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Wind Uplift and Spray Polyurethane Foam (SPF)

A report written by Huntsman Polyurethanes

You can't do anything about weather; however you can find ways to better weather a storm. Closed cell spray foam insulation applied to the underside of the roof can greatly reduce the risk of wind and water damage during significant storm events.

Too many homeowners living in hurricane and tornado-prone regions know first-hand the damage monster storms can deliver to homes and communities. While predicting storm paths and calculating potential damage has improved, living in coastal regions invariably puts homes in harm's way in severe weather events. **Today, builders, remodelers and architects are discovering better ways to protect homes from the potential destruction a hurricane, tornado or severe weather event can cause. Closed cell spray polyurethane foam (SPF) insulation is proving to be an important tool in this fight.**

Each year an average of 11 tropical storms develop, and only six gain enough strength to be classified as a hurricane. These storms can have sustained winds that range from 74 mph (Category 1) to over 155 mph (Category 5). According to the National Oceanic and Atmospheric Association (NOAA), over a three year period about five hurricanes strike land along the U.S. coastline — approximately two of these classified as a Category 3 storm or higher.

When hurricanes do make landfall in the United States, the cost in property damage can be considerable. Losses associated with hurricanes average over $5.1 billion per year and cumulatively, have topped $148 billion since the year 2000.

HURRICANES DAMAGE HOMES IN THREE PRIMARY WAYS:

1. Storm surge damage
2. Wind damage
3. Water damage from rain

While storm surges only impact areas within a few miles of the ocean, wind and rain damage can spread extensively inland. In 2008, Hurricane Ike made landfall in Galveston, Texas and headed northeast leaving a swath of destruction across the United States and into Canada. Hurricane Ike was so powerful it left almost 1 million people without power in Ohio, even after it had been downgraded to a tropical storm.

SAFFIR-SIMPSON HURRICANE SCALE

Storm Classification	Wind Speed (mph)
Tropical Depression	0-38
Tropical Storm	39-73

Hurricanes	Wind Speed (mph)
Category 1	74-95
Category 2	96-110
Category 3	111-130
Category 4	131-155
Category 5	> 155

The Saffir-Simpson Hurricane Scale is used to determine the size and strength of a storm based on sustained wind speeds.

Source: National Oceanic and Atmospheric Administration (NOAA)

RECENT HURRICANES AND THEIR COST

Year	Hurricane Name	Category	Cost (US $)
2012	Sandy	Category 1 (sustained winds near 90 mph)	>$52 billion
2008	Ike	Category 4 (sustained winds near 135 mph)	$19.3 – $21 billion
2005	Wilma	Category 2 (sustained winds of 100 mph)	$16.8 billion
2005	Rita	Category 5 (sustained winds of 165 mph)	$10 billion
2005	Katrina	Category 5 (sustained winds of 175 mph)	$75 billion
2005	Dennis	Category 3 (sustained winds of 111 mph)	$2.23 billion

Source: National Oceanic and Atmospheric Administration (NOAA)

WIND DAMAGE

According to AccuWeather Inc., of the three primary ways hurricanes can damage homes, wind are the greatest cause of property loss. When Hurricane Andrew struck Florida in 1992, it was at that time, the most expensive natural disaster in American history. This storm caused over $26 billion in damage, destroyed over 25,000 homes and severely damaged over 100,000. Of those damaged, over half the homes had significant damage to the roof as a result of wind damage.

Hurricane winds are unique and pose a specific threat to wooden frame built homes and traditional roof systems. First, the sustained winds from a hurricane can last for hours with occasional gusts up to 50 percent greater than sustained air speed. This means a Category 2 hurricane, with winds at 100 mph, could have gusts that exceed 150 mph, which is equal to category 4 strength. Also, because hurricanes move slowly, wind direction changes slowly as the storm passes. **This means that any weakness in the roof system will eventually have to face the brunt of the storm.**

Finally, winds from hurricanes can create a challenge for roof systems simply because of the dynamics of wind flow around a home. As air speed increases, the amount of pressure put on the home exponentially rises. A sustained wind speed of 75 mph will deliver about 19 pounds of pressure per square foot (psf), while a 150 mph wind will create almost 80 psf. To put this in context, a standard 4 x 8 sheet of roof sheathing could face over 2,500 pounds of force when set directly in front of a category 4 hurricane.

