NATURAL HAZARD MITIGATION INSIGHTS

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WIND-RESISTANCE OF ROOF COVERINGS

Wind and hail catastrophes[1] resulted in an estimated $40 billion in insured losses from 1991 through 1995, or an average of $8 billion each year.[2] Even if the arguably distorting effect of Hurricane Andrew's losses are deleted, the average is still $4.8 billion per year.

Wind damage to roofs is a large part of these numbers. The most pervasive type of damage to buildings in southern Dade County as a result of Hurricane Andrew was the loss of roof coverings and sheathings.[3]

THERE IS NO ADEQUATE TEST METHOD TO DETERMINE HOW WELL ROOF COVERINGS WILL STAND UP IN A WINDSTORM.

Wind damage to roof structures can lead quickly to further and far more expensive losses. For example, rain and wind have easy access to the exposed interior, resulting in extensive damage to contents or even loss of the entire building.

In addition, the roof shingles, tiles and ballast blown off in a storm can act like missiles, propelled by the wind into nearby properties, multiplying the overall losses for the community.[4]

A report by the Southern Building Code Congress International after Hurricane Andrew noted that some builders believe roof coverings do not warrant the increased cost of wind-resistant design, since they are not expensive to replace.[5] But the loss of a roof covering and its underlying sheathing can often lead to massive internal damage. Durable roofing materials have value far beyond their own cost.

There is no adequate test method to determine how well roof coverings will stand up in a windstorm. The primary test methods for commercial roof coverings, for example, use air pressures in a closed system, rather than wind.

The primary test method for asphalt shingles was developed over 30 years ago, and uses 60 mph winds generated by a fan and blown across a small sample of the roof. The reason a 60 mph speed was chosen is that it was the maximum capacity of the fan at the time. Meantime, hurricane winds can exceed 150 mph. Building codes in hurricane-prone regions call for buildings capable of resisting 110 mph winds, and the recommended minimum design speed in the United States is 70 mph.

Damage to residences makes up the bulk of the losses in hurricanes. Commercial

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buildings and roofs receive more engineering attention and therefore perform better in high winds. For that reason, this paper primarily addresses residential roof coverings.

The Insurance Institute for Property Loss Reduction believes there should be an up-to-date consensus test method that measures the resistance of residential roof coverings to the types of wind speeds and pressures found in real windstorms. If roofing products are tested by that yardstick, consumers will be able to make better decisions about the quality of the roof coverings over their heads. Better decisions should lead to better products.

TYPES OF ROOF COVERINGS

This paper addresses roof coverings, not the roof decking (or sheathing), the roof frame (or truss), or the frame-wall connection. Each of these other aspects of a roof system is also important to the roof's performance in high winds, but is beyond the scope of this discussion.

Roofs fall typically into two categories — steep slope and low slope — due to the characteristics common to each category. In the colder regions of the United States, most residential roofs have a steep slope. Regardless of location, most commercial roofs have a low slope.

The most common types of steep-slope coverings are asphalt, wood and metal shingles; tiles (nailed or set in mortar); and metal panels. The most common types of low-slope coverings are single-ply membranes, built-up roofs and spray-applied polyurethane foams. Single-ply membranes are made at a factory, shipped to the site, and held in place with adhesives, ballast (rocks or gravel) or metal fasteners. Built-up roofs are constructed at the site itself by pouring the covering material over a prepared surface.

THE PROBLEM

Building codes require buildings to be capable of resisting specified wind loads. In general, it is not their function to tell an architect or builder precisely how to design or construct a house. Consequently, the codes do not identify particular wind-resistance tests that roof coverings must satisfy.[6]

It is up to the builder or architect to specify the appropriate building components, including the roof covering, capable of doing the job. For that job, builders can refer to wind-resistance standards published by organizations such as Factory Mutual Research Corporation (FM) and Underwriters Laboratories Inc. (UL).

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There are residential building codes that take a prescriptive approach, which means they prescribe how to build a house in such a way that it will resist the appropriate wind loads, rather than simply demand performance under a specified wind pressure. For example, the Southern Building Code Congress International publishes a Standard for Hurricane Resistant Residential Construction, which specifies the uplift-resistance of connectors between the roof truss and sidewalls, depending upon the wind zone and the building width. However, it says nothing about the wind resistivity of the roof covering itself. The builder or architect must make that decision.

The One and Two Family Dwelling Code published by the International Code Council also emphasizes construction details rather than performance requirements. It specifies that roof coverings must conform to various standards published by others, but none of those standards deals with resistance to uplift or wind pressures.[7]

EXISTING STANDARDS

There are a number of wind-resistance standards. They take varying approaches, but none adequately mimics an actual high-wind event, which involves positive (pushing) pressure from the side and from below, negative (pulling) pressure from above, and instantaneous, on-and-off bursts of wind back and forth, all of which cause varying uplift pressures.

