

CLOSED-CELL SPRAY FOAM

Resisting Wind Uplift in Residential Buildings

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Enriching lives through Innovation

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OVERVIEW

- **BACKGROUND**
 - Problem Definition
 - Current Solutions
- **TEST METHOD**
 - Modified ASTM E330 Test Procedure
 - Test Specimens
- **TEST RESULTS**
 - Key Results
 - Impact on Roof Design Loads
 - Unvented Attics: Meeting the Building Code
- **CONCLUSIONS**
- **NEXT STEPS**
- **ACKNOWLEDGEMENTS**



BACKGROUND: Problem Definition



- **HURRICANE DAMAGE** accounted for a vast majority of insurance claims during the last two decades
- **\$130B** in losses since 1989
- **\$85B** in losses in 2004-2005 alone

TOP 15 MOST COSTLY HURRICANES IN THE UNITED STATES				Estimated Insured Loss	
Rank	Dates	States Affected	Hurricane	\$M when occurred	\$M (2007)
1	Aug. 25-30 2005	AL FL GA LA MS TN	Katrina	41,100	43,625
2	Aug. 24-26 1992	FL LA	Andrew	15,500	22,902
3	Oct. 24 2005	FL	Wilma	10,300	10,933
4	Aug. 13-14 2004	FL NC SC	Charley	7,475	8,203
5	Sep. 15-21 2004	AL DE FL GA LA MD MS NJ NY NC OH PA TN VA WV	Ivan	7,110	7,803
6	Sep. 17-22 1989	GA NC PR SC VA VI	Hugo	4,195	7,013
7	Sep. 20-26 2005	AL AR FL LA MS TN TX	Rita	5,627	5,973
8	Sep. 3-9 2004	FL GA NC NY SC	Frances	4,595	5,043
9	Sep. 15-29 2004	DE FL GA MD NJ NY NC PA PR SC VA	Jeanne	3,655	4,011
10	Sept. 21-28 1998	AL FL LA MS PR VI	Georges	2,955	3,758
11	Oct. 4 1995	FL AL GA NC SC TN	Opal	2,100	2,856
12	Sep. 14-17 1999	NC NJ VA FL SC PA 10+	Floyd	1,960	2,439
13	Sep. 11 1992	HI	Iniki	1,600	2,364
14	Sep. 5 1996	NC SC VA MD WV PA OH	Fran	1,600	2,114
15	Sep. 15-16 1995	PR VI	Marilyn	875	1,190

(1) Property coverage only.
 (2) Adjusted to 2007 dollars by the Insurance Information Institute.

Source: Insurance Information Institute

<http://www.iii.org/media/facts/statsbyissue/hurricanes/>



BACKGROUND: Problem Definition



Roof deck failures are the leading cause of residential building loss

Houses with damaged or missing roof sheathing in Florida



BACKGROUND: Problem Definition

“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% of the insured value.**”

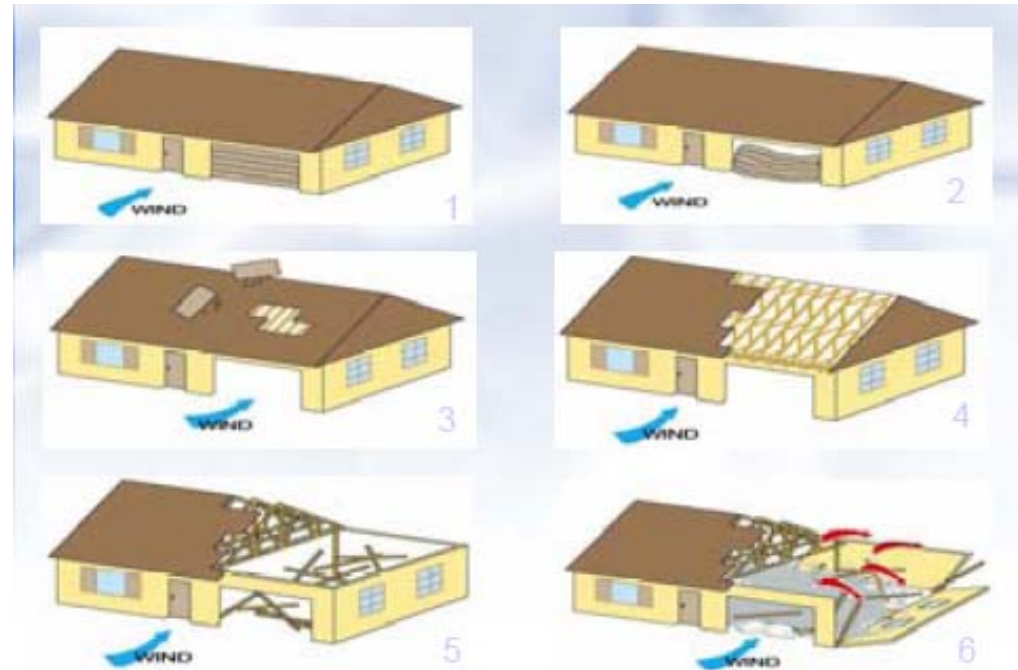
Source: Applied Research Associates, Inc., Development of Loss Relativities for Wind Resistive Features of Residential Structures, Florida Department of Community Affairs (contract number 02-RC-11-14-00-22-003), 2001.



