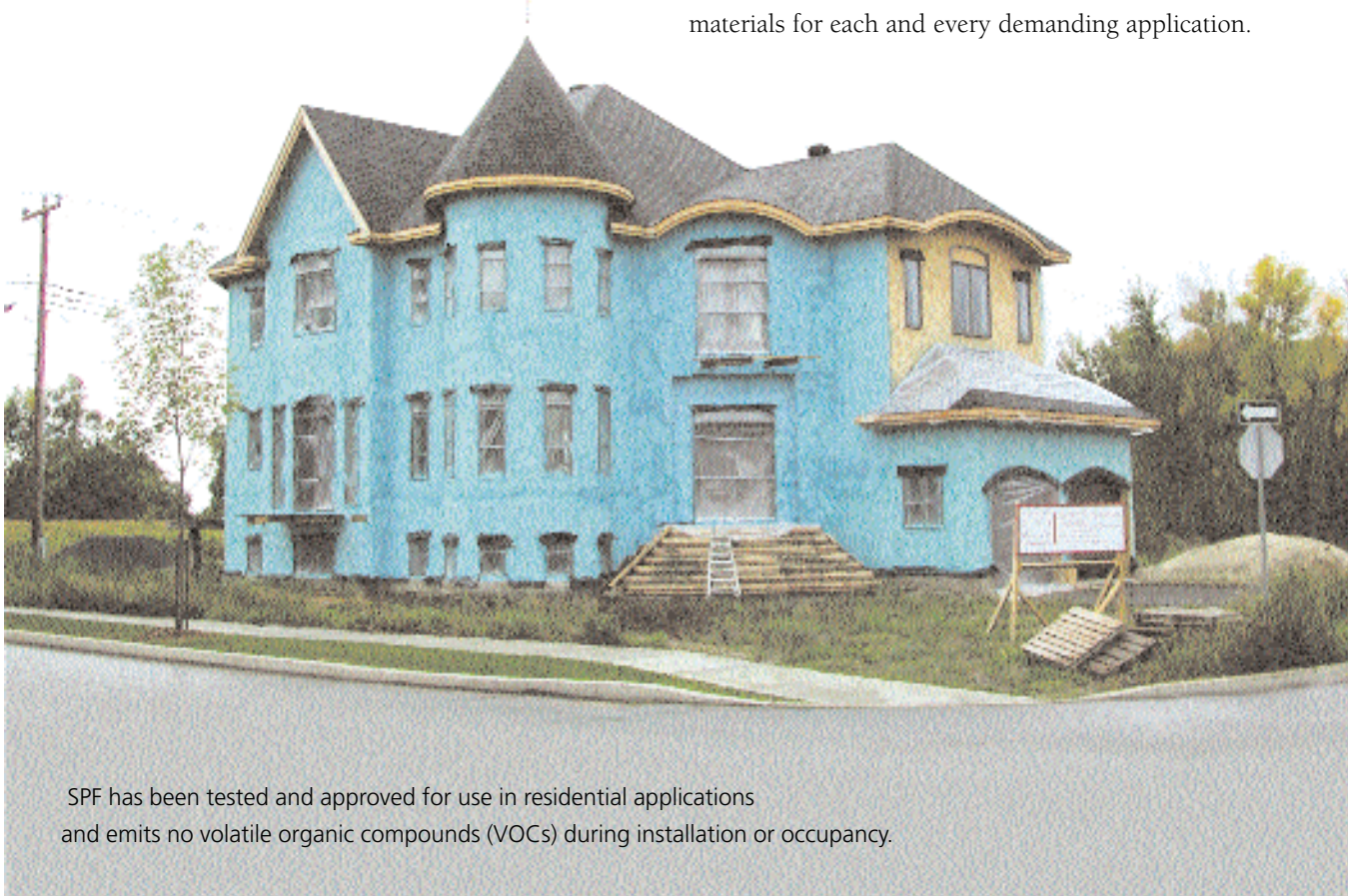


High-Performance Buildings Drive

By Tom Harris

‘Engineered Materials’

The role of materials in construction is changing. No longer is the process limited to making commonly available materials fit ever-more challenging designs and performance requirements. Instead, we are seeing a new wave of engineering customized building materials for each and every demanding application.



SPF has been tested and approved for use in residential applications and emits no volatile organic compounds (VOCs) during installation or occupancy.

Photo courtesy Great Northern Insulation

Photo courtesy of Great Northern Insulation



The Air Barrier Association of America (ABAA) approves the use of SPF engineered building envelope system to meet the 29 state commercial energy codes meeting or exceeding ASHRAE 90.1-89, *Energy Standard for Buildings Except Low-Rise Residential Buildings*.

