

# modern materials

Vol. 4 No. 2

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## The **\$SAVINGS** Behind **Foam Plastic**

## Surprising New Wall Assembly Study from NAHB Research Center



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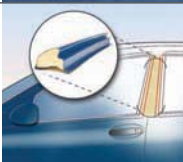
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When winter comes around, energy costs can be particularly high for homeowners in colder climates. As such, specifying the correct insulation materials is key. This particular home benefits from the use of structural insulated panels (SIPs)—a composite building product combining traditional material with plastic foam. A new study suggests plastic building products can be more thermally efficient than previously thought.

Inset photos courtesy American Polysteel.

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# Is Foam Insulation ‘Plastic?’ Welcome to the Knowledge Issue II

**W**hat’s in a name? Sometimes calling the same thing by different terms leads to confusion over what it actually is.

In the previous issue of *Modern Materials*, we examined your responses to our Web and mail survey, conducted by Accountability Information Management (AIM) on behalf of the American Plastic Council (APC). One of the questions asked what the most ‘energy-efficient’ material was and unsurprisingly you picked foam insulation by far—twice the second place material, fiberglass (Table 1). However, it was interesting to note among the material choices listed, ‘plastics’ were rated far lower in the survey, selected by only 10 percent of participants. Either our readers don’t know foam insulation is plastic or they may not know the low thermal conductance of plastics as an insulator in general.

Building Material	Percentage of Respondents
Foam insulation	48%
Fiberglass	19%
Concrete	17%
Wood	15%
Masonry	10%
Plastics	10%
Metal	2%
Other	2%
Glass	2%

**Actual question (311 respondents):** Which of the following building materials do you think is the most energy-efficient in the long-term operation of a building (i.e. least energy needed to heat and cool)?

‘Plastics’ and ‘foam insulation’ are one and the same. Whether extruded polyurethane, polyiso, expanded polystyrene (EPS), extruded polystyrene (XPS) rigid boards, or sprayed polyurethane foam (SPF), the various foam products are all plastics.

The confusion over ‘plastics’ versus ‘foam’ is also evident in another survey question. AIM asked *Modern Materials* readers about some of the most common uses for plastics (Table 2). ‘Insulation’ did not even make the top 10, despite the fact ‘foam’ was considered the most energy-efficient material in the above question.

Since the majority of the impact a building has on the environment comes from its ‘use’ phase (the heating and cooling energy and its associated pollutants), insulation should be an important consideration when seeking the ultimate goal of doing no harm to the environment.

One commonly ‘unknown’ fact is certain insulating foam plastics vary with regard to the gas used to create the product’s bubbles. Think of millions of bubbles (closed cells) in a rigid foam board; trapped in each cell is air or gas. This characteristic alone does not determine the success of a particular foam insulator, but it can play a role. How the molecules in the bubble bounce inside and convey heat to the adjacent walls of each cell determines how the heat flows through the material. A good insulator reduces the heat flow across the millions of cells in the foam. (For a real-time illustration of this property,

visit [comp.uark.edu/~jgeabana/mol\\_dyn/KinThI.html](http://comp.uark.edu/~jgeabana/mol_dyn/KinThI.html).) This is a simplification, but there are many ways these plastic products and foams help limit the impact of the ‘use’ phase of the building on the environment.

This issue of *Modern Materials* presents several insulation-related

Building Material	Percentage of Respondents
Molding trim	91%
Plumbing	87%
Decking and fencing	86%
Windows	84%
Siding	83%
Housewraps	72%
Doors	70%
Flooring	68%
Wallcoverings	66%
Beams/balustrades/ columns	55%
Kitchen and bath fixtures	54%
Roofing	52%
Insulation	52%

**Actual question (311 respondents):** Based on your experience, which of the following building materials are made from plastic? Check all that apply.

studies and how-to articles. One feature explores how SPF solved the riddles on a particularly demanding project, while another examines proper specification and assembly of XPS sheathing. Brand new this month are the just released findings of a recent NAHB Research Center insulated wall panel study comparing a conventional ‘stick and batt’ wall assembly to several plastic building product alternatives. The study showed plastic building products can reduce the heat flow of a wall in real-world, windy conditions up to 29 percent compared to the baseline wall. R-value, it seems, does not tell the whole story. Finally, another piece examines how new tax laws can achieve tax deductions and credits for improving insulation.

Remember: foam plastics work well in a variety of applications beside walls, including roofing, air barriers, ceilings, attics, and basements, pipes and tanks, cold storage areas, freezers, walk-in coolers, climate-controlled clean rooms, and produce storage.