VELOCITY PRESSURE AS A FUNCTION OF WIND SPEED

Wind Speed (mph)	75	95	110	130	155	180	200
Velocity Pressure (psf)	19.0	30.6	41.0	57.2	81.3	109.7	135.0

Source: American Society of Civil Engineers, 1990

Understanding Wind Uplift Characteristics

However, when hurricane force winds strike the home, the flow of the air around the building is rarely consistent or direct. Due to the design of a roof, air pressure can vary greatly in different parts of the roof, which can increase the possibility of damage. **Roof damage of this nature can result from wind uplift, one of the leading causes of roof failures during a hurricane.**

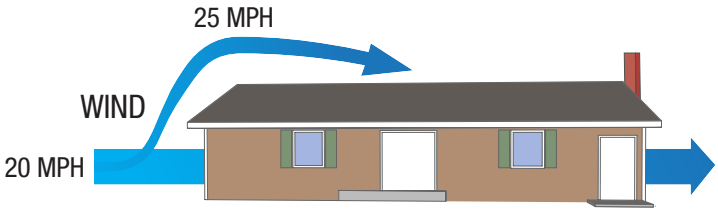
What is Wind Uplift?

Wind uplift is a naturally occurring vacuum created in strong wind events that results in a rapid and sustained loss of air pressure due to high winds or a disruption in the "laminar flow" of air around the building. Laminar flow is a concept which states that air will try to stay in contact with whatever object it is passing over. If this flow is interrupted because of a sharp rise, curve or fall in the object, the path of the air stream continues and under it a vacuum is created.

Roof damage caused by wind uplift occurs when the air pressure below the roof is greater than the air pressure above the roof. High wind speeds, in general, can cause a reduction in air pressure as they flow over objects.

At the same time, negative pressure is developed on the roof surface by wind flowing over the roof surface, while positive pressure to the underside of the roof deck is developed from the wind blowing through open windows and doors of the building. The result is an upward force on the roof.

The combination of the negative pressure and positive pressure can double the destructive force of the wind causing roof assembly failure.

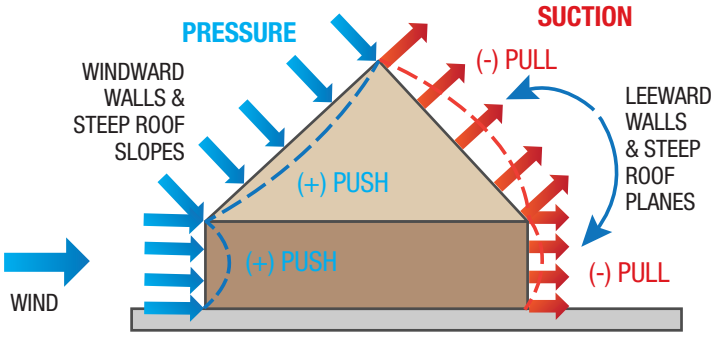


During strong gusts, on relatively flat roof surfaces where the wind is flowing more than striking, air pressure can quickly drop as air speed increases. This loss of air pressure can act as a vacuum and start to pull roofing material into the air stream where the direct force of the wind will potentially sweep them away.

The other force that can create uplift is a disruption in the laminar flow of air around the roof. In the case of a roof, as wind strikes the leading edge, the roof forces the air to flow over the ridge. However, laminar flow is often lost on the lee side of the home, which creates uplift on the downward side. If the wind speed is great enough, this vacuum can pull off shingles, lift eaves, and start to weaken the whole roof structure.

As hurricanes move through an area and wind direction shifts, all parts of the roof can become exposed to both the direct pressure of the wind, and also the effects of uplift. When the wind is blowing parallel to the eaves and ridge, uplift is created along the rake, or inclined edge of a sloped roof over a wall. When the wind is blowing directly towards the roof or at a 90-degree angle from the eaves and ridge, uplift can target the downwind side of the ridge and corners.

The dynamics of simple air pressure against the exterior of the house can create incredible pressure and uplift on a roof and result in extensive damage. Additionally, internal pressures cause roof failures in hurricanes as well.



Pressure vs. Suction

Source: American Society of Civil Engineers, 1990

When windows or garage doors implode during a hurricane, air pressure within the home increases suddenly and significantly. While exterior surfaces are generally designed and built to withstand extreme air pressure, interior walls and doors are not. The increased air pressure can inflate the home like a balloon. When this happens roof sheathing can quickly be blown up and away from the home. Not only do the high wind speeds create a vacuum above the roof, but inflation within the home increases air pressure beneath the roof causing it to be blown off.

