Navigating the Different Densities of Sprayfoam

by Rick Duncan, PhD, PE

Photos courtesy Spray Polyurethane Foam Alliance

A HIGH-PERFORMANCE BUILDING ENVELOPE MATERIAL, SPRAYED POLYURETHANE FOAM (SPF) IS INCREASINGLY USED IN COMMERCIAL STRUCTURES AS AN INSULATION AND AIR BARRIER. SPRAYFOAM IS PLAYING A GROWING ROLE IN SUSTAINABLE NEW CONSTRUCTION, ENERGY-ENHANCING RETROFITS, AND EVEN THE NET-ZERO ENERGY MOVEMENT.

The material acts as a single-source solution for thermal, air, and moisture control, providing architects and builders with the ability to seal the building enclosure via one product and eliminating the need to specify numerous additional products to accomplish the same performance. Used in all climate zones, the material is durable, versatile, and light. It tenaciously adheres to nearly every construction substrate, expands in place, and remains there without settling, providing consistent performance over the structure's life.

SPF is offered in a range of densities, classified into three categories:

- open-cell (or low-density) foams consisting of 8 to 22-kg/m^3 (0.5 to 1.4-pcf) density with an open-cell structure;
- closed-cell (or medium-density) foams of 24 to 37-kg/m^3 (1.5 to 2.3-pcf) density with a closed-cell structure containing an insulating gas; and
- roofing (or high-density) closed-cell foams of 40 to 56-kg/m^3 (2.5 to 3.5-pcf) density.

Regardless of density, all sprayfoam options perform as insulation and air barriers. However, the density and cell structure affects the product performance characteristics and should be a key consideration when specifying SPF for different building assemblies. Understanding the variations and fundamental pros and cons between the categories of SPF helps ease the specification process for new or retrofit commercial facilities.

Open-cell insulation

Open-cell SPF is relatively soft to the touch, with the material's structure providing flexibility to the foam. Offering excellent thermal insulation and air-sealing capabilities, it is ideal for filling interior walls and ceilings where there is no risk

of water contact. Impermeable to air movement, it helps reduce the escape of conditioned air, which, in turn, lowers energy demands and operating costs.

An important distinction of open-cell SPF is its vapor permeability, which allows it to absorb and release moisture vapor more freely than closed-cell foams. This characteristic alone makes the low-density material ideal for interior applications rather than exterior ones where water contact is possible.

Open-cell SPF may also better accommodate the seasonal movement of some structures than its closed-cell counterpart. (For example, special design considerations may be needed in the installation of closed-cell SPF beneath large roof structures.) The material also performs better than the other sprayfoam classes in the area of sound attenuation because it is a softer material that absorbs sound better than more rigid closed-cell foams. Open-cell SPF tends to be the lower installed cost option because of higher yield (at the same R-value) and lower total labor costs, since open-cell foams can be installed to required thickness in a single pass.

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Photos courtesy BioFoam

Closed-cell insulation

Considered the medium-density foam class, closed-cell SPF is a rigid foam option that offers a higher R-value, or resistance to heat flow, per inch as compared to its open-cell counterparts. Instead of containing air in the cells like open-cell SPF, the cells contain a fluorine-based gas that is low in thermal conductivity, similar to double- or triple-pane windows. This gas entrapped in the cells provides the higher R-value per inch than open-cell SPF.

Closed-cell foam is ideal for continuous insulation (ci) applications in commercial structures; it can be used in both interior and exterior applications where it essentially replaces commonly utilized rigid extruded polystyrene (XPS) and polyisocyanurate (polyiso) foam boards.

Installed at a thickness of 50 mm (2 in.) or more, the material will also meet Class II vapor requirements (*i.e.* moisture permeance between 0.1 and 1.0 Perms) for colder climates, whereas open-cell SPF needs an additional vapor retarder coating or covering for these locations. It is also widely utilized in smaller spaces requiring higher R-values or where severe moisture could be an issue. With classification from the Federal Emergency Management Agency (FEMA) as a flood-resistant material, this type of sprayfoam insulation is widely specified in regions where flooding is more likely to occur.