BACKGROUND: Problem Definition

SEQUENCE OF A RESIDENTIAL ROOF DECK FAILURE

- (1) Wind impingement
- (2) Venturi or airfoil effect and/or opening failure pressurizes underside of deck
- (3) Initial roof deck uplift
- (4) Progressive roof deck uplift
- (5) Total roof system failure
- (6) Total building failure



© State Farm Mutual Automobile Insurance Co.

Source: Used with permission from State Farm Mutual Automobile Insurance Co.



BACKGROUND: Problem Definition

DESIGN LOAD REQUIREMENTS PER IRC

130.4 psf load requirement at Zone 3 (overhangs) for 150 mph peak wind

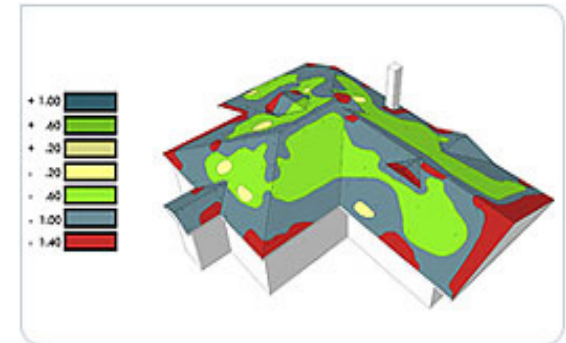
Table 2.4 Roof and Wall Sheathing Suction Loads

(For Sheathing and Sheathing Attachment)

Three Second Gust Wind Speed (mph)	85	90	100	110	120	130	140	150
	Dual Slope Roof							
Sheathing Location ¹	Suction Pressure (psf) ²							
Zone 1	13.4	15.0	18.5	22.4	26.6	31.2	36.2	41.6
Zone 2	25.8	28.9	35.7	43.2	51.4	60.4	70.0	80.4
Zone 3	33.7	37.8	46.7	56.5	67.2	78.9	91.5	105.0
Zone 3 Overhang	41.9	47.0	58.0	70.1	83.5	98.0	113.6	130.4
Zone 4	14.5	16.2	20.1	24.3	28.9	33.9	39.3	45.1
Zone 5	17.9	20.1	24.8	30.0	35.6	41.8	48.5	55.7

¹ The dimension, Z, is measured as 10% of the minimum building dimension, but not less than 3 feet.

² Tabulated framing loads assume a building located in Exposure B with a mean roof height of 33 feet. For buildings located in other exposures, the tabulated values shall be multiplied by the appropriate adjustment factor in Table 1.1.

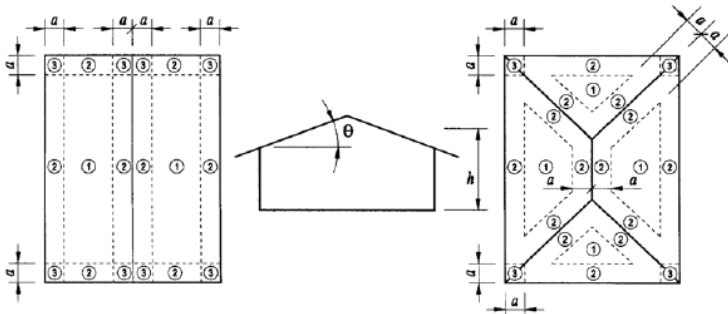




BACKGROUND: Problem Definition

DESIGN LOAD REQUIREMENTS PER ASCE 7

138.7 psf load requirement at Zone 3 (corner) for 170 mph peak wind



a : 10 percent of least horizontal dimension or $0.4h$, whichever is smaller, but not less than either 4% of least horizontal dimension or 3 ft (0.9 m).

