Hurricane Performance of Spray Polyurethane Foam Roofing

ROGER V. MORRISON
NCFI, Div. Barnhardt Mfg. Co., Inc.
1515 Carter Street
Mount Airy, NC 27030

ABSTRACT

The 2004 hurricane season in Florida provided a unique opportunity to observe the performance of SPF roofing systems following actual high wind events.

The four hurricanes which came ashore that year demonstrated that SPF roofs performed very well. Most SPF roofs survived with undamaged or with minor surface damage and building occupants remained protected by the roof system.

Some roofing failures were noted, however, due, in part, to the failure of the structural roof deck or the substrate.

Figure 1: Condominium roof near Jensen Beach. Left photo is before hurricanes Frances and Jeanne. Left photo is after. No damage was observed.

SPF ROOFING SYSTEMS

Spray-applied as a liquid, SPF reacts and expands in-place to form a firmly adhered, rigid, seamless mass of closed-cell foam. SPF roofs are typically applied as recovers over existing membranes (such as built-up or modified bitumen). They may also be applied directly to a structural deck (such as steel, concrete or wood) as a new construction application or following a tear-off. SPF roofs are covered for ultra-violet light protection with either a coating system or a layer of gravel.

Based on small-scale wind uplift testing, spray polyurethane foam (SPF) roofing systems have achieved some of the highest wind uplift ratings in the roofing industry today. Because of the adhesive, compressive and tensile strengths of SPF, the typical mode of failure in small scale testing (typically 12 x 24 feet panels) is the fastening of the deck (i.e., screw pull-out). Testing over recover panels has suggested that the added stiffness of the SPF roof increases the uplift resistance of an existing membrane.

2004 HURRICANE EXPERIENCE

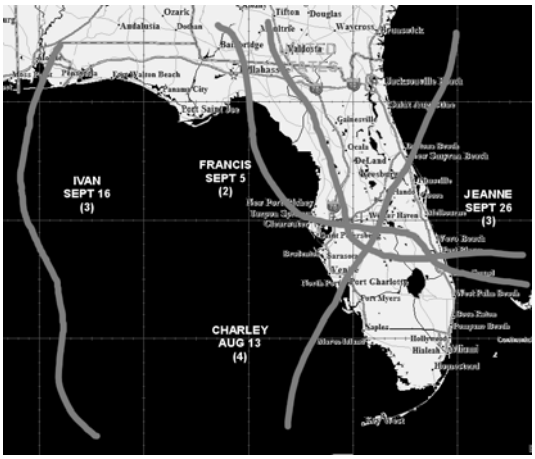

Figure 2: 2004 hurricane tracks.

Four hurricanes struck Florida in 2004: Charley (August 14, Category 4), Frances (September 5, Category 2), Ivan (September 16, Category 3), and Jeanne (September 26, Category 3). All but Ivan made landfall in areas where large numbers of SPF roofs were present. Inspections of these roofs indicated that, in general, SPF fared exceptionally well, keeping building occupants and contents protected and dry. However, some SPF roofs experienced deck failure, substrate failure, and surface damage.

Hurricanes are categorized as 1 to 5 according to wind speed using the Saffir-Simpson Scale. However, the hurricane category does not accurately reflect the danger or damage

potential of the storm. For example, the wind pressure differential increases as the square of the wind speed. Additionally, the potential damage ratio increases even more dramatically with wind speed than does the pressure differential (see Table 1).

Table 1. Wind Speeds, Wind Pressure and Potential Damage

Hurricane Category	Wind Speed mph	Wind Pressure Ratio (50 mph = 1)	Potential Damage[1]
1	74 – 95	2.2 – 3.6	1
2	96 - 110	3.7 – 4.8	10
3	111 - 130	4.9 – 6.8	50
4	131 - 155	6.9 – 9.6	250
5	> 155	> 9.6	500

Thus, in comparing a Category 4 storm (Charley) with a Category 2 storm (Frances), the wind speed might be 40 % greater; the pressure ratio woud be approximately 100 % greater; and the potential damage would be 25 times greater.

Figure 3: Three modes of failure are evident on this SPF recover of a built-up roof. (1) Deck (hollow-core concrete panels at top); (2) Substrate (built-up roof at left foreground); and (3) Surface Damage (at right foreground).

Hurricane Charley made landfall on August 13 near Punta Gorda. There were a number of SPF roofs in this area and it afforded an excellent opportunity to assess damage. Hurricane Ivan made landfall on September 16 near Pensicola but there were few SPF roofs in the region. Hurricanes Frances (landfall September 5) and Jeanne (landfall September 26) made landfalls in the same area near Stewart. These two hurricanes provided an opportunity to assess the effectiveness of SPF repairs installed between the two storms.

