria with objective-based design requirements. The Canadian Commission on Building and Fire Codes identified several general objectives that the code is intended to achieve, including safety, health, accessibility, and fire and structural protection.

In the long term, the movement towards objective-based design codes is likely to impact the structural engineering design profession and construction industry as significantly as the Charter of Rights and Freedoms has impacted the legal profession. The transition is likely to be challenging, as designers struggle to define problems using broad objectives in place of familiar technical criteria. A large part of the challenge is that many of our current technologies are not adequately benchmarked, for example, 2-by-4 studs on 16-inch centres may be a widely used form of construction, but what specific features make it attractive? Quantification of the performance of traditional forms of construction is essential to measure the adequacy of new forms of construction through the development of new testing standards and protocols.

The University of Western Ontario's "Three Little Pigs" research facility is a full-scale testing facility to study structural, building envelope and moisture-related issues in houses. It will permit, for the first time anywhere, the application of realistically simulated time and spatially varying wind loads to full-scale houses in a controlled manner up to failure. It is this aspect of the project that led to naming of the facility after the famous children's story. Construction is now under way at a site at London International Airport: the first house "specimen" will be completed in spring 2006 and the facility will become fully operational by the end of 2006. A novel loading system (the "Big, Bad Wolf" in the story), is under development. Different building materials can be tested within the structural system (i.e., on the house) and separately under more standard testing conditions. Water will be introduced to see how it moves through the building envelope. Novel, real-time mould growth sensors are being developed to determine drying rates necessary to mitigate its formation and growth. In other words, all aspects of Canadian housing will be studied.

The resilience of houses to wind, snow or rain damage is controlled through the design, construction and maintenance of each individual structure, by builders and individual homeowners. The success of this strategy requires building codes that provide adequate levels of reliability without unduly inhibiting the implementation of new technologies. Moreover, builders and homeowners have to be educated about the importance of getting it right. Damage surveys after major failure events and full-scale testing, like the testing conducted at the Three Little Pigs facility, provide valuable scientific data that is necessary to improve our building codes and educate our construction industry.

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