Shingle Damage: In the Eye of the Storm

Gregory A. Kopp
Associate Professor and Canada Research Chair in Wind Engineering, University of Western Ontario

New research is trying to get a true measure of wind speeds and shingle damage in order to help model for hurricane damages.

Damage surveys following major wind events are critical for identifying potential problems with building codes, construction practices and building products.

In order for the surveys to be of value, it is necessary to know the wind speeds that caused — or did not cause — damage, since all design is based on the induced forces at particular wind speeds. This is more challenging than it may appear: wind speeds in the neighbourhoods where houses and other buildings have been damaged are rarely measured.

Usually, the only direct measurements of ground-level wind speeds are at airports or other weather stations. But these are sparsely spaced, are often far from where the hurricane makes landfall, and often do not function during the storm because of power outages.

Although 'hurricane hunter' aircraft measure wind speeds in the hurricane, these are far above ground and assumptions have to be made about what is happening down where the houses are. Hurricane hunters nevertheless provide valuable data for input to numerical models, which are getting increasingly better at predicting or estimating surface wind speeds.

Recently, there has been a significant effort to get portable anemometers into storms; at least three different groups are now making these measurements routinely. In the 2004-05 hurricanes, these groups tried to find the highest wind speeds in the hurricanes, since hurricanes are categorized by these speeds on the Saffir-Simpson Scale.

More recently, the emphasis has shifted to relating the speeds in open areas near the coast, where the highest speeds are found, to those in suburban neighbourhoods, where the majority of houses are.

DIRECT OBSERVATION

Photograph of tower belonging to the Florida Coastal Monitoring Program of the University of Florida, deployed in a suburban neighbourhood in Houma, Louisiana during Hurricane Gustav. This tower measured peak gust wind speeds of less than 80 mph. The house in the background was undamaged except for loss of about 2% of shingles. Nearby houses lost up to 50% of the shingles.

Hurricane Gustav was not a particularly powerful storm, although it is estimated to have caused upwards of US$10 billion in damage. And yet, despite the damages related to Gustav, its wind speeds were significantly lower than those used for design in this area. Measured peak gust speeds in Houma were about 80 mph, while the design speed for the region is 140 mph.

Much of Gustav's damage was caused by flooding and storm surge. But wind damage also played a role, with much of the media attention focussed on Baton Rouge. However, much closer to coast, where wind speeds are highest, the eyewall passed close to Houma, Louisiana, an area which had been hit by the 2005 hurricanes. This provided an opportunity to evaluate recent construction and measure wind speeds in typical suburban neighbourhoods. University of Florida researchers, Drs. Forrest Masters and Kurt Gurley and their team positioned 5 portable towers in several neighbourhoods in and around Houma and then waited for Gustav to arrive.

One of the advantages (for researchers) of a hurricane making landfall during the day is that you can see what is going on. And what we saw surprised us. Shingles were coming off everywhere, even in the weaker winds in the range of 40 to 60 mph prior to arrival of the eye of the storm. What was worse is that these failures appeared to be particularly bad for the new houses built since Hurricane Rita in 2005. When you can stand outside in the wind, effortlessly, and watch things coming apart, you know there is a problem.

HIGH ROOF SLOPES, FEW TREES

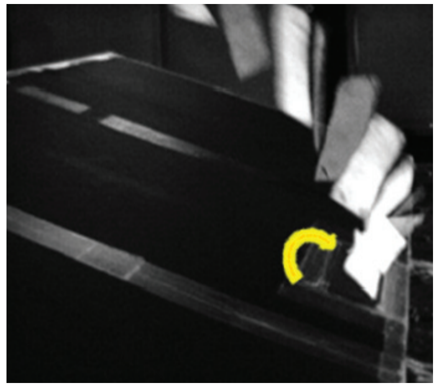
Photograph of a recently-constructed house in Houma, Louisiana the morning after Hurricane Gustav made landfall. The general lack of debris indicates a relatively minor wind event, although one cannot see all of the shingles in the backyard that flew off from the front of the house. Note that this area had been evacuated and no one had yet returned to clean-up; we were the only people here except for Emergency Response Personnel.