Deck Failure

Roof decks are commonly constructed of concrete, steel or plywood. Decks provide the structural support for the waterproofing and insulating components of the roofing system. Deck failure results from high pressure differentials.

Figure 4: Deck failure. An overhead door failed immediately below the location of this deck failure.

When wind encounters an obstruction, such as a building, air pressure tends to increase on the windward side relative to the leeward side. As wind passes over a roof, the velocity increases because the air must travel a greater distance; as air velocity increases, its pressure tends to decrease (similar to air passing over an aircraft wing). Thus, air pressure on the top of the roof tends to be lower than the underside. Exacerbating this effect, if a window or door suddenly fails, the pressure within the building can suddenly and catastrophically spike, blowing off portions of the roof deck which might have otherwise withstood the wind loads. Roof deck failures remove portions of the roofing membrane and insulation and expose building interiors to rain and wind damage.

Substrate Failure

When installed as a recover, SPF roofing is applied directly to an existing membrane, such as a built-up or modified bitumen roof. Testing indicates that an installation of SPF over an existing roof will tend to increase the wind uplift resistance of the combined system. However, the increased resistance has not been quantified. If the underlying substrate/membrane did not meet

code requirements, there is no guarantee that recovering it with SPF will.

The typical mode of substrate failure was a loosening of the windward edge followed by a peel-back of the membrane. Depending on the security of the underlying insulation, the peel-back may or may not take insulation boards with it. At some point in the peel-back process, the membranes typically ruptures, leaving the remaining substrate and SPF intact.

Figure 5: Substrate failure. Deck remained intact, underlying built-up roof peeled up taking SPF recover with it.

Figure 6: Substrate failure close-up. Edge nailer was rotted and built-up roof was insufficiently fastened.

Substrate failures are due to:

- Insecure edges and
- Insufficient adhesion or fastening of the membrane and insulation boards to the deck.

Membrane roof systems are highly dependent on the roof edge for their security; yet roof edges are the most exposed detail on the roof. Furthermore, the pressure difference across the membrane tends to add extra uplift forces to the edge. Once the edge submits to these forces, a membrane peel-back is almost inevitable.

Roof edges are usually fabricated from metal and fastened to a wooden roof edge nailer with screws, nails and/or cleats. The security of the metal edge is dependent on its stiffness, the quality and quantity of the fasteners as well as the security of the nailer.

Surface Damage

Surface damage of SPF roof systems occurred where wind-borne missiles (such as tree limbs and broken ceramic roof tiles) impacted the SPF. Gravel scour occurred at windward roof corners, and in some cases, near roof protrusions and roof mounted equipment. Little or no loss in waterproofing resulted from surface damage.

Figure 7: Surface damage (missile impact).

Figure 8: Surface damage (gravel scour).

SPF REPAIRS AND PATCHES

Hurricanes Frances and Jeanne made landfall in approximately the same location (near Stuart, Florida). Many damaged conventional roof systems were patched and repaired with SPF

following Frances. In many cases, the SPF patches/repairs withstood the winds of Jeanne better than the remaining areas of the patched conventional roofs.

GENERAL OBSERVATIONS

- There were no SPF adhesive failures observed (i.e., no separation of SPF to the substrate to which it had been applied).
- Sloped roofs where asphalt shingles or ceramic tiles had been covered with SPF fared quite well.
- Many SPF roofs survived undamaged or with minor surface damage.
- While gravel movement was present at windward corners, little or no gravel loss was observed.

Figure 9: This SPF patch (right-middle of photo) was installed after Hurricane Frances. Hurricane Jeanne damaged the remaining roof, leaving the SPF patch intact.

CONCLUSIONS

Generally, SPF roofs performed very well in the 2004 hurricane zones. Failures were limited to deck and substrate failures. Surface damage of SPF roofs occurred but was not a cause of failure or leakage.

Substrate failure could be minimized or eliminated by improving edge and membrane security when installing SPF roofs. Possible improvements are:

Remove the existing membrane a few feet in at roof edges and then apply SPF directly to the deck in these areas;

Refasten the existing membrane at edges and in the field.

Application of SPF as a repair and patch method was very successful. SPF repairs and patches were more wind resistant that the original roof system.

Photos were provided by:
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[1] **Pielke, Jr., R. A. and C. W. Landsea 1998. "Normalized Hurricane Damages in the United States: 1925-1995,"** ***Weather and Forecasting*****, 13: 621-631, www.aoml.noaa.gov/hrd/Landsea/USdmg/**