Blown off roof

House is still standing, but the roof has been torn off

In the Federal Emergency Management Agency (FEMA) post-hurricane analysis of Hurricane Ivan, which struck the coastal areas of Alabama and Florida in 2004, the mitigation assessment team reported the most common roof damage to homes affected by the storm was the removal of shingles and roofing underlayment.

When roofing materials begin to fail during a hurricane, damage to the home can rapidly increase. If roof coverings are damaged or blown away, rainwater can enter into the attic space, soak insulation, saturate drywall, and weaken the structure. After Hurricane Andrew, 65 percent of the homes that filed insurance claims reported damage from rain. Compounding the problem of water in the structure is mold growth. Once building materials become saturated, mold growth can quickly lead to indoor air quality issues that can persist long after the storm has passed.

Of greater concern, though is the potential for a complete building to collapse. **Catastrophic failure of roof systems can quickly lead to a complete collapse of the building.** Often when homes are completely destroyed it is the roof system that fails first, allowing wind and rain to enter the home unchecked. Post-hurricane analysis of Hurricane Ivan supported the conclusion that existing approaches to roof fastening were either insufficient or improperly installed. This is especially true of older buildings that were built before the more stringent building codes were enacted. Among the observations of the mitigation assessment team was:

- Older building codes methods did not always result in resistance to high design wind pressures on critical building areas such as corner and wall areas.
- Even if an older building code was in place, the enforcement of the code may have been ineffective.
- Older buildings may have suffered from degradation of strength due to corrosion, termites, dry rot, poor maintenance, or a variety of other factors.
- Construction methods and materials commonly used at the time the older buildings were built may now be considered inappropriate for a high-wind area.

These observations led to a common theme that hurricane clips or straps were ineffective, if corroded or not installed correctly. **Installing closed cell SPF to the underside of the roof deck glues the whole structure together reducing or eliminating the "weak spots" that a corroded or poorly attached hurricane clip might have.**

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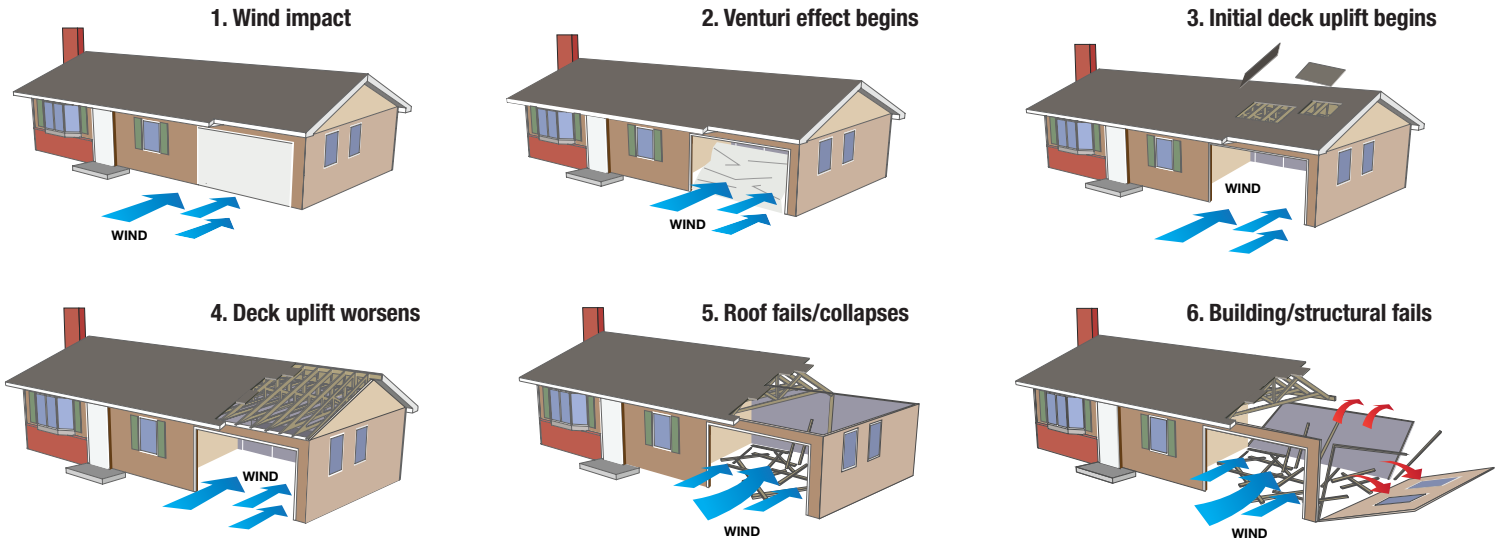