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# PLASTICS Takes Improvement to the Wall

NEW NAHB RESEARCH CENTER WALL STUDY  
ABOUT HEAT FLOW—R-VALUE NOT THE WHOLE STORY

By Craig Drumheller, NAHB Research Center

“Plastic building products can reduce heat flow an average of 18 to 25 percent over baseline wall under windy conditions.”

In an effort to more realistically quantify the energy performance of a variety of wall system alternatives under simulated ‘real-world’ conditions, the National Association of Home Builders (NAHB) Research Center, through the labs of Architectural Testing Inc., conducted a series of residential wall panel tests during 2005 and 2006. The purpose was to compare the most common ‘baseline wall’ (i.e. fiberglass batt insulation between 2x4 wooden studs finished with interior drywall) against several walls containing plastic building products (including foam plastic insulating materials).

R-value represents resistance to conductive heat flow, where higher numbers indicate increased thermal resistance. (In other words, the higher the R-value, the greater the insulating power.) Although R-value has been traditionally used in building codes for decades to quantify minimum insulation requirements for standard wall construction, it does not provide a complete accounting of the overall wall system’s energy performance. Effects such as thermal bridging of framing members, air and wind infiltration resistance,

File photo



Prior to the National Association of Home Builders (NAHB) Research Center insulation study, wall samples, similarly aged, are readied for their hot box testing.

and stack effect on the building shell under normal, ‘real-world’ operating conditions are not considered in the R-value.

This study is unique in its evaluation of overall wall system performance. It was designed to characterize the energy consequences of wall construction and insulation material choices under simulated wind pressure conditions. To more accurately represent various climates and

‘real-world’ conditions, each wall system was tested under two conditions:

- in a ‘static state’ condition with no additional atmospheric wind pressures at one outdoor temperature; and
- with a 24-km/h (15-mph) ‘wind loading’ at three different outdoor temperatures.

Testing showed all the wall systems performed similarly (within the statistical accuracy of the testing apparatus) under

no-wind conditions. Of course, all walls under wind conditions performed less well than with no wind. Nonetheless, once simulated ‘real-world’ wind loading was applied, the wall systems with plastic building products performed between 14 and 29 percent better, with performance, relative to the baseline wall, increasing as the outside temperature rose. This indicates air infiltration plays an important role in the

Table 1  
**Panel Study Parameters**

Interior finish	Insulation*	Sheathing	Weather barrier
12.7-mm (1/2-in.) gypsum	R-13 KFB (88.9 mm [3.5 in.])	11-mm (7/16-in.) OSB	None
1/2-in. gypsum	R-13 KFB (3.5 in.)	7/16-in. OSB	House wrap
1/2-in. gypsum	54 mm (2.1 in.) of spray foam insulation R-13	7/16-in. OSB	None
1/2-in. gypsum and OSB	Net R-15 SIP (92 mm [3 5/8 in.])	7/16-in. OSB	None
1/2-in. gypsum	R-13 KFB (3.5 in.)	1/2-in. rigid foam board ~R-3.3	Tape

\* Nominal R-values • OSB = oriented strand board • KFB = kraft-faced fiberglass batt • SIP = structural insulated panel

thermal performance of a wall system in 'real-world' conditions.

This study addressed the net effect of temperature and wind pressure differences across a variety of residential walls, comparing them to the most common 'stick and batt' wall construction. The testing shows how a wall assembly would be expected to perform thermally while actually in use.

The test protocol was designed so the performance tests would be equitable for all the wall assemblies; additionally, the testing process was designed in such a manner to be repeatable. No two walls are made of exactly uniform materials due to factors such as wood warping, oriented strand board (OSB) thickness variations, and nail placement.

As such, special effort was made to ensure framing leakage through OSB-sheathed walls was both reasonable and consistent (ASTM International E 283, *Standard Test Method for Determining Rate of Air Leakage through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen*). Also, benchmarking was performed on each wall sample. The R-value of each individual material was tested (ASTM C 518, *Standard Test Method for Steady-state Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus*, at 24 C [75 F] mean temperature) and from the

material test results, a theoretical whole wall R-value was calculated for each wall that became its benchmark.

The benchmark was then compared to the actual whole wall test results at Architectural Testing Inc. of York, Philadelphia (ASTM C 1363, *Standard Test Method for Thermal Performance of Building Materials and Envelope Assemblies by Means of a Hot Box Apparatus*). The ratio of actual performance of a wall system over a wall's benchmark became the basis of comparison between the wall types. This enabled reasonable comparison of walls with differing R-values. This method fairly handicaps walls of

various R-values to capture differences in performance of a wall system under different conditions. Conditions were representative of both typical and extreme 'real-world' conditions in various climates.

