All About the Nails

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Research on hurricane damage reiterates the importance of the basics in home building: when it comes to preventing roof damage, the nails need to attach the roof to the walls.

It's hard to think about hurricanes in the middle of winter in Canada. It is far more likely that we are thinking about snow or freezing rain. When we get a very heavy snowfall, we often worry about the weight on our roofs. Failures do occur, as the 1998 Ice Storm in Eastern Ontario and Quebec painfully illustrated.

Roof collapses under extreme snow loads involve failures of major structural components. Wind is different. Wind causes uplift when it blows over and around a house. One can best understand how wind acts on a roof by imagining a house turned upside down, with additional weights hanging off of it, especially near the corners and edges, and then shaking it. The nails become critical, holding the trusses to the walls, and holding the sheathing onto the roof.

One of the surprising aspects of damage surveys following major hurricanes is how little broken lumber you will see. You just don't see broken sheets of plywood or 2x4s. This is because they come off the roof intact. In fact, a lot of the damage in Hurricane Andrew, the worst wind disaster in U.S. history, was caused because so many nails on so many houses missed their mark. If one sees broken lumber at a hurricane damage site, it is usually because something has hit the structure such as a sheet of plywood or a roof tile from a neighbour's house. To mitigate wind damage, paying attention to these small details is critical.

At the University of Western Ontario (UWO), we have developed technology to test these details at the Insurance Research Lab for Better Homes (IRLBH). The project receives funding from Canada Foundation for Innovation and the Ontario Innovation Trust in partnership with the Insurance Bureau of Canada and the Institute for Catastrophic Loss Reduction. The lab has recently conducted tests using innovative technology on a full-scale, two-storey, gable roof house.

The idea behind the IRLBH is to replicate hurricane-force winds, as well as other types of damaging winds, on low-rise buildings and houses. The experiment uses specially designed actuators and vinyl pressure bags to apply both positive (i.e. push) and negative (i.e. pull) pressures on full-scale specimen. One can develop hurricane-force winds in a laboratory in a few ways; the most obvious is to build a very large and very powerful wind tunnel. The team at UWO considered this prohibitively expensive, so we developed an alternative method using the pressure actuator concept. This costs about one-tenth of what such a large wind tunnel would cost, in terms of both capital and operational costs.

The actuators are first attached to a steel exo-skeleton that surrounds the house. (See Figure 1 on Page 62.) These are used to apply pressures on the house via inflation of the vinyl bags. When the steel frame around the house holds all 100 actuators and accompanying airbags, the surface of the home would scarcely be visible. Indeed, when this takes place, members of the research team would have to enter the house by crawling under it and using a trap door located in the floor. For the first tests, however, only the roof was rigged up with actuators and vinyl bags.

The results of the tests had some surprising aspects.

The roof was first subjected to the fluctuating, dynamic pressures consistent with a Category 1 hurricane. After subjecting the roof to this for 15 minutes, all we observed were minor cracks in the drywall. The nails had moved less than a millimetre.

After stopping and restarting the actuators, each time ramping up the pressure, it was discovered that the nails in the roof began to pull out a bit at a time. (See Figure 2 on Page 62.) There are several high-speed wind gusts over the duration of 15 minutes; these cause significantly elevated pressures. The largest uplift forces are of short duration, typically less than a few seconds and often less than a second. In fact, in these particular tests, there is a moment in which the load tripled in value in about half a second. For Category 1 wind speeds, this meant nails pulling out about 1 mm. For Category 3 wind speeds, this meant nail displacements of about 20 mm. However, as the gust passed, the weight of the roof would push the trusses back down, taking the nails with them. By the time the Category 3 test was completed, there was total failure of the toenails; they had no capacity left to resist the wind uplift. At this point, the

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only thing holding the roof in place was its own weight.

As a result of these tests, it became evident that it is possible for a roof to become completely disconnected from the walls, yet settle back down with little visible evidence of such a catastrophic failure having taken place. A roof can be sitting on the walls, appearing to be fine, when in reality it has become disconnected from the structure. Remarkably, the drywall showed only minor cracking. Such a failure may only be detected if someone were to enter the attic and conduct a very careful inspection of the connections. If such a home were to be hit with another wind event days, weeks or even years later, it could conceivably lose the roof in a much weaker wind storm.