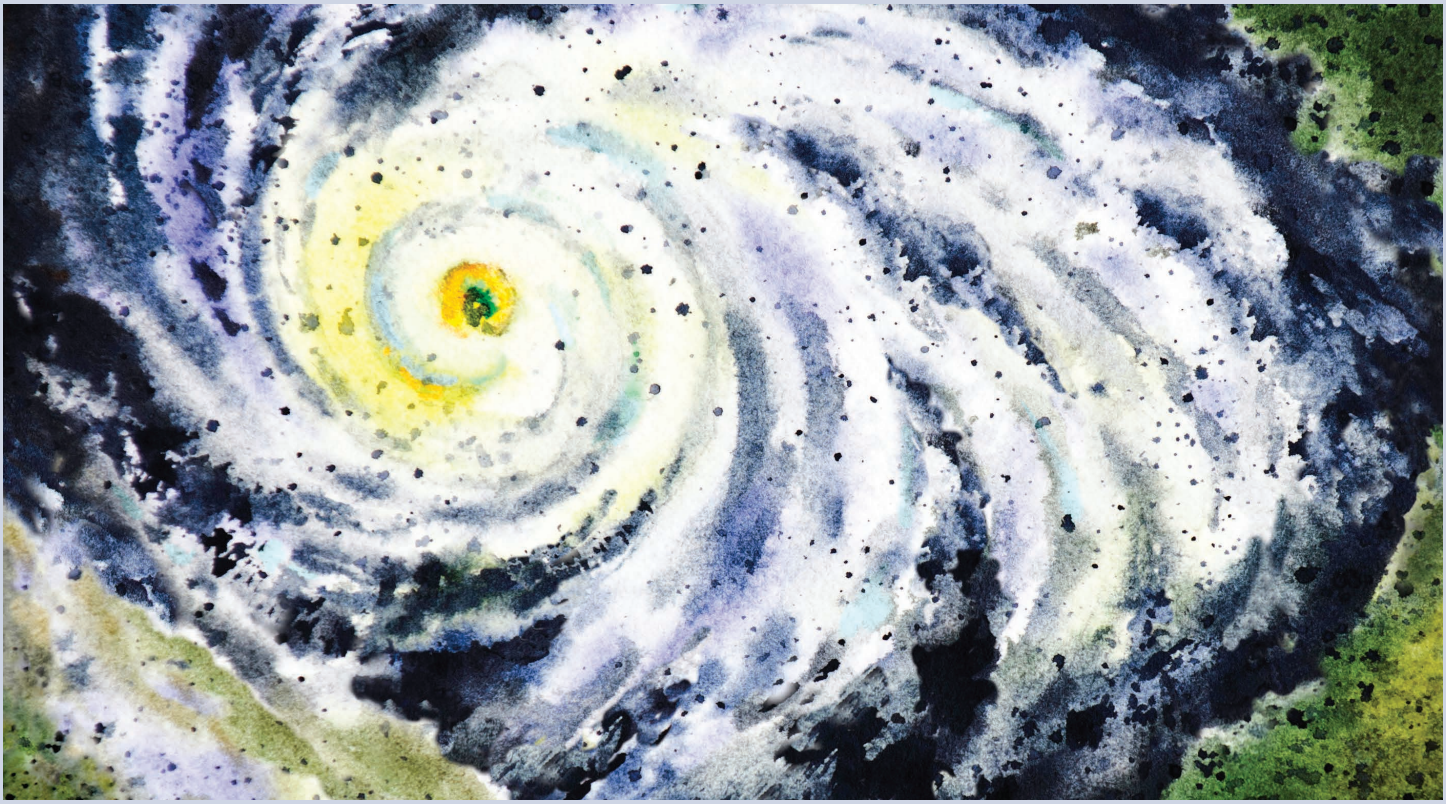

THE IMPORTANCE OF HURRICANE RESISTANCE RATINGS

It's not hard to imagine that if you own a home in hurricane country you might decide to invest in some preventative building products to protect your property. But finding the right products that will actually defend your home from a category 4 storm isn't always as easy as it sounds. While there are plenty of products on the market that "guarantee" protection, few have gone through the difficult, expensive, and time consuming process of getting certified as approved for use in high velocity wind zones (HVHZ), where wind speeds can exceed 140 miles-per-hour.