Owners and developers, particularly in the owner-occupied and public sectors, are demanding higher performance buildings, as witnessed by the influx of new construction guidelines, such as Building for Environmental and Economic Sustainability (BEES®) and Leadership in Energy and Environmental Design (LEED), not to mention stricter codes. Among other things, higher performance can mean greater durability, improved safety, better energy efficiency, and improved occupant comfort.

The building science community has known for some time that improving the quality of the building envelope is one of the best ways of improving specific elements of overall building performance. Consider, an estimated 54 percent of energy consumption in the United States is directly/indirectly related to buildings and their construction.¹ The U.S. Department of Energy (DoE) reports 40 percent of the energy cost of heating and cooling a building is wasted by uncontrolled air leakage through the building envelope. This uncontrolled leakage can also contribute to premature building deterioration, condensation, spalling, ice damming, poor indoor air quality (IAQ), and mold growth.

Riding the wave toward better-performing envelopes is spray polyurethane foam (SPF). The performance of the envelope is directly related to its structural integrity, durability, and continuity of air barrier systems. This is where engineered, customizable materials, like SPF, can make important contributions.

Engineered to optimize site-specific performance

The first documented application of SPF in the United States occurred in 1958. In recent years, SPF has evolved into one of the fastest growing polymers in construction. It is a two-component

product engineered at the molecular level for a specific purpose, including roofing insulation, cathedral ceilings, attics and air seals, wall insulation and air barrier systems, below-grade foundation insulation, and below slab-on-grade.

Three types of SPF are used within the engineered building envelope:

- medium-density (MD) 24 kg/m³ to 48 kg/m³ (1.5 pcf to 3 pcf),
- low-density (LD) 8 kg/m³ (less than 0.5 pcf), and
- sealant foams.

MD-SPF can be used when strength, and high moisture resistance and insulating values are desired. LD-SPF can lower insulating value and moisture resistance, but offers a modest degree of sound control. Sealant foams are used to caulk around windows, doors, sill plates, and other locations to seal against unwanted air infiltration in both new construction and the thriving retrofit market.

Closed-cell formulations typically range in density from 27 kg/m³ to 51 kg/m³ (1.7 pcf to 3.2 pcf), while compressive strength ranges from 103 kPa to 345 kPa (15 psi to 50 psi). The density and composition of closed-cell foams can add structural integrity to the building. Open-cell foams used for insulation have densities of 8 kg/m³ to 16 kg/m³ (0.5 pcf to 1 pcf) and offer compressive strengths of 28 kPa to 83 kPa (4 psi to 12 psi), adding minimal or no structural integrity. (These products do not qualify as air barriers as defined in ASTM International E 2178, *Standard Test Method for Air Permeance of Building Materials*.)

R-values of SPF used in air barrier, insulation, and roofing applications with densities ranging from 24 kg/m³ to 51 kg/m³ (1.5 pcf to 3.2 pcf) typically range between 6 and 7.5 per inch. 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 inch.

Closed-cell, MD-SPF is sprayed-in-place, making it seamless and 100-percent fully adhered (where applied). It requires no fasteners

or adhesives, and may not shrink or sag over time, making it ideal for use in vertical wall, cathedral ceiling, and below-grade exterior applications. It conforms to irregular shapes and expands to fill cracks, gaps, holes, and seams for monolithic air impermeability and insulation performance.

Safety

SPF can help prevent mold growth. To survive and thrive, mold requires an ambient temperature between 4 C and 38 C (40 F and 100 F), 60 percent or higher relative humidity, oxygen, and a food source (gypsum wallboard, wood, adhesives, ceiling tiles, insulation, paint, plywood, paper, and cardboard are all potential sources of nutrition). SPF air barrier systems actually retard mold growth by eliminating condensing surfaces and stopping the migration of moisture-laden air through the building structure.

SPF has been tested and approved for use in residential applications and is approved by the Air Barrier Association of America (ABAA) for meeting state energy codes.^{2,3} It emits no volatile organic compounds (VOCs) during installation or during occupancy.⁴ SPF systems using zero ozone-depleting blowing agents are available and approved for use by the U.S. Environmental Protection Agency's (EPA's) Significant New Alternatives Policy (SNAP) program.

Only trained professionals can install SPF systems. SPF and equipment manufacturers, the National Roofing Contractors Association (NRCA), Roofing Consultants Institute (RCI), Society for Protective Coatings (SSPC), Air Barrier Association of America (ABAA), and the Spray Polyurethane Foam Alliance (SPFA) have all made a commitment to quality control through training and education. The SPFA Accreditation Program can provide the industry with up-to-date training in the application of spray polyurethane foams, coatings, and good business practices.

The joint training efforts of trade groups, associations, and manufacturers have contributed to a drastic reduction of the typical failure modes of early SPF roofs, and created a roster of highly-trained, certified contractors across North America from which to choose.

