This article discusses field observations and research that document the ability of closed-cell spray polyurethane foam (ccSPF) to add structural strength to roof and wall assemblies.

It has been known for many years that an SPF roofing system can enhance the wind uplift resistance of a roof covering. Field observations of SPF performance after Hurricanes Hugo and Andrew led to the Spray Polyurethane Foam Alliance (SPFA) sponsoring wind uplift testing of SPF roofing systems by Underwriters Laboratories (UL) and Factory Mutual Global (FM Global). According to UL, SPF’s resistance exceeded the capacity of the equipment to measure wind uplift pressures. UL observed that SPF roofs applied over BUR and metal increased the wind resistance of those existing roof coverings. FM Global measured ccSPF’s adhesion to concrete at over 990 psf of uplift pressure; and over metal deck assemblies, at over 220 psf of resistance. (Note: The mode of failure was fastener back-out, not the foam.) But little mention has been made of ccSPF’s ability to prevent structural damage to roof and wall assemblies.

**ROOF DECK STRUCTURAL ENHANCEMENT**

First, let’s look at some recently conducted laboratory research. In 2008, Honeywell Corporation, Huntsman Corporation, and NCFI Polyurethanes sponsored research on the wind uplift enhancement capability of ccSPF installed to the underside of wood deck assemblies. This was prompted by field research conducted by groups such as the Roofing Industry Committee on Weather Issues’ (RICOWI) hurricane team investigators and veteran SPF industry professionals. The investiga-
tors observed examples of ccSPF installed to the interior structure of a building that appeared to minimize or eliminate structural damage caused by high wind events, while other sections of the building without ccSPF were destroyed by pressurization.

The sponsors contracted with the Hurricane Research Center located at the University of Florida to conduct ASTM E330-02 (Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights, and Curtain Walls by Uniform Static Air Pressure Difference) testing of wood roof deck assemblies (Figure 1). According to ASTM, “This test method is a standard procedure for determining structural performance under uniform static air pressure difference.” This typically is intended to represent wind loads on exterior building elements and is accepted by the state of Florida and Miami Dade County for testing structural elements (including roof deck assemblies) for high wind resistance.

Two types of SPF applications were tested on OSB panels with wood studs installed in accordance with Florida Building Code requirements for high-wind-velocity regions.

The results were eye opening. Even with a roof deck assembly that was constructed to comply with Florida’s high wind requirements, the ccSPF increased wind uplift resistance on the 3-in fill from 3 to 3.2 times its original resistance. The fillet-style application increased wind uplift resistance from 1.9 to 2.2 times its original resistance. (See Table 1.)

**CASE STUDY 1**

White’s Lumber, Port Isabel, TX
Hurricane Dolly Investigation; Mason Knowles Consulting, LLC

Before Hurricane Allen blew into South Padre Island, TX, in 1980, the author installed a portion of an SPF application to the office section of a lumberyard’s post-frame-construction building. The crew completed one corrugated wall and roof section before the storm hit. After the storm, the only metal remaining were the sections insulated with ccSPF.

*Figure 2 shows White’s Lumber’s open-end, post-frame-construction building. New metal was installed to half of the building (right side of the photo) in 2008, and the old metal originally installed in 1980 is on the left. For close to 30 years, there were no significant wind events in the area.*

In 2009, Hurricane Dolly—a category 2 storm, packing winds of more than 110 mph—made a direct hit on the towns of Port Isabel and South Padre Island, TX. White

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### Maximum Wind Uplift Load PSF (pounds per square foot)

<table>
<thead>
<tr>
<th>SPF</th>
<th>Avg.</th>
<th>Max.</th>
<th>Min.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Std. Dev.</th>
</tr>
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<tr>
<td>None</td>
<td>75</td>
<td>105</td>
<td>47</td>
<td>75</td>
<td>71</td>
<td>76</td>
<td>47</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Fillet</td>
<td>175</td>
<td>195</td>
<td>146</td>
<td>195</td>
<td>178</td>
<td>178</td>
<td>146</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>3-in Fill</td>
<td>250</td>
<td>283</td>
<td>200</td>
<td>283</td>
<td>246</td>
<td>200</td>
<td>254</td>
<td>269</td>
<td></td>
</tr>
</tbody>
</table>

*Table 1*
Lumber and Supply lost half of its roof, as shown in Figures 3 and 4. But something looks strange, doesn’t it? The left side of the building has a new metal skin installed in 2008, while the right side has metal panels that are over 29 years old. As can be seen, the new metal blew off in the storm, while the old metal remained in place. Both are 29-gauge metal with similar fasteners and fastening patterns (in fact, the new metal portion had a closer fastening pattern than the old section, and both are fastened to the same wood framing).