Certain closed-cell sprayfoam may also be applied at temperatures as low as −15 C (5 F), making it ideal for use in colder climates where weather will not impede installation and exceptional heat flow resistance provides added benefit. These medium-density sprayfoams possess higher tensile and bond strength than low-density options and are proven to add

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SPF is self-flashing and can be optimal for use with various penetrating components.

structural strength to the building. Closed-cell foams will have a higher installed cost than open-cell SPF installed to the same R-value.

Roofing foam

In roofing applications, SPF is applied to the top surface of low-slope roofs, where it acts as both a protective material and as an insulator. Roofing foam is the highest-density and strongest class of sprayfoam with a compressive strength of 276 to 414 kPa (40 to 60 psi). This high density is essential in roofing applications, as the material must withstand normal foot traffic and provide a barrier to moisture and rain, weather cycling, and, with proper coatings, additional elements including wind, hail, and ultraviolet (UV) light.

When installed, the SPF creates a monolithic continuous insulation layer over the exterior, acting as a vapor retarder, water-resistant barrier, air barrier, and thermal insulator. Similar to low- and medium-density sprayfoam, it provides air-sealing and consistent R-value at a wide range of service temperatures.

As a roofing material, SPF is lightweight and optimal for use when:

- roof deck is an unusual configuration or shape;
- sloped application must provide the roof controlled drainage;
- substrate includes many penetrations (*e.g.* photovoltaic [PV] panel supports);
- structure is located in a region of extreme weather cycling;
- structure is unable to support additional weight on the roof;
- removal of the existing roofcovering is cost-prohibitive; or
- multiple roof penetrations and other roof-mounted equipment need proper flashing.

SPF roofing is considered a cost-effective option, with the installed price very competitive with other low-slope roof systems. It does require protection with a coating to prevent surface degradation from ultraviolet (UV) exposure, mechanical wear, and other weathering processes. It can be coated with a number of elastomeric coatings including acrylic, silicone, butyl rubber, polyurethane, and polyuria—however, acrylic and silicone are most commonly applied.

Specification of open- and closed-cell SPF insulations in one renovation

The Natural History Building has been a distinguished landmark at the University of Illinois for well over a century. Built in 1892, the building was originally designed by the renowned Nathan Ricker—an Illinois alumnus himself and the first person to earn a degree in architecture in the United States. With an architectural look best described as High Victorian Gothic, the red brick structure sits on a rough stone foundation. Colored brick and stone adorn the exterior.

Biofoam was responsible for insulation retrofit work at the University of Illinois' Natural History Building in Urbana. It installed 250 mm (10 in.) of open-cell foam to the underside of the existing roof and 50 mm (2 in.) of closed-cell SPF to the inside of the exterior masonry walls.

Since its inception, the 13,750-m² (148,000-sf) educational facility has provided a functional space for college-level learning. However, the university closed the building in May 2014 due to significant structural deficiencies. Since then, the property underwent an extensive $70-million renovation aimed at making the building more structurally sound while transforming it into a modern, technologically advanced learning environment. The enhancement also focused on preserving the original architectural detail envisioned by Ricker, which ultimately led the Natural History Building to securing its place on the *National Register of Historic Places* in 1986.

One of the dramatic improvements to the building was a major enhancement to the envelope's insulation. Biofoam Inc., a Chicago-based insulation, roofing, and waterproofing contractor, was brought in to handle this part of the retrofit.

Recognizing the variances in performance, cost, and best-use applications in the envelope for both low-density (*i.e.* open-cell) and higher-density (*i.e.* closed-cell) SPF, the project's design team specified two types for the facility's envelope. Following those specifications, Biofoam installed 250 mm (10 in.) of open-cell foam to the underside of the existing roof and 50 mm (2 in.) of closed-cell to the inside of the exterior masonry walls.