Durability

SPF has a 40-year track record of proven in-field performance. Like so many other building materials, SPF needs to be maintained to ensure longevity. Thankfully, though, these systems can require minimal maintenance, and when minor repairs are required, they can usually be effected with a tube of silicone or urethane caulk, (depending on the type of coating used in the original installation).

In the mid 1990s, NRCA's National Roofing Foundation (NRF) commissioned Structural Research Inc. of Middleton, Wisconsin, to perform an independent field and laboratory assessment of SPF roof systems to establish and verify existing performance attributes.⁵

The study included the inspection of 140 SPF roofs with acrylic, silicone, and urethane coatings, ranging in age from six months to 27 years. Four climates were included in the study: hot, humid summers with moderate winters (Texas); hot, dry summers with wet, cool winters (California), moderate to hot summers with very cold winter temperatures, and heavy snow and ice (Illinois and Wisconsin), and; moderate to hot summers, and cold and damp winters (New York).

The NRCA/NRF study, combined with testing performed by Underwriters Laboratories (UL) Inc. and FM Global, along with documentation gathered by Thomas L. Smith of TlSmith Consulting after Hurricane Andrew (which decimated Dade County, Florida, 10 years ago), shows the following about SPF's performance:

Compressive strength

The average compressive strength for all samples was 404 kPa (58.6 psi), while the highest compressive strength of 685 kPa (99.3 psi) was recorded at a New York installation with silicone coating dating back to 1975. (Minimum required compressive strength for newly-installed SPF roofs is 276 kPa [40 psi]).⁶ (Determined using ASTM D 1621, *Standard Test Method for Compressive Properties of Rigid Cellular Plastics*).

Apparent core density

The average apparent core density was 51.6 kg/m³ (3.2 pcf) for all samples. The highest was 78 kg/m³ (4.9 pcf) from a location in northwestern Wisconsin installed in 1974, while the lowest was 30.1 kg/m³ (1.9 pcf). Rene M. Dupuis of Structural Research Inc., the author of the report, noted the recommended minimum foam densities for newly installed SPF roofs had risen over the years to a minimum 44.9 kg/m³ (2.8 pcf) by the 1990s. (Determined using ASTM D 1622, *Standard Test Method for Apparent Density of Rigid Cellular Plastics*).

The newest SPF roof in the NRCA/NRF study had a core density of 64.1 kg/m³ (4.0 pcf) with a compressive strength of 448 kPa



Did You Know?

The energy saved with the use of plastic housewrap surpasses the energy used to make these plastic products—some in less than two months after installation.



Plastic lumber used in decks, railings, fencing, trellises, furniture, edging, and decorative products—often made of recycled material—is weather-resistant, low-maintenance, and can last decades.

Photo courtesy of Great Northern Insulation



SPF is sprayed in place, making it seamless and 100-percent fully adhered (where applied). It requires no fasteners or adhesives, and may not shrink or sag over time, making it ideal for use in vertical wall, cathedral ceiling, and below-grade exterior applications.

(65 psi). The oldest had a density of 56.4 kg/m³ (3.5 pcf) with a compressive strength of 685 kPa (99.3 psi).

Moisture content values

Average moisture content was negligible, at 1.02 percent by weight. Dupuis noted the physical properties of the evaluated roofs came up positive—regardless of the age of the installation—in most cases exceeding the required minimums for new installations despite in-field service of 25 years or more. (Determined by oven drying samples at 50 C [122 F]).

Wind uplift

SPF offers a very high wind uplift resistance rating. Independent testing organizations like UL and FM Global test various roofing systems for wind uplift performance then publish the results in their directories. Mason Knowles, SPFA's executive director, reports SPF's wind uplift resistance exceeded the capacity of UL's equipment during laboratory testing. UL also observed SPF applied over built-up roofs (BURs) and metal increased their wind uplift resistance. Knowles says FM Global's testing showed similar results over concrete, metal, and wood.

Abuse resistance

A primary cause of failure during severe weather is flying debris or hail actually puncturing a roof. SPF systems can offer resistance to impact. During his post-Hurricane Andrew investigation, Thomas Smith discovered even when debris punctured the SPF foam straight down to the metal deck, the roof did not leak, and could actually remain unrepaired indefinitely without developing leakage problems.

Results from testing conducted by the National Research Council (NRC) of Canada's Canadian Construction Materials Centre (CCMC)—wherein they measured the structural aging of an SPF air barrier system by subjecting it to a loading schedule—show SPF air barriers offer long-term durability greater than or equal to the building's life span. The testing involved: one-hour sustained positive and negative pressure set at 0.6 kPa (0.09 psi), 2000 cycles of positive and negative pressure set at 0.8 kPa (0.12 psi), and a gust of wind of positive and negative pressure of 1.2 kPa (0.17 psi).