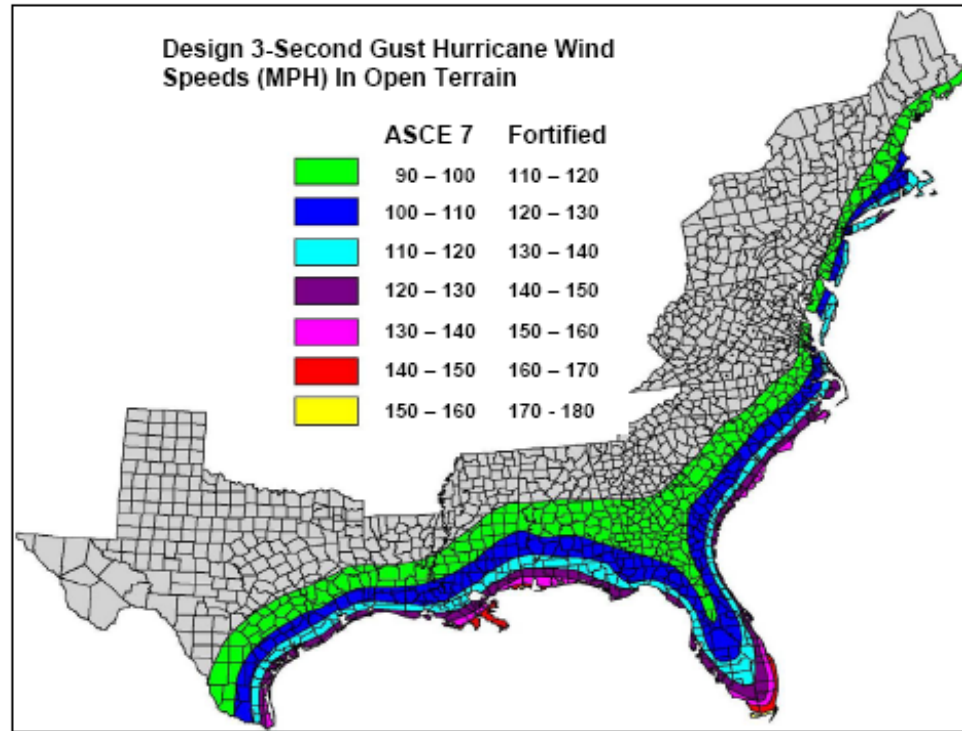
Design Wind Speed (mph)	Zone 1 (Interior)	Zone 2 (Edge)	Zone 3 (Corner)
10 square foot effective area			
130	-37.3	-57.9	-81.1
150	-49.7	-77.1	-108.0
170	-63.8	-99.0	-138.7
20 square foot effective area			
130	-36.0	-54.1	-75.9
150	-48.0	-72.0	-101.1
170	-61.6	-92.4	-129.9
100 square foot effective area			
130	-34.8	-45.0	-65.6
150	-46.3	-60.0	-87.4
170	-59.4	-77.0	-112.3

*Based on a suburban exposure with a mean roof height of less than 30 ft.



BACKGROUND: Problem Definition

Wind uplift from hurricanes can affect millions of homes....



Note 1: As indicated above, add 20 MPH for FFSL Design Wind Speed.

Note 2: Wind-borne debris protection is required in all of Florida.

Note 3: In other coastal states when the ASCE 7 Design Wind Speed is between 90 and 100 MPH, wind-borne debris protection is required within 1 mile of the coast.



BACKGROUND: Problem Definition

WHY DON'T ROOF DECKS SURVIVE?

- Older nailing schedules used for deck attachment
- Real-world nailing doesn't match code
- Over-driven fasteners
- Nail misses

**“Belt and Suspenders”
approach is required!**





BACKGROUND: Current Solutions

1990's Clemson Univ. Research: Adhesive Caulks

- Investigations of adhesives used on retrofit basis (DIY)
- “Any wood adhesive product with the **AFG-01** or **ASTM C557** designation should provide adequate reinforcement if applied as suggested....”
- 10 of 11 adhesives tested to a failure pressure of at least 150 psf
- Retrofit applications of adhesives recommended only as a **temporary** measure (until re-roofing) because of unknown effects of attic environmental conditions on the strength of adhesives

Sources:

Adhesive and Sealant Council Project Report “Adhesive Systems for Roof Assemblies - Monthly Report 2 Contract No. H-21521CA”

Clemson University Report “Holding onto Your Roof”
http://www.haznet.org/haznet_pdf/hoty.pdf





BACKGROUND: Current Solutions

Foamed Adhesives: ITW™ Foamseal®, Oxford, MI

- SF2100 Hurricane Adhesive System
- U.S. Patent 5,890,327
- Foamed polyurethane adhesive applied to truss (or rafter) joints and sheathing seams by a certified applicator.
- Existing and new construction roof systems

