Sustainability Characteristics of SPF Roofing and Insulation Systems

By Mason Knowles, Modern Materials Magazine, November 2003

Building owners have used spray polyurethane foam (SPF) as a roofing, insulation, and sealing product for many years. What they may not have known then, but is being increasingly proven through research and performance studies on SPF applications, is the material demonstrates many sustainable characteristics. This article presents information on two important SPF applications in construction. The first addresses roofing, presenting investigative research performed by Rene Dupuis and Dean Kashiwagi, SprayPolyurethane Foam Alliance (SPFA) -sponsored projects at FM Global (FM) and Underwriters Laboratory (UL) Inc., cool roof research by Lawrence Berkeley Labs, and articles written by roofing experts like Thomas Smith and Patrick Downey. Energy studies are courtesy of Texas A&M University.

The second section addresses building interior applications. This section includes research by Mark Bomberg, W.C. Brown, Robert Alumbaugh, M.K. Kumaran, N.V. Schwartz, Anthony Woods, and others, in addition to SPFA-sponsored projects with the National Association of Home Builders (NAHB) research center and Oak Ridge National Laboratories (ORNL), and field investigations by private companies.

Roofing

Between 1983 and 1996, Dean Kashiwagi surveyed and documented the performance of more than 1600 SPF roofing systems. In 1998, Rene Dupuis published results of his inspection and evaluation of more than 160 SPF roofing systems in six different climates of the United States. The surveys conducted by Dupuis and Kashiwagi are very similar in their conclusions: SPF roofing systems are highly sustainable. In Kashiwagi’s 1996 report, the oldest performing SPF roofs were more than 26 years old. Of the roofs he surveyed, 97.6 percent did not leak and 93 percent had less than one-percent deterioration—pretty good statistics considering 55 percent of those roofs were never maintained. Kashiwagi and Dupuis also noted the physical properties of SPF did not diminish over time, and more than 70 percent of the roofs were applied over existing roofing systems.
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Energy savings

Many large companies and institutions have documented energy savings from the use of SPF roofing systems. Texas A&M calculated the energy consumption of their buildings before and after the application of such systems. After studying more than 743,224 m2 (8 million sf) of roofing, they concluded the energy savings paid for the cost of SPF retrofits within three to four years.

How do spray polyurethane foam roofs deliver such dramatic results? Black-surfaced roofs have measured peak temperatures up to 87.8 C on a 32-C day (190 F on a 90-F day). If the interior temperature is maintained at 25.6 C (78 F), the resulting temperature difference is 44 C (112 F). Fasteners alone can reduce the effective insulation value between 1.5–31.5 percent, depending on the number and type. On a hot summer day, typical dark-colored membranes absorb radiant heat.

The roof’s surface temperature rises. Thermal bridges, such as fasteners and gaps in insulation boards, transport heat into the building. Spray polyurethane foam reduces energy costs because it:

• is applied above the roof deck;
• eliminates thermal bridging by providing a continuous layer of insulation over existing thermal bridges in the roof deck and/or assembly;
• has a very high aged R-value of between six to seven (per inch); and
• is typically coated with light-colored, reflective coatings.

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Durability

Performance studies and research suggest SPF roofing systems can last 30 or more years. Additionally, they require low maintenance, resist leaks caused by hail and wind-driven debris, resist high wind blow-off, can add structural strength, and minimize moisture damage within the building envelope.
ORNL reports: *The principal causes of premature roof failure are moisture intrusion and lack of wind resistance. Moisture in roofing systems leads to dripping, accelerated failure of the insulation and membrane, structure deterioration, depreciation of assets, and poor thermal performance. Similarly, the loss of a roof during a major windstorm not only causes structural damage, but also exposes building contents to the elements. The insurance industry identifies roofing as the primary contributor to disaster-related insured losses.*

SPF roofing limits moisture intrusion because of its 90-percent closed-cell properties. Damage to the system typically does not cause leaks into the building, and moisture intrusion is isolated to the areas of damaged foam cells. As reported by Dr. Dupuis: “One unique aspect of SPF roofs... is they are not in immediate danger of leaking, providing the penetration does not extend all the way through the foam.”

SPF roofing systems have exceptional wind uplift resistance. Field observations of SPF performance during hurricanes Allen, Hugo, and Andrew led the industry to conduct laboratory testing of SPF systems at Underwriters Laboratories and FM Global.
Imagine UL’s surprise when SPF’s wind uplift resistance actually exceeded the capacity of their equipment. UL also observed SPF roofs applied over a built-up roof (BUR) and metal increased the wind uplift resistance of those roof coverings. FM’s testing showed similar results for concrete, metal, and wood.