Application of the open-cell sprayfoam focused on the underside of the facility's cathedral roof, up to 8.5 m (28 ft) in some areas. Scaffolding was assembled around many obstacles to apply the foam where ceiling heights were greatest, as the structure's age does not allow for lifts above the first floor. The sprayfoam selected was a 0.50-pound variety that required no additional ignition barrier to meet the requirements of Appendix X—a test for fire resistance of assemblies in limited-access areas such as attics and crawlspaces. The open-cell foam is ideal for this interior application.

Open- or closed-cell SPF could have been used for this application. While the latter provides an integral vapor retarder required in colder climates, it must be applied in multiple passes to achieve the desired thickness and R-value. Open-cell SPF needs almost twice the thickness to achieve the same R-value as closed-cell SPF, but the entire thickness can be applied in a single pass, saving on installation labor and making the installed cost less than its closed-cell counterpart for a fixed R-value.

The closed-cell sprayfoam was applied to the exterior walls, behind the brick masonry. The

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32-kg/m³ (2-pcf) medium-density foam acts as an insulation, air barrier, and moisture barrier. The Class A fire-rated sprayfoam adds structural strength to the building, with a compressive strength of 220 kPa (32 psi) and a tensile strength of 440 kPa (64 psi). Resistant to moisture, the sprayfoam also prevents the growth of mold and mildew. These characteristics are key indicators of its performance as an exterior sprayfoam product.

"With this enhancement, the Natural History Building is not only a world-class educational facility, but a true energy-efficiency performer," said Tiffiny Flaim, president of Biofoam. "We expect long-term energy cost reductions to reach 30 percent. And, to boot, the facility is expected to achieve a [U.S. Green Building Council Leadership in Energy and Environmental Design] USGBC LEED Silver designation, in part because of the high-performance insulation applications."

The Natural History Building brings all programs within the university's School of Earth, Society, and Environment (including the atmospheric sciences, geography and geographic information science, and geology departments) under one roof for the first time. The historic structure is also home to teaching programs in the School of Integrative Biology, which encompasses animal and plant biology, along with entomology, as well as the Integrative Biology Honors program. Enhanced classroom interiors have been designed to encourage collaboration among students and teachers, and laboratories showcase the latest advanced technologies.

"With such a rich architectural and educational history, the Natural History Building is a gem of the university and the community," added Flaim. "It was well-deserving of this significant upgrade."

Importance of industry certification

With the growing use of SPF in the built environment, the verification of best-practice adherence among installers, contractors and suppliers is ever important. As such, professional certifications and accreditations have become a critical designation for all involved in the installation of SPF. The Spray Polyurethane Foam Alliance (SPFA) offers a Professional Certification Program (PCP), giving all installers, field examiners, contractor companies, supplier companies, and supplier representatives the opportunity to prove their knowledge and adherence to best practices. **CS**

ADDITIONAL **INFORMATION**

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Rick Duncan, PhD, PE, is the technical director of the Spray Polyurethane Foam Alliance (SPFA), an organization representing contractors, material and equipment manufacturers, distributors, and industry consultants. Prior to joining SPFA in 2008, Duncan held the positions of senior marketing manager for Honeywell's SPF business and global program director for CertainTeed/Saint-Gobain. He holds a PhD in engineering science and mechanics from Pennsylvania State University and is a registered professional engineer in the state. Duncan can be contacted by e-mail at rickduncan@sprayfoam.org.

Abstract

This article examines how to choose the right sprayed polyurethane foam (SPF) insulation density for specific areas of a commercial project, ranging from unvented attics, cathedralized ceilings, and attic floors to basement, exterior, and interior walls. Climate considerations will also be discussed, as the piece draws on specific projects exemplifying best practices in sprayfoam application.

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