The shape and slope of the roof deck and the edge configuration are also critical to shaping pressure loads in real storms. A single, uniform load of air pressure pushing on a small sample does not come close to the nonuniform effect of wind blowing over a roof, but that is the traditional way to test a roof covering for wind resistance.

The performance of a roof covering depends in part on the substrate materials to which it is applied. For that reason, the testing agencies (FM and UL) generally prepare a test panel assembled to the manufacturer's specifications, including type and thickness of deck, application method, thickness of insulation and type of roof covering. From there, the test methods vary.

Factory Mutual

For the most part, Factory Mutual tests and certifies commercial, rather than residential, roof coverings. There are two primary reasons. First, the insurance companies affiliated with FM write property insurance for commercial structures. They base their rates in part on whether the structure has various FM approved components. A building whose roof meets a rigorous FM Approval Standard will attract a lower premium than a building with an unapproved roof, all other things being equal.

Second, architects for commercial projects tend to specify a roof covering that meets an FM Approval Standard. Residential construction does not generally get the benefit of an architect's preparation of specifications.

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Both of these factors create pressure for commercial, but not residential, roof covering manufacturers to comply with the FM standards.

For wind uplift resistance, FM uses either a 9-ft-by-5-ft or a 12-ft-by-24-ft frame.[8] Mechanically attached membrane roof coverings with fastener spacings greater than 4 feet on center are tested in the larger 12-ft-by-24-ft frame because the smaller 9-ft-by-5-ft frame produces unreliable results with roof coverings that have extended spacings.

The frame clamps a roof sample in place while an air compressor pushes air at it from below. The set-up holds the air against the roof sample in a closed system. The air does not escape around the sample. It is important to keep in mind that this and similar test methods do not use wind at all; instead, they create air pressure which pushes against the underside of the roof sample until the pressure is released.

The sample must withstand at least 60 psf or 90 psf uplift pressure for one minute to qualify for Factory Mutual Class 1-60 or 1-90, respectively, and so on up to Class 1-180.

This test procedure applies to most but not all types of roof covers. For instance, insulated steel deck roofs are tested on a different frame but with the same compressor blowing air at the same pressures from below.

FM will also test the top of the roof sample to determine how well it can withstand negative or vacuum-type pressure. An architect has the option to specify a roofing system that complies with the topside negative pressure test. The bottomside positive pressure test is mandatory. For roof decks that are impermeable to air, there is no option: FM applies pressure both to the underside using compressed air and simultaneously to the top using a vacuum chamber.

Underwriters Laboratories

Underwriters Laboratories has three standards for resistance to uplift or wind pressure. First is the UL 580 standard, which is more rigorous and produces more conservative results than the FM methods, but which is similar to the FM methods because it uses no wind at all. A generator creates air pressure (or a vacuum) that pushes (or pulls) the roof sample.

> **IT IS WITHIN A BUILDER'S PREROGATIVE TO PUT ASPHALT SHINGLES THAT HAVE NO WIND-RESISTANCE LISTING WHATSOEVER, ON A HOUSE LOCATED IN A 100-MPH WIND ZONE.**

UL 580 has not been as widely accepted among manufacturers as the FM test methods. As a result of industry objections, UL developed a second and less rigorous test procedure, UL 1897, which is even closer to the FM test methods. It tests resistance to uniform air pressure starting at 15 psf and increasing by an additional 15 psf every minute until failure or a designated pressure is reached without failure.

A third standard, UL 997, which applies only to self-sealing and interlocking shingles, actually does use wind. It calls for a fan to blow air at 60 mph through a 3-ft-by-1-ft opening at a test panel for two hours. The test panel is 50-inches-by-66-inches, tilted toward the horizontal stream of air so that the third course of shingles from the bottom edge is on the same plane as the airstream.

UL developed this procedure in concert with the roofing industry in response to concerns that asphalt shingles, although the most widely used covering on steep-slope roofs in the United States, have relatively poor wind-resistance. UL 997 was not intended to test resistance to uplift pressure but rather to test the strength of the bond holding the shingles down flat or interlocked.

American Society for Testing and Materials

The American Society for Testing and Materials (ASTM) publishes a "Standard Test Method for Wind-Resistance of Asphalt Shingles" (D3161) which, like UL 997, calls for a 60 mph wind blown horizontally for two hours through a 3-ft-by-1-ft opening at test panels at least as big as 50 inches by 66 inches. ASTM does not conduct any actual testing; it simply develops test protocols.

Dade County

The Metro Dade Building Code Compliance Office in Dade County, Florida, set out to create a new, comprehensive set of weather-resistance building standards and test methods applicable to all new construction, both residential and commercial. Dade County will not issue a building permit unless the building components comply with whatever test methods are applicable. Compliance testing can be done for a component manufacturer by any independent testing company that meets Dade's requirements. Underwriters Laboratories and

Factory Mutual, for example, have received Dade's approval as testing companies.