According to Dupuis and other industry experts, SPF is a very good impact-absorbing material. Hail and wind-driven missiles rarely cause leaks in an SPF roof. Any damage can typically be repaired at a later date without compromising the long-term performance of the system.

One of the most famous examples is the New Orleans Superdome. A severe hailstorm damaged areas of the SPF roof in 1978, and the city debated for the next 10 years on how best to execute repairs. Finally, in 1992, the roof was repaired and re-coated. Despite such a long time before repairs were finally carried out, the roof never leaked from the hail damage. (In truth, some leaks were reported, but those were caused by bullets fired at the roof during Mardi Gras.)

ORNL also reports the need for multiple roofs makes roofing one of the largest contributors of solid waste. According to the National Roofing Contractors Association's (NRCA's) 1999 survey, more than 68.5 percent of the $11.3-billion, low-slope re-roofing market includes the tear-off and replacement of existing roof membranes.

SPF roofing systems display excellent adhesion to a variety of substrates, including BUR, modified bitumen (mod-bit), concrete, wood, asphalt shingles, clay tile, and metal. Since it adds little weight, and can be applied in various thicknesses to add slope and fill in low areas, SPF roofing systems are often used as a re-cover for existing roofs without tear-off. As such, SPF installed over existing roof coverings greatly reduces the amount of construction debris sent to landfill.

To top it off SPF roofing systems demonstrate significant sustainable characteristics: they have a long life, are renewable, save energy, add durability to buildings and control moisture in them, and contribute very little to the waste stream.
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Insulation and air barrier systems

Environmental control within a building envelope depends on stable interactions between heat, air, and moisture transports. To control these factors, one must have effective air barriers, rainscreens, weather barriers, and thermal insulation of a continuous nature so gaps do not compromise the designed climate control. The durability of a material in a building envelope depends on the outdoor and indoor climate, type of construction, and conditions of service. A small change in one of these variables may result in material failure during the first year, or flawless performance for 40.

The use of SPF systems can significantly affect the durability and climate control of a building. Three forms are typically employed within the building envelope: high-density (24 kg/m3 to 32 kg/m3 [1.5 pcf to 2 pcf]), low-density (less than 8 kg/m3 [0.5 pcf]), and sealant foams. High-density SPF is used when strength, and high moisture resistance and insulating values are desired, while low-density is used when insulation, air barrier, and sound control are desired. Sealant foams are used to caulk around windows, doors, sill plates, and other locations to seal against unwanted air infiltration/exfiltration.
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R-value

SPF's aged R-value varies depending on the formulation, blowing agent used, and application. Aged R-values of SPF used in insulation and roofing applications with a density ranging from 24 kg/m3 to 48 kg/m3 (1.5 pcf to 3 pcf) typically ranges between 6 and 7.5 per 25 mm (1 in.). Factors affecting R-value include: application thickness (the thicker the foam, the better the aged R-value), substrate, and covering systems used (the lower the perm-rated covering and substrate, the higher the aged R-value). Low-density (8 kg/m3 [0.5 pcf]), open-celled SPF typically has a stable aged R-value ranging from 3.4 to 3.6 per 25 mm (1 in.)

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In 1997, ORNL performed whole- and clear-wall testing of SPF between metal stud walls. High-density, 19-mm (0.75-in.) SPF was applied between the studs, with an additional 13 mm (0.5 in.) applied on top. Results confirm SPF greatly reduces the thermal bridging effect of metal studs. By controlling moisture infiltration, SPF also provides greater durability to buildings. The number one cause of building

deterioration is moisture within the building envelope. Many buildings' performance in hurricanes and other catastrophic events are adversely affected by moisture damage.
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Structural strength

SPF can add structural strength to buildings. Testing conducted by the National Association of Home Builders' (NAHB's) research center shows SPF insulation between wood- and steel-stud wall panels increases rack and shear by a factor of two to three when sprayed onto gypsum wallboard and vinyl siding, and increases racking strength by 50 percent when sprayed onto oriented strandboard (OSB). "During a design racking event, such as a hurricane," concludes NAHB, "there would be less permanent deformation of wall elements and possibly less damage to a structure braced with SPF-filled walls."

SPF provides better climate and moisture control by:
• providing a continuous air barrier;
• preventing moisture infiltration through air leakage;
• minimizing dew point problems and condensation;
• avoiding thermal bridging;
• resisting heat movement in all directions; and
• providing reliable performance under varying climatic conditions.