Five wall types were assembled for whole-wall thermal testing. Plastic building products such as building wrap, spray-in-place foam insulation, rigid foam plastic insulation, and structural insulated panels (SIPs) of foam plastic were compared to the baseline wall's benchmark construction (Table 1). Note: the R-value of spray polyurethane foam (SPF) may degrade after installation. Generally, most degradation





Photo courtesy NAHB Research Center

This wall panel is being tested for air leakage using ASTM E 283, *Standard Test Method for Determining Rate of Air Leakage through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen*, standard procedures.

Joints were sealed and holes drilled to control air leakage in all oriented OSB-sheathed panels to a consistent level.



Photo courtesy American Plastics Council

occurs within the first couple of months after application. To account for this possible change, the SPF panels tested were warehoused nearly a year prior to the study.

The tested baseline wall represented the most common wall construction used in home building today (NAHB Research Center): a 2.4-m (8-ft) high, 101.6-mm (4-in.) overall thickness, wood-stud-framed wall with studs spaced 406.4 mm (16 in.) on-center (oc), sheathed with OSB, R-13 kraft-faced fiberglass batt (KFB) insulation, and 12.7-mm (0.5-in.) drywall covering the inside. Furthermore, best installation practices and the manufacturers' specifications were used. Individual insulation products were thermally characterized through alternate testing to validate the overall wall and

material performance designations.

Since each plastic-insulated wall performed better than the baseline under windy conditions, it was concluded the supposed performance values based on traditional R-value measurements and calculations are not a complete indicator of how well a wall system will resist the loss or gain of energy.

### Summary

This laboratory testing clearly demonstrated the benefits of using plastic building products (including plastic foam insulation) by showing significantly improved energy performance of residential wall systems under 'real-world,' wind-loaded conditions at various temperatures, compared to the baseline wall construction, as specified below.

#### *No wind and moderate temperature (static state)*

When there is no wind at 21 C (70 F) inside and -4 C (25 F) outside, all wall systems performed similar to their expected calculated benchmark. Compared to a typical batt insulation baseline, wall systems with plastic building products had a heat flow reduction of only three percent (not statistically significant).

#### *Wind and extremely cold temperature*

Under a 24-km/h (15-mph) wind pressure, at 70 F inside and a temperature of -26 C (-15 F) outside, plastic building products and foam plastic-insulated wall panel

systems reduced heat flow an average of 18 percent better than the baseline.

#### *Wind and moderate temperature*

Under a 15-mph wind, at 70 F inside and a temperature of 25 F outside, the performance results changed significantly. The wall systems with plastic building products overall reduced heat flow an average of 20 percent better than the baseline.

#### *Wind and extremely hot temperature*

Under a 15-mph wind, at 70 F inside and a temperature of 46 C (115 F) outside, wall systems with plastic building products reduced heat flow an average of 25 percent better than the baseline. One panel sample performed 29 percent better in this category.

### Conclusion

An important finding is all the walls containing plastic building products performed similarly to the baseline wall with respect to reducing heat flow in the 'no-wind' conditions. Interestingly, though, when 'real-world' wind conditions were applied, the research found all wall systems with plastic building products performed similarly better than the baseline. It also found that, as the temperature changed, all wall systems with plastic building products performed similarly better as a group to the baseline wall at each new temperature level.

An important implication of this research indicates in order for a typical (i.e. stick and batt) wall to meet the performance of a 'plastic' wall under windy conditions, it would need to perform at least 15 percent better. This is equivalent to upgrading the wall insulation from R-13 to R-15. As mentioned earlier, the higher the R-value, the greater the insulating power. (Design professionals should ask an insulation seller for a fact sheet on R-values.) Nonetheless, without considering changes in air infiltration between the batt types, this means approximately 85 percent more fiberglass material would need to be inserted in the same 88.9-mm (3.5-in.) cavity to achieve similar performance results to plastic building products in this study, according to the NAHB Research Center. ☺

### About the Author

Craig Drumheller is a senior engineer with the National Association of Home Builders (NAHB) Research Center.

# Plastic Polyurethane FOAM Tying the Building Together

by Robert Braun

**F**or more than 25 years, the importance of air tightness in design and construction has been stressed in technical literature. The danger of air leakage is it can lead to reduced occupant comfort, increased heating and cooling loads, damage to the building envelope, and even indoor air quality (IAQ) issues. As such, air barriers—a system of building envelope components, which stop airflow into and out of buildings—have been code-required for commercial construction in Canada since the mid-1980s and in Massachusetts since 2001.

As other U.S. local codes consider adopting similar requirements, there is a heightened focus on practical design elements for air barriers. Aerosol expanding polyurethane foams—a cost-efficient, durable, and easily applied plastic material—can be of great advantage when used appropriately.