System Benefits:

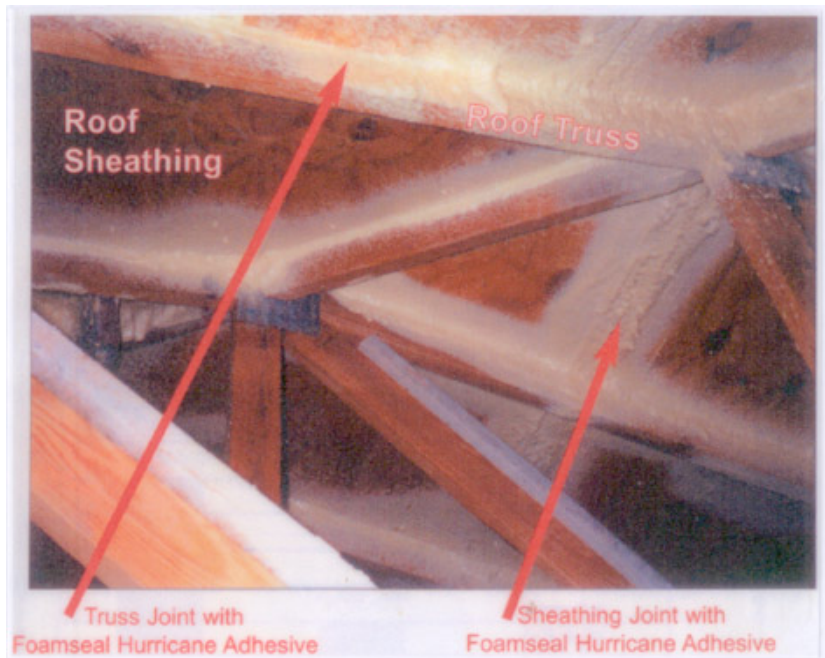
- 2-4 times increase in uplift resistance over nails-only systems;
- Reduction in water intrusion through roof deck joints should the roofing be blown off
- Qualifies as an approved Superior Roof Sheathing Attachment and Secondary Water Resistance mitigation by the Florida Windstorm Underwriting Association

Source: Adhesive and Sealant Council Project Report "Adhesive Systems for Roof Assemblies - Monthly Report 2 Contract No. H-21521CA"

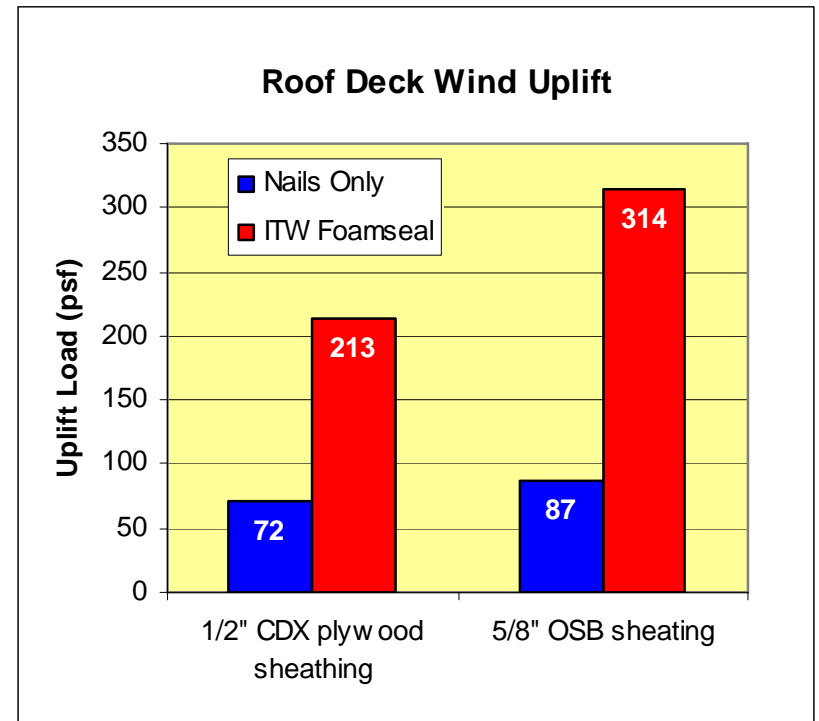


BACKGROUND: Current Solutions

When applied between deck and framing members, ITW™ Foamseal® SF2100 Hurricane Adhesive System can provide significant wind uplift resistance in Category IV or V conditions



Source: ITW Foamseal website: www.itwfoamseal.com





BACKGROUND: New Solution

Why Not Closed-Cell Spray Foam ?