Dade County divides roofs into two general types: continuous assemblies having a homogenous membrane and discontinuous assemblies having overlapping components. In the first category are commercial single-ply and built-up roofs. In the second are residential shingles and tiles. There is no wind test that applies across the board.

The starting point for all of the discontinuous (residential) assemblies is protocol PA 100-95, which tests for infiltration by wind-driven rain. It is not designed to measure performance against code design wind speeds in South Florida. Basically, it calls for a fan-induced wind speed up to 110 mph. Water is supplied to the wind stream by a sprinkle pipe capable of simulating 8.8 inches of rainfall per hour.

Asphalt shingles have a separate and additional wind-only test. They have to withstand a static stream of fan-induced 110 mph winds for two hours, targeted at the third row of shingles from the bottom of a test specimen angled away from the fan (PA 107-95). This is similar to UL 997 and ASTM D3161, but with a higher wind speed. It does not duplicate the vortices and microbursts that whip shingles off a roof in a windstorm.

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Mortar and adhesive-set tiles have to pass a static uplift resistance test (PA 101-95), which involves drilling a hole into a tile on a test specimen, inserting a concrete anchor or an epoxy bolt, and pulling on the anchor or bolt from above. Dade officials concluded that windstreams in a lab do not accurately measure the field performance of tiles set in mortar or adhesive.

The other types of discontinuous assemblies — fiber cement shingles, slate shingles, wood shakes and metal shingles — have no wind-only or uplift-only test. Dade County relies strictly on the wind-driven-rain test to measure their performance in high winds but does publish separate design criteria.

The starting point for all continuous (commercial) assemblies is protocol PA 114-95, which has three uplift pressure tests to choose from, none of which involves wind:

- mechanically attached assemblies are subjected to a static, pushing air pressure from below and dynamic suction or negative pressure from above;
- totally or partially adhered assemblies are subjected to a static, positive pressure from below; and
- liquid and spray-applied assemblies are pulled at from above by an eyebolt secured to a hoisting device. There is no air pressure at all in this option.

Other Test Methods

Manufacturer trade associations have also begun to develop their own pressure-resistance tests. For example, the Asphalt Roofing Manufacturers Association has funded the development at Colorado State University of a model that indicates the pressures across the surface of an asphalt-shingled roof. The Metal Building Manufacturers Association and the American Iron and Steel Institute have sponsored work at Mississippi State University on an electromagnetic grid that simulates air pressure on a metal roof. The grid pulls on the roof sample at various points with magnetic force. Neither of these efforts has any application beyond either asphalt shingles or metal roofs.

CONCLUSION

Residential builders typically do not call for roof coverings that comply with FM, UL or ASTM standards, and building codes do not require them to do so. In short, it is within a builder's prerogative to put asphalt shingles listed by UL 997 for 60 mph winds, or even shingles that have no wind-resistance listing whatsoever, on a house located in a 100-mph wind zone, providing only that the builder installs the shingles as the codes specify.

Even if residential builders were insisting that the roof coverings they purchase comply with wind-resistance tests, the problem would not be solved. The existing standards for wind-resistance of roof coverings simply do not do a good job of simulating either the dynamics of wind or of wind flow over a roofing system.

There should be a consensus test method capable of determining, with reasonable approximation, the resistance of residential roof coverings to high winds, rather than to air pressures or a simple, static, narrow stream of 60 mph wind. Consumers are entitled to know how well their roof coverings will perform the next time a windstorm cuts through their community.

*This report was written by **Paul A. Devlin** of the Insurance Institute for Property Loss Reduction.*

REFERENCES

1. Catastrophe serial numbers are assigned by the Property Claims Service (PCS) when insured losses exceed $5 million (to be increased to $25 million Jan. 1, 1997) and result in a significant number of individual claims. Flood damage is included in this number, but not if it is covered by the National Flood Insurance Program, so the flood aspect is not substantial.

2. Property Claim Services division of American Insurance Services Group.

3. FEMA/Federal Insurance Administration, Building Performance: Hurricane Andrew in Florida, FIA-22 (December 1992), p.2.

4. Gary G. Nicholas and Sam Gerace, "Survey of Hurricane Andrew," Southern Building (March/April 1993), p. 14.

5. Nicholas and Gerace, "Survey of Hurricane Andrew", p.14.

6. The one exception is the National Building Code published by the Building Officials and Code Administrators International Inc. It calls for mechanically attached, low-slope, non-ballasted roofing systems to be tested in accordance with Factory Mutual Approval Standard 4450 or 4470 or Underwriters Laboratories 580.

7. Chapter 9 of the One and Two Family Dwelling Code.

8. Factory Mutual Approval Standards 4450 and 4470.

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