Better climate and moisture control saves energy, makes a building more comfortable, and reduces deterioration, thereby extending the life of a structure. SPF's climate control ability enables a downsizing of the heating and cooling equipment required for a building, further reducing energy use and upfront costs. Sideby-side energy efficiency comparisons have shown up to 40-percent energy savings by using SPF over commonly specified insulation materials. The use of high-density SPF within a building can add significant structural strength, minimizing damage from movement and racking events.
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Ozone depletion and global warming

Some groups still consider sprayed polyurethane foam harmful to the environment because of the blowing agents used in the higherdensity formulations. The following should set the record straight.

Before 1992, most high-density SPF used CFC-11 as the main blowing agent (a chlorofluorocarbon). From 1992 onward, HCFC-141b (a hydrochlorofluorocarbon) was the blowing agent of choice. (HCFC-141b will be phased out in the next couple of years. The most likely replacement candidates include blends of HFC-245fa [a hydrofluorocarbon], pentane, or water.) HCFCs and HFCs are considered environmentally superior to CFCs because they are essentially destroyed in the lowest region of the atmosphere. HFCs do not contain chlorine and have no ozone depletion potential (ODP). While HCFCs contain chlorine, only a small percentage can affect the ozone layer because most of the HCFCs released at ground level are destroyed in the lower atmosphere before they reach the stratospheric ozone layer.

The global warming potential (GWP) of a material is calculated by its total environmental warming impact (TEWI). The TEWI of a material is the total effect of the combination of direct (chemical) emissions and indirect (energy-related) emissions on global warming. In the case of insulation systems, the direct effect equals total greenhouse gases released into the atmosphere. The indirect effect is calculated by estimating the equivalent carbon dioxide (CO2) emissions based on how long the system remains in place before replacement, along with the total amount of fuel consumed.

With the world's dependence on fossil fuels for primary energy needs, and the predominant contribution of CO2 to global warming, energy efficiency is crucial. Carbon dioxide contributed 55 percent of the greenhouse gases affecting global warming between 1980 and 1990. CFC blowing agents contributed 17 percent of greenhouse gases during the same period. Replacing CFC blowing agents in foam insulation with HCFCs reduced SPF's GWP by 92 percent. SPF's exceptional insulative quality reduces the amount of CO2-producing fossil fuels one has to burn for heating and cooling purposes.

The GWP of a gas is calculated from its energy-absorbing properties over a specified length of time. The longer it takes for a gas to be purged from the atmosphere, the worse its GWP. It takes more than 500 years for CO2 emissions to be purged from the atmosphere. Even after 500 years, 19 percent of CO2 survives to propagate global warming. Most HCFC-141b and HFC-245fa blowing agents leave the atmosphere within 10 years.

While most roofs are replaced within 15 years, wall insulation systems typically remain in place until a building is remodeled or demolished. The longer the insulation system remains in place, the more reduction in global warming. SPF roofing systems are generally not replaced, thereby increasing their effectiveness
at reducing global warming. Employed in insulation systems, SPF's ability to provide effective air barriers and control moisture increases its effectiveness at reducing global warming.
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Energy costs of production

Franklin and Associates Ltd.'s study, Comparative Energy Evaluation of Plastic Products and Their Alternatives for the Building and Construction and Transportation Industries, compares the total energy requirements for the manufacture of plastic products to the total energy requirements for the manufacturer of plastic alternatives. The unique feature of this type of analysis is its focus on all the major steps in the manufacture of a product—raw material extraction from the earth, fabrication, and even transport—rather than a single manufacturing step.

The study concludes plastic products in the building and construction industry use less energy from all sources than other materials. According to the Franklin study, polyurethane foam insulation saved 3.6 trillion kJ (3.4 trillion Btu) in manufacturing energy over fiberglass insulation in 1990. To get an idea of how much energy that equals, consider 1.1 trillion kJ (1 trillion Btu) is equivalent to almost 170,000 barrels of oil, and 28.3 million m3 (1 billion cf) of natural gas.

As mentioned earlier, SPF helps reduce tear-off debris in roofing applications. SPF's on-site application process generates very little debris and waste. A typical 929-m2 (10,000-sf) roofing project produces less than 0.4 m3 (0.5 cy) of scrap SPF, tape, and plastic (used for masking), and from one pint to three gallons of waste solvent (depending on type of protective covering used). Compare this to the typical 929-m2 re-roofing project, which produces more than 7.6 m3 (10 cy) of construction debris from tear-off and application waste. At the present, so little scrap SPF is produced, material recycling is practically

impossible.
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