- Polyurethane chemistry delivers adhesive bonding
- Water-resistance provides secondary water barrier in the event of shingle loss; Expands in-place to seal all cracks and gaps
- Unlike adhesives, foams flexibility allows thermal expansion between adjacent roof deck panels
- Blocks wind-driven rain and structural failure from soffits
- Insulates under roof decks providing energy efficient unvented (conditioned) attic design

**Structural testing
needed to prove
concept**





TEST METHOD: Method Overview

ASTM E330-02 “Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights and Curtain Walls by Uniform Static Air Pressure Difference”

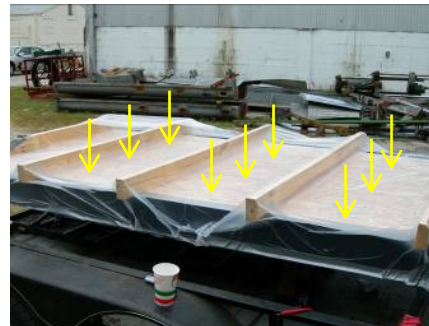
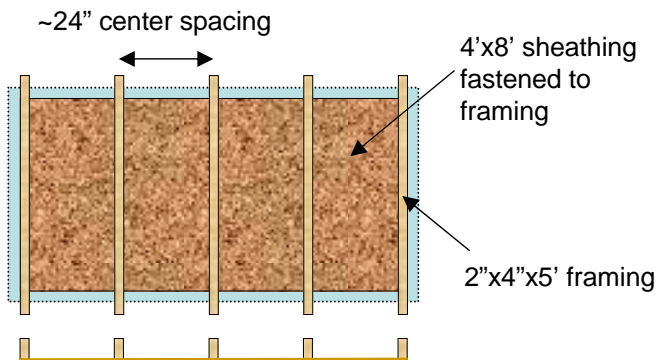
- Method accepted by the Florida Building Code and Miami-Dade for hurricane resistant structures
- Procedure routinely performed at the Department of Civil and Coastal Engineering at the University of Florida – Gainesville
- Project Principal Investigator – Dr. David O. Prevatt. P.E.



TEST METHOD: Test Procedure

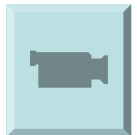
MODIFIED ASTM E330 TEST PROCEDURE

1. Attach 2x4x5' members across width of sheathing
2. Place specimen in a 4.5' x 8.5' vacuum box so that sheathing is face-down and 2x4s straddle the box
3. Seal with 2 mil PE film for Single direction loading
4. Draw vacuum inside box applying pressure to inside surface of the specimen (15 psf increment, 10 second hold)
5. Record pressure at failure





TEST METHOD: Test Procedure



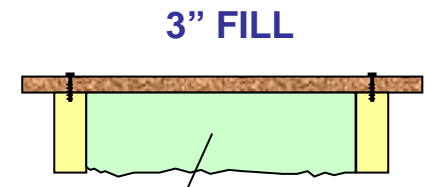
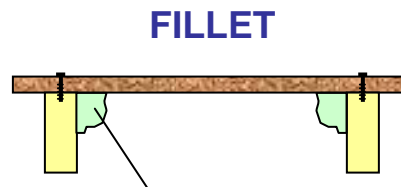
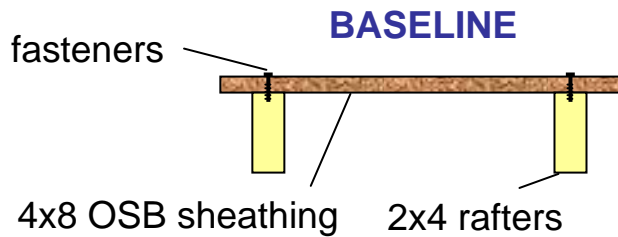


TEST METHOD: Specimen Preparation



SPECIMEN PREPARATION

- NCFI Polyurethanes InsulStar® 2lb foam applied by Xtreme Foam
- 15 specimens produced in total
- Fastener type: 6d common
- 6" spacing ends and 12" spacing in field (pre 2001 nail schedule)



NCFI InsulStar® foam (applied by Xtreme Foam – Orlando, FL)