The Florida Building Commission offers a classic example of how building products can be rated and certified based on how well they will perform in hurricane prone regions. In order to qualify for use in a HVHZ, building products must undergo extensive third-party evaluation and follow a specific production, inspection, and quality assurance path set out by the Florida Building Commission. This includes validation from a qualified test lab, independent certification agency, evaluation entity or Florida registered architect or a recognized professional engineer.

Because some local building codes are more stringent than general state-wide building codes, products are usually certified on the local level first, and then have an option to achieve state product approval. Products that must go through certification in order to be approved for use in HVHZs include:

- Panel walls
- Exterior doors
- Roofing products
- Skylights
- Windows and shutters
- Structural components and building envelope products

Only after successfully passing the product testing phase and approval from the Florida Building Commission can building products be rated and certified as appropriate to use in HVHZs.

For builders, architects, and homeowners, choosing products rated for hurricane force winds can mean the difference between property protection and property destruction. Too often products claim to be storm resistant, but have not gone through the process of independent evaluation. When dealing with the concerns of damage to roof structures, choosing building products that have been rated and certified to reduce the chance of uplift is especially important.

In hurricane-prone areas like Florida, building codes for new construction now mandate protection for up to 120 mph winds or Category 3 hurricanes. Other improvements to buildings include more aggressive nail patterns in roof assemblies and taping the seams in roof sheathing to reduce water intrusion. While more stringent building codes help reduce the amount of damage to new homes, what actually happens during hurricanes does not always match expectations.

In the case of Hurricane Ivan, building codes had prescribed a design wind speed of between 140 and 150 mph, meaning that new residential construction was meant to withstand a Category 4 hurricane. However, post-hurricane Ivan reports indicate that even though actual sustained wind speeds were recorded around 109 mph (Category 2 strength); damage to building exteriors was significant and widespread. Specifically, roof decking, windows, doors and wall cladding all appeared to have been exposed to much greater wind speeds and suffered considerable damage. **The observations concluded even when hurricane wind pressures are 25 percent to 40 percent less than code-prescribed measures, roof systems can still be vulnerable to hurricane destruction.**

CLOSED CELL SPRAY POLYURETHANE FOAM RECOGNIZED BY FEMA

One technology gaining traction among architects, builders and federal agencies for use in improving roof integrity during hurricanes is closed cell spray polyurethane foam.

In its Home Builder's Guide to Coastal Construction, Federal Emergency Management Agency (FEMA) highlights the benefits of closed cell SPF. In fact sheet 1.8, "Non-Traditional Building Materials and Systems," FEMA incorporates an entire section on sprayed closed-cell foam insulation and the inherent advantages of its use in coastal building practices. Major points include the speed of installation versus batt insulation; foam expanding to fit wall cavities, formation of a rigid barrier to keep moisture out, and "offers acceptable flood resistance" (citing a National Flood Insurance Program technical bulletin). The fact sheet goes on to explain a complete system of flood-resistance would also include corrosion-resistant metal, or pressure-treated wood framing, for maximum effectiveness in a severe flood situation.

Closed cell SPF is an insulation that also functions as an air and bulk water barrier and as moisture vapor retarder. SPF is made by reacting MDI (A-side or iso) with a polyol blend (B-side or resin). The two liquid components are joined under pressure in a spray nozzle where they are applied directly onto wall, roof or building assembly. Once the reacting liquid hits a surface, it expands and solidifies into a foam matrix. SPF is typically applied by certified professionals. Closed cell SPF (2-3lb. per cubic ft.) has a high R-value of over 6 per inch, provides structural enhancements to buildings, and is effective in all climates. It is typically installed in wall cavities, attics, basements, crawl spaces or on a building's exterior walls.

In 2007, Dr. David O. Prevatt conducted a study at the University of Florida's Department of Civil and Coastal Engineering to determine how closed cell SPF could be used to increase the structural integrity of roof assemblies during severe weather events like hurricanes.

Specifically, the research focused on evaluating how the SPF could protect the roof from uplift and reduce the chance of water intrusion during storm events. To test the material, two approaches were taken. First, a continuous 3-inch thick blanket of closed cell SPF was applied between the 2 x 4 roof rafters to evaluate the effectiveness of a full, monolithic covering of closed cell SPF in the roof assembly. The next approach was to apply closed cell SPF as a three-inch fillet to the junction of the roof plywood deck and the roof rafter/truss top chords.