As a result of these observations during the storm, the team decided to conduct a damage survey on the following day of more than 1,000 houses in Houma, in randomly chosen streets, but covering every quadrant of the city. It was apparent that shingle failure was the only real issue in Houma, aside from the downed power lines and trees, so our damage survey focussed on this issue alone. It seems that the problems were primarily with new construction with relatively high roof slopes and few trees around. Preliminary analysis suggests these failures may have been due to insufficient connection between the adhesive on the underside of the shingle, with the roof. This led to shingle tabs flipping over and pulling the shingles over the nail heads. The close-up photos show this in detail:

Close-up photographs showing typical shingle failures with the nails still in the roof (left) and one of the shingles that came off with two nail holes visible (right).

Aside from direct costs associated with the replacement of the roofing material, other potentially more significant costs can arise from these types of failures. One is obviously water penetration, while the other is more indirect, namely, the costs associated with damage when the shingles become wind bourne and impact adjacent structures. Fortunately, neither seems to have played much of a role during Gustav because of the low wind speeds. One wonders what would have happened if the wind speeds had been much higher.

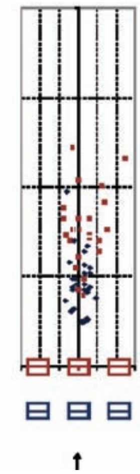
SHINGLES, HIGH WIND SPEEDS



Close-up stroboscopic image showing a single realization of shingle flight from the roof of a house in a scale model wind tunnel study. In this image, the shingle fails in the lower right, gets caught up in high speed flow at the roof edge, and accelerates upwards, eventually moving downstream with a speed higher than the gust speed upstream of the house that actually caused the failure.

To answer that question, we have been conducting wind tunnel studies at the University of Western Ontario on shingle and roof tile flight in order to assess the risk due to shingles impacting and penetrating adjacent houses. We have found several surprising facts, perhaps the most important pertaining to the flight speeds of the shingles. Typically, shingles can fly at speeds in the range for 50% to 120% of the undisturbed, upstream gust wind speed. This is a large range and is due to the nature of the turbulent wind gusts. While the shingles do not fly faster than the wind (actually they can, but there is not space to explain that interesting fact here), wind is actually accelerated above the roof of the house. Since the shingles are so light, they also accelerate quickly, leading to these high flight speeds. What this means, practically, is that they carry a lot of energy and the potential to break windows. They can also travel very far. Just as important for answering the question above, is to determine the flight speeds which break windows, and such research is currently being conducted at the University of Florida using full-scale impact tests. We have just begun to link the data from these two types of experiments.

SHINGLE DISTRIBUTION PATTERN



Typical flight distances observed in wind tunnel experiments. Note the great variability and that typical trajectories are further than the distance between houses.

As this research progresses we will be able to link all of this observational data in loss models which consider typical neighbourhood layouts, shingle loss frequencies (from damage surveys such as these, sponsored by the Institute for Catastrophic Loss Reduction), the flight distance data (from the wind tunnel tests), and the full-scale impact test results to develop probabilistic models for shingles hitting windows and breaking them. This is then linked to observed financial costs associated with the broken windows (due to water penetration and potential subsequent roof or sheathing failures due to internal pressurization) so that expected losses versus wind speed can be established. Relating storm wind speeds in open areas near the coast to wind speeds in the typical suburban and urban neighbourhoods (from observed tower data) is required for such models. Of course, loss models already exist, but the point to be made here is that it is of critical importance to incorporate all of this new information so that they are based on the most accurate engineering data available. These same data are also critical for the development of loss mitigation strategies, modifications to building codes, identification of code enforcement issues, and improvements to product tests. All of this starts by riding out the storm to get that data accurately.