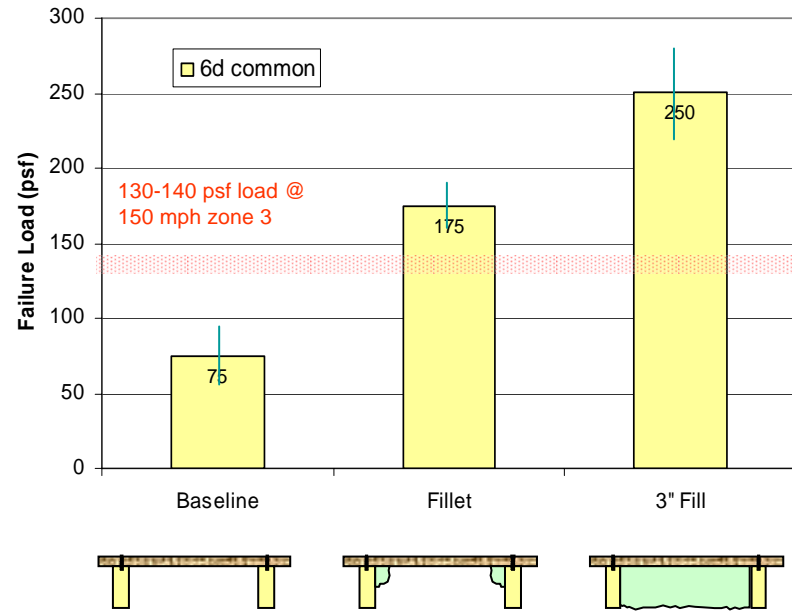
TEST RESULTS: Key Results

KEY RESULTS

- 3" fill increases wind uplift resistance 3.0x-3.2x
- Fillet increases wind uplift resistance 1.9x-2.2x
- No effect of fasteners. Unfastened panel with fill yields 267 psf
- Failure modes can vary

NOTE: 8d ringshank nail fastener test data to be added by June 2008

ASTM E330 TEST RESULTS



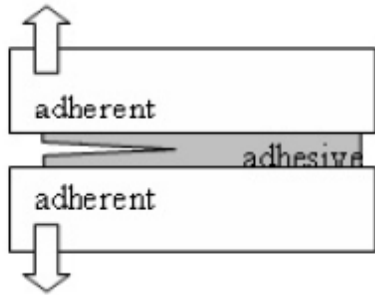
SPF	Avg	StdDev	Max	Min	1	2	3	4	5
A: None	75	21	105	47	75	105	71	76	47
B: Fillet	175	17	195	146	195	178	178	146	178
C: 3" Fill	250	31	283	200	283	246	200	254	269



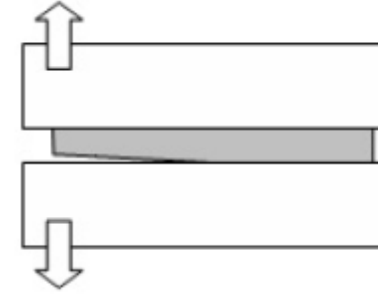
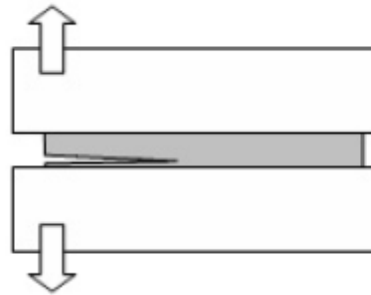
TEST RESULTS: Key Results

KEY RESULTS

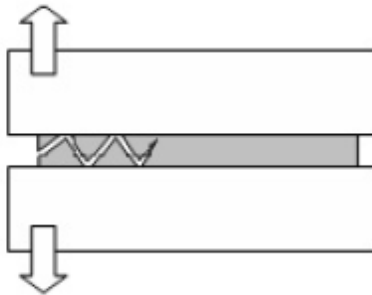
- Failure modes can vary



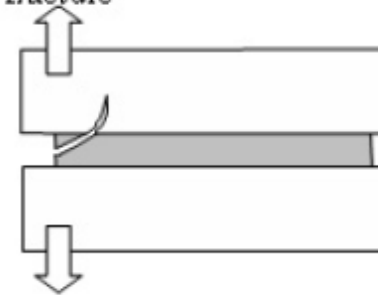
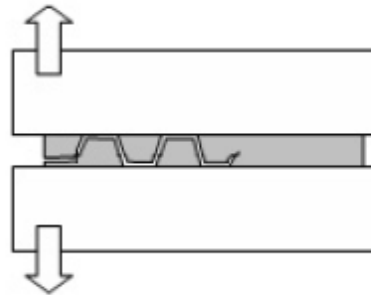
“Cohesive” and “cohesive near the interface” fracture