The study concluded that using closed cell SPF, either in a continuous 3 inch blanket or in fillets, increased the roof panel wind uplift capacity by 2.6 times that of roof panels fastened using conventional mechanical fasteners and nailing patterns.

In fact, roofing sections with closed cell SPF applied as an adhesive were able to withstand air pressures in excess of 153 psf, or roughly the wind speed found in a category 4 hurricane.

SPF ADDS RACKING STRENGTH

Three separate studies in 1992[1], 1996[2] and 2006[3], conducted by the National Association of Home Builders (NAHB) Research Center and Architectural Testing Inc., compared relative structural strength of common baseline wall assemblies to similarly constructed wall assemblies insulated with closed cell SPF. **The studies found (closed cell) SPF could add from 75 to 300 percent increase in racking strength to walls of oriented strand board (OSB), plywood, gypsum wallboard, vinyl siding and polyiso board.**

1. Testing and Adoption of Spray Polyurethane Foam for Wood Frame Building Construction, May1992 prepared by NAHB Research Center for The Society of the Plastics Industry/Polyurethane Foam Contractors Division.
2. Test results reported by Bob Dewey, Mechanical Engineer, NAHB Research Center to Mason Knowles, The Society of the Plastics Industry/Spray Polyurethane Foam Division (November 1996).
3. Architectural Testing Inc. (ATI) 2006 Racking Performance Tests.

The research demonstrated SPF significantly increased rack and shear strength in both wood and metal stud construction. Additionally, it was learned that SPF increased strength of weaker substrates, such as gypsum drywall, vinyl siding and polyiso foam insulation at a much greater percentage than stronger substrates, such as OSB and plywood.

Closed cell SPF applied to the underside of a roof increases the racking strength

Special bracing for wind resistance would not be required for strength purposes when using SPF in the walls. As a structural material, closed SPF can add strength to wall and ceiling assemblies of all sizes and heights, depending on the framing.

The most recent study, conducted in 2006, demonstrated that even 1.5 inches of closed cell SPF provides equivalent racking strength enhancement to polyiso sheathing as 3.5 inches of closed cell SPF.

The results of the tests are outlined below:

SPF installed between metal studs: (3.5 inches)
- Increased racking strength of drywall sheathed walls: 2,400 lbs. to 5,380 lbs.
- Increased racking strength of OSB sheathed walls: 4,800 lbs. to 6,000 lbs.

SPF installed between wood studs: (3.5 inches)
- Increased racking strength of vinyl sheathed walls: 913 lbs. to 2,800 lbs.
- Increased racking strength of plywood sheathed walls: 2,890 lbs. to 5,300 lbs.
- Increased racking strength of polyiso sheathed walls: 1,109 lbs. to 2,159 lbs.

SPF installed between wood studs: (1.5 inches)
- Increased racking strength of polyiso sheathed walls: 1,109 lbs. to 2,257 lbs.

According to Applied Research Associates, Inc., *Development of Loss Relativities for Wind Resistive Features of Residential Structures*, Florida Department of Community Affairs, "Roof deck attachment during a hurricane is critical to the survival of the building. Once a building loses one or more pieces of roof deck, the losses increase exponentially due to the vast amount of water that enters the building. Field observations and insurance claim folders indicate that the house quickly becomes a major loss once the roof deck begins to fail in a hurricane. In other words, even if the walls are intact and the roof trusses do not fail, loss of roof deck and a few windows typically leads to losses greater than 50 percent of the insured value."

CONCLUSION

It is estimated that over 60 percent of existing residential homes in hurricane-prone regions currently do not have adequate wind resistance when faced with even a lesser hurricane. Retrofitting homes along the Gulf Coast and Eastern Seaboard continues to be a challenge for states trying to pro-actively reduce the risk of property loss from hurricanes.

To date, several manufacturers of closed cell SPF have met the Florida Building Commission's 2007 Florida Building Code Performance Standards for wind uplift resistance.

Other organizations like the Insurance Institute for Business and Home Safety, specifically suggest installing closed cell SPF along the joint between the roof sheathing and the rafters or trusses (fillet method) as an approach to keep wind and water out of the home during severe weather events.

If you live in an area with a history of hurricanes, the odds of having to ride-out a category 5 storm are low. However, history has shown that even tropical depressions and wind speeds in the double-digits are significant enough to cause considerable damage to homes, and especially roofs. Making sure your home is prepared for a strong storm, and that your roof can weather the wind and rain of a hurricane can provide peace of mind and protection of property.

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