There is a simple explanation. When the metal was replaced in 1980, the owner contracted with the author to install a 2-lb, closed-cell spray foam in a “picture frame” pattern to help secure the metal panels to the wood trusses. Twenty-nine years later, this safety net proved invaluable (Photo 5). Unfortunately, when the owner replaced the metal on half of the building in 2008, he could not find an SPF applicator to replace the foam (Photo 6). Consequently, high winds blew off major portions of the new metal panels.
As shown in Figures 7 and 8, the main cause of failure of the new metal skin was pulling of the fasteners through the metal.

**INCREASING RACKING STRENGTH OF ASSEMBLIES**

Research demonstrates that ccSPF can help increase the racking strength of wall assemblies. Three research studies have been conducted by the Spray Polyurethane Foam Alliance (SPFA) and its predecessor, the Polyurethane Contractor’s Division (PFCD) of the Society of the Plastics Industry, on the racking strength of ccSPF. In 1992 and again in 1996, PFCD contracted with the
NAHB Research Center to conduct racking load tests on ccSPF-insulated wall panels. The NAHB Research Center concluded, “During a design racking event such as a hurricane, there would be less permanent deformation of wall elements and possibly less damage to a structure that was braced with SPF-filled walls.”

The 1992 research tested ccSPF installed at 3 inches to wall panels constructed of plywood and vinyl cladding, respectively. The panels used 2- x 4-in wood studs with spacing at 16, 24, 32, and 48 inches off center (OC). As indicated in Table 2, ccSPF increased the maximum average racking load of a vinyl-clad wall assembly from 913 lbs to over 2,800 lbs at 16-in spacing and more than 2,300 lbs, even at the 48-in stud spacing. It doubled the maximum average racking load of a plywood-clad wall assembly at 16-in spacing and was 2.2 times the racking load at 24-in spacing.

The 1996 study measured the racking strength of OSB- and drywall-clad walls, respectively, with metal studs at 16 in OC. As indicated in Table 3, the ccSPF-insulated walls at 3 in thick increased the drywall-clad wall from 2,400 lbs of racking load to 5,380 lbs, and the OSB-clad walls from 4,800 lbs of racking load to 6,000 lbs.

In 2007, SPFA tested ccSPF-insulated walls constructed with 2-in x 4-in wood studs, 16 in OC to both polyiso- and OSB-sheathed wall assemblies at Architectural Testing, Inc. (ATI). As indicated in Table 4, the ccSPF doubled the racking load of the polyiso-sheathed wall assemblies.

**CASE STUDY 2**

**Pascagoula Shrimp and Ice Company Hurricane Katrina Investigation; RICOWI**

As shown in Photo 9, internal pressurization destroyed the tongue-and-groove roof deck of this ice plant during Hurricane Katrina. However, the metal building section (depicted in Photo 10) that was insulated with ccSPF and connected to the same structure, survived with no damage.
None of the areas insulated with ccSPF sustained any damage. An interesting observation is that many of the ccSPF-insulated portions of the building were areas that would be considered less structurally sound than other areas (if they were not structurally reinforced with ccSPF). Figure 11 shows the foam sprayed against metal roof decking and corrugated metal wall panels.

**EXTERIOR ccSPF APPLICATIONS TO MINIMIZE WIND AND WATER DAMAGE**

Another use of ccSPF is on the exterior of buildings to prevent their damage from high winds and flying debris. There are many cases of ccSPF installed to the exterior of metal buildings, houses, and small commercial buildings where such application has minimized structural damage and water intrusion. The foam acts as a shock absorber for wind-driven debris; a barrier to wind-driven rain; an air barrier to reduce the potential for high wind pressurization of the building; and a glue that holds it together and distributes the load so that if pressurization occurs, the weakest individual components and fastenings are not exposed to the full brunt of the pressure.
**CASE STUDY 3**

**Port Isabel RV Park**

**Hurricane Dolly**

Investigation;

Mason Knowles Consulting, LLC

A recent example of this design is the recreation building at the Port Isabel RV Park. Around 1978, a tropical storm caused damage to the exterior wood cladding, allowing water intrusion into the building. After unsuccessful attempts to correct the problem, the author was contracted to install 1.5 in of ccSPF to the outside of the entire structure. The application of ccSPF stopped the leaks into the building.

In 1980, the building was directly in the path of Hurricane Allen, a category 5 storm when it hit Port Isabel. Wind speeds were recorded in Port Mansfield (50 miles north of Port Isabel) at 130 knots. The Port Isabel Press reported two weeks after the storm that the Coast Guard station at Isla Blanca Park on South Padre Island (one mile from the buildings in Port Isabel) recorded wind speeds in excess of 125 mph. The wood structure survived with no damage and no leaks.

Many other buildings in the immediate vicinity were seriously damaged from high winds and water intrusion.