“Adhesive” or “interfacial” fracture



Fracture jumping from one interface to the other



Fracture in the adherent

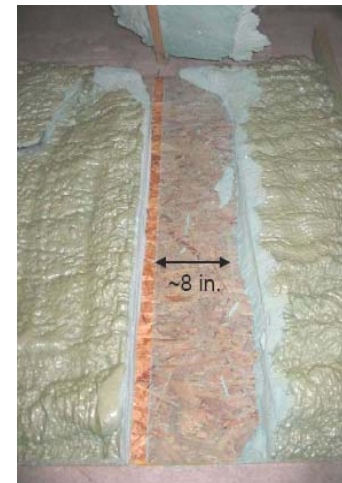
Source: www.wikipedia.org



TEST RESULTS: Key Results

KEY RESULTS

- Failure modes can vary





IMPACT: Codes and Building Practice

SEVERAL CONTROVERSIAL QUESTIONS TO ADDRESS

1. Unvented Attics
2. Fire Safety
3. Hurricane Resistance
4. Asphalt Shingle Life
5. Roof Leak Detection
6. Challenging Installation



IMPACT: 1. Unvented Attics

1. UNVENTED ATTICS

- Unvented attics save energy, especially in buildings with ductwork and HVAC equipment in attic
- Proven energy savings = 9-23% in hot climates
- Permitted by 2007 Supplement to the 2006 IECC Model Code
- **CHECK WITH STATE AND LOCAL MODIFICATIONS TO SUPPLEMENTAL CODE LANGUAGE**

CHAPTER 8 – ROOF-CEILING CONSTRUCTION SECTION 806.4 – Unvented attic assemblies.

Unvented attic assemblies (spaces between the ceiling joists of the top story and the roof rafters) shall be permitted if all the following conditions are met:

1. The unvented attic space is completely contained within the building thermal envelope.
2. **No interior vapor retarders are installed on the ceiling side (attic floor)** of the unvented attic assembly.
3. Where wood shingles or shakes are used, a minimum ¼ inch (6 mm) vented air space separates the shingles or shakes and the roofing underlayment above the structural sheathing.
4. **In climate zones 5, 6, 7 and 8, any air-impermeable insulation shall be a vapor retarder**, or shall have a vapor retarder coating or covering in direct contact with the underside of the insulation.
5. Either Items a, b or c shall be met, depending on the air permeability of the insulation directly under the structural roof sheathing.
 - a) **Air-impermeable insulation only. Insulation shall be applied in direct contact to the underside of the structural roof sheathing.**
 - b) Air-permeable insulation only. In addition to the air-permeable installed directly below the structural sheathing, rigid board or sheet insulation shall be installed directly above the structural roof sheathing as specified in Table R806.4 for condensation control.
 - c) Air-impermeable and air-permeable insulation. The air-impermeable insulation shall be applied in direct contact to the underside of the structural roof sheathing as specified in Table R806.4 for condensation control. The air permeable insulation shall be installed directly under the air-impermeable insulation.



IMPACT: Fire Safety

2. FIRE SAFETY

- Most closed-cell spray foams meet Class 1 rating per ASTM E84
- Requirements detailed in Section 2603 of ICC
 - 15 minute thermal barrier in occupied spaces
 - ignition barrier in unoccupied spaces*
- Ignition barrier requirement may be waived by product ICC-ESR by full-scale fire testing
- **CONSULT SPF MANUFACTURERS LITERATURE REGARDING IGNITION BARRIER REQUIREMENTS IN ATTICS**

** Definition of unoccupied space depends on many factors including ease-of-access, presence of combustion appliances, and if the attic is to be used for storage. This is a building-dependent, discretionary call often made by the local jurisdiction/building code official. **Always consult your local code official to determine attic space classification***



IMPACT: Hurricane Resistance

3. HURRICANE RESISTANCE

- ccSPF holds roof sheathing to joists and trusses. Additional mechanical devices are necessary to hold joist and trusses to the supporting wall
- Incentives in the form of premium discounts and direct subsidies are emerging in legislatures of hurricane-zone states to encourage wind mitigation practices for new and existing homes
- Florida has made most significant strides – state requires insurer discounts for wind mitigation measures
- Other states considering: TX, SC, MS, LA
- NCFI Polyurethanes InsulStar® product first ccSPF to receive approval by Florida Building Commission #9975



IMPACT: Asphalt Shingle Life

4. ASPHALT SHINGLE LIFE AND WARRANTY

- Service life of asphalt shingles decreased by elevated temperature
- Elevated shingle temperatures caused by many factors:
 - latitude of the building site
 - shingle color
 - roof pitch/orientation
 - insulation applied under a roof deck
- Some asphalt shingle manufacturers may void shingle warranty when installed on insulated roof decks, Others do not.
- **CONSULT APPLICABLE SHINGLE WARRANTY AND DISCUSS WITH HOMEOWNER/BUILDER BEFORE APPLYING SPRAY FOAM UNDER A ROOF DECK**