Given the importance of the nailed connections, the IRLBH team ensured that every nail used to secure roof sheathing and every toenail connection in the house was recorded in detail. This will aid in the ongoing interpretation of the experimental data and to aid computational modelling. Such computational modelling is of critical importance since there are many variations on the shapes of houses and only a few, at most, will ever be tested in the lab. After combining calibrated computational models and wind tunnel test data for a wide range of house and building shapes, the data will ultimately be used for the development of probabilistic failure (risk) models.

So, resistance to wind loads is really all about the nails. Nails that are sunk but miss joists or trusses, or nails that result in connections that badly crack the wood, are as useful as having no nails at all. An improperly sunk nail can mean the difference between one nail holding just a few pounds of force and another one being able to handle 80 pounds of force or more. These details are critical.

As reflected in the Vision Statement of the IRLBH, the idea behind the facility is to find optimal solutions that "mitigate damage to homes and other light-frame structures under extreme environmental conditions; conditions such as wind, wind-driven rain, snow, and the various factors that support mould growth." These initial tests conducted at the IRLBH are important first steps to realizing that mandate.

Figure 1 (right): Photograph of the two-storey test house at the Insurance Research Lab for Better Homes.

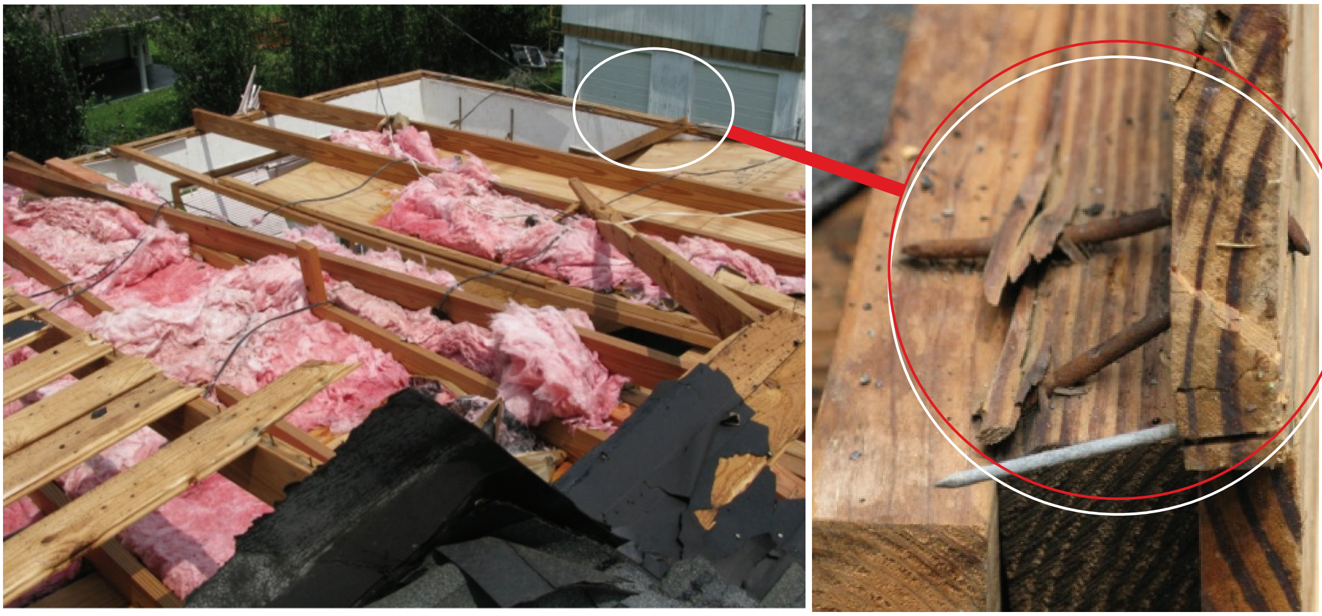

Figure 2: Photograph of roof damage to a house in Houma, Louisiana caused by Hurricane Gustav. The roof joists at the corner were not connected to the walls. The photograph on the right shows a close-up of the corner of the roof section that flew off of the house. There were toenails in the joist, they just had not been connected to the walls.