In 2009, the building was in the direct path of Hurricane Dolly, with up to 110 mph winds. Again, the building survived with no damage except for a small crack (see Photo 15) and no water intrusion.

**CASE STUDY 4**

**Military Tent and Plywood Buildings**

Reinforcement;

Department of Defense

Presentation at Sprayfoam 2010

The Department of Defense (DOD) has an ongoing program to insulate tents and other nonair-conditioned structures in selected bases in Iraq and Afghanistan with 2-lb density ccSPF (Photos 16 and 17). The main goal is to protect against high temperatures in the areas. According to John Siller of the Power Surety Task Force of the DOD, “The foam is providing outstanding performance in this goal.” [Editor’s Note: See “How Insulation Saves Lives and $$ in Iraq and Afghanistan” on page 42 for more about this project and the activities of an RCI member]
Figure 18 – This metal building was approximately 50 yards from the mortar shell’s impact.

working in the Middle East.

But a recent incident may be prompting the military to look seriously at using ccSPF to protect structures against damage from mortars or improvised explosive devices (IEDs). On October 17, 2008, Mearl “Skip” Kline was working with a crew from West Roofing that was insulating tents with ccSPF at a military base just outside the city of Baqubah, Iraq. According to Kline, “The base was attacked by what Army personnel assumed to be 107mm rockets. We hit the ground when we heard the shells coming into the camp. The shells impacted approximately 40 yards from us and 80 to 100 yards away from the ccSPF tents. We were told this type of ordnance has a kill radius of approximately 30 yards. The tents [that were insulated with ccSPF] absorbed shrapnel from the shells without [the shrapnel] penetrating the structures. After the attack, Army personnel were impressed by the foam’s ability to absorb the shock of the shrapnel hits. Many expressed a desire to use the foam to increase the impact resistance from enemy shells.” (See Photos 18 and 19.)

THE FUTURE OF ccSPF AS A STRUCTURAL MATERIAL

It is clear from the research and case studies cited that ccSPF can be an important tool for designers to enhance the high-wind resistance of buildings. However, some important steps are required to use the materials as a structural enhancement.

Figure 19 – Shell fragments still capable of severely wounding personnel were embedded in the foam of the structures, 80 to 100 yards away from impact.
ADDITIONAL RESEARCH AND TESTING

1. Since 29 gauge is a low-strength metal sheathing material, it is much more likely that fasteners will pull out of such metal, causing damage in a high-wind event. A thicker sheathing might have survived the storm without damage.

2. Wind-driven debris will typically cause dents, cracks, and gouges to exterior applications of ccSPF. A sealant compatible with the coating can repair small (less than 4 in) mechanical damage. Larger areas of damage can be repaired by removing the damaged foam and replacing it with new foam using high-density foam kits or standard SPF proportioning equipment. Recoating may be required if the damage covers large areas of the structure.

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SPECIFICATIONS AND GUIDELINES

1. While not a new product, the term “ccSPF” is the most current designation that refers to a typical closed-cell spray polyurethane foam ranging in density from 1.5 to 3.5 lbs per cu ft used for insulation and roof coverings. The newer designation differentiates the product from a low-density, nonstructural, open-cell spray polyurethane foam that has become popular in interior applications as an insulation and air barrier material.

2. FM Class 1 Roof Coverings Test Program of SPF Roofing Systems (sponsored by SPFA), 2005.


5. NAHB Research Center, ccSPF wall panel performance testing, sponsored by the Polyurethane Foam Contractors Division of the Society of Plastics Industry (PFCD), 1992 and 1996.

6. Roofing Industries Committee on Weather Issues (RICOWI), Hurricane Katrina Wind Damage Investigation, 2005.


CONCLUSIONS AND COMMENTS

Based on research and field observations, it appears that the installation of ccSPF to either the exterior or interior of a building can result in significant structural benefits and reduced building damage from impact and high winds. Additional information needs to be developed by the SPF industry, building research, and design community to provide the tools necessary to offer this product as a primary structural enhancement material.

REFERENCES


FOOTNOTES

1. Mason Knowles Consulting, LLC, providing technical services and educational programs for the spray polyurethane industry. He has more than 40 years’ experience in the SPF industry as a contractor, material supplier/manufacturer, equipment manufacturer, and trade association professional. Knowles is the former executive director of the Spray Polyurethane Foam Alliance (SPFA); chairman of ASTM D08.06, Subcommittee on Spray Polyurethane Foam Roofing; chairman of the ASTM task group for the spray polyurethane foam standard specification (ASTM C1029); a member of the National Institute of Building Science’s Building Envelope Thermal and Energy Committee; a member of the RICOWI Hurricane Investigation Team; and a roofing/building envelope inspector.

Mason Knowles