SPF air barriers can add structural strength to buildings. Testing conducted by the National Association of Home Builders (NAHB) Research Center shows SPF insulation between wood- and steel-stud wall panels increased rack and shear two to three times when sprayed onto gypsum wallboard and vinyl siding, and increased racking strength by 50 percent when sprayed onto oriented strandboard (OSB). According to the NAHB Research Center, "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."⁷

Energy efficiency

SPF offers an aged insulation design R-value of 6 per inch, depending on the thickness of the application (the thicker the foam, the higher the R-value). And because SPF is self-adhering and spray applied, it requires no fasteners and eliminates thermal bridging around boards, even when ship-lapped or staggered, by providing a continuous layer of insulation over existing thermal bridges in the roof deck and assembly.

Texas A&M University studied the energy efficiency performance of 27 different buildings on the campus that had received an SPF roof between 1980 and 1984. The results show the university was able to recover the complete cost of the roofs through energy savings realized over an average of 4.5 years.⁸

Stack effect

The DoE reports 40 percent of the energy cost of heating and cooling a home is wasted by uncontrolled air leakage through the building envelope. Wind pressurizes the windward side of the building and depressurizes the other sides and roof, accounting for up to 25 percent of total air leakage. The remaining 75 percent of air leakage is induced by stack effect and fan pressurization.


To combat this air leakage, the versatility of polyurethane chemistry is employed to create an engineered solution in the form of one- and two-component air sealing polyurethane foams used to seal gaps, cracks, and holes, and provide the all-important air barrier continuity between the elements of the building envelope.

Proof of the connection between a retrofitted building envelope and reduced HVAC operating costs can be found in many documented projects. In the 1970s, 17 percent average electricity savings resulted from simple air sealing of roof/wall joints in single-story public schools in Toronto, Canada. Perimeter air sealing of high-rise apartment buildings in Ottawa, Canada, and Toronto showed an average of more than 10-percent reduction in electrical demand, and about nine percent reduction in electricity consumption.

The Air Barrier Association of America (ABAA) approves the use of SPF-engineered building envelope systems to meet the 29 state commercial energy codes that meet or exceed American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) 90.1-89, *Energy Standard for Buildings Except Low-Rise Residential Buildings*.

Looking forward

To gain a real understanding of end-use performance, the industry is moving toward evaluating the thermal performance of an entire wall instead of just the R-values of individual materials. Joint work is being planned by the NAHB Research Council and the American Plastics Council (APC) to evaluate different wall systems with the goal of developing guidelines for an accepted energy performance rating for entire wall systems.

Numerical models incorporating material-specific characteristics have existed for many years, but very little field data has been collected to verify them. Work in this field is continuing at NRC and several centers throughout the United States. The University of Syracuse in New York has assembled a consortium of building material manufacturers and building practitioners directed at developing new and improved wall systems, while Oak Ridge National Laboratory (ORNL) and DoE continue research into the contribution of the building envelope to the safety, durability, and energy efficiency of the structure. 

Notes

¹ According to a 1998 report by Godfried Augenbroe and Annie R. Pearce of Georgia Institute of Technology.

² Canadian Construction Materials Centre (CCMC), *Evaluation Report 12932-R*, National Research Council (NRC) of Canada.

³ Air Barrier Association of America (www.airbarrier.org).

⁴ Air Barrier Association of America (www.airbarrier.org).

⁵ Dupuis, R.M., "Field and Laboratory Assessment of SPF Roof Systems," Proceedings of the 4th International Symposium on Roofing Technology, 1996.

⁶ National Roofing Contractors Association (NRCA), *Roofing and Waterproofing Manual*, 4th Ed.

⁷ National Association of Homebuilders (NAHB) Research Center. "SPF Wall Panel Performance Testing, 1992 and 1996." Berkeley, CA.

⁸ 1985 study by Gerald Scott, PE, of Texas A&M University showed significant energy savings on 27 different campus buildings re-roofed with SPF between 1980 and 1984. The complete cost of re-roofing was covered by energy cost savings within 4.5 years.

About the Author

Tom Harris is the product manager for BASF's Spray Foam Group in the United States. Over his 20-year career within the polyurethane systems business he has chaired eight Technical Committees within The Society of the Plastics Industry (SPI), Canadian General Standards Board (CGSB), National Research Council (NRC) of Canada, and the Canadian Urethane Foam Contractors Association (CUFCA). Harris is currently contributing to two ASTM International committees, one National Roofing Contractors Association (NRCA) committee, and the Spray Polyurethane Foam Alliance's (SPFA's) Building Envelope committee. He also represents BASF as a founding member of the Air Barrier Association of America (ABAA).



Did You Know?

The manufacture of PVC pipe provides overall energy savings when compared to some alternative materials.



Entry doors with a foam plastic core can inhibit sound and add insulation value that can lower heating and cooling energy requirements.