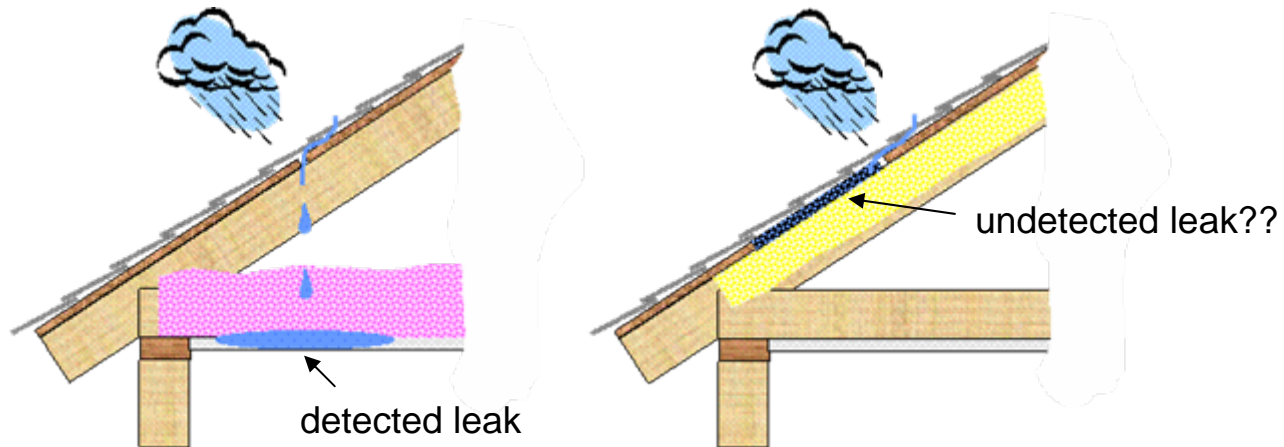




IMPACT: Roof Leak Detection

5. ROOF LEAK DETECTION

- Can roof leaks be detected with ccSPF under roof decks?
- ccSPF creates a secondary water barrier and creates a stronger roof deck. How many years would it take for an undetected leak to cause isolated roof deck degradation, if ever at all?”
- Can protection offered by SPF likely outweigh potential damage from roof leaks?
- **THIS POTENTIAL ISSUE IS AN AREA OF INTEREST TO OUR INDUSTRY AND MAY BE ADDRESSED IN FUTURE RESEARCH PROGRAMS**





IMPACT: Installation Challenges

6. INSTALLATION CHALLENGES

- Access to entire roof deck can be a problem, especially in retrofit homes and trussed construction
- Uniform application in soffits of low-slope roofs
- **MAY NEED DEVELOPMENT OF SPECIALIZED SPRAY GUNS**





CONCLUSIONS

A ccSPF fillet can increase the wind uplift capacity by more than 2x the uplift capacity of the panel fastened using only nails.

A continuous 3 in. thick ccSPF layer can increase the wind uplift capacity by as much as 3x that of the control roof panel

Nail selection did not appear to have an effect on the uplift capacity. The uplift capacity may be increased by using thicker sheathing panels or selecting a different sheathing material (i.e. plywood).

The performance of aged ccSPF may be a factor in the uplift capacity of the retrofitted roof panels suggested by the increased variability in wind uplift capacity results for the “aged” ccSPF-retrofitted panels.

The use of SPF as a retrofit technique for roof member-to-wall connections **needs further validation** through experimental studies, .



NEXT STEPS

FUTURE RESEARCH CAN INCLUDE...

- Effect of sheathing flexural stiffness on uplift load
- Integration of attic baffles
- Aged performance of ccSPF
- Relation of uplift capacity to application technique, pattern or foam volume
- Moisture content variations of sheathing and wood members
- Effect of ccSPF in limiting drainage
- Repair and removal ccSPF retrofitted panels and roof members
- Effectiveness of ccSPF as a secondary waterproofing layer
- Analytical design methods for using ccSPF as a structural adhesive



ACKNOWLEDGEMENTS

This work was jointly sponsored by **Honeywell** and **Huntsman** and performed at the **University of Florida's Department of Civil and Coastal Engineering**.

The sponsors of this research would like to thank **NCFI Polyurethanes** for donating their InsulStar® 2lb foam for this study. We would also like to thank **Xtreme Foam** for their assistance during the specimen preparation process..



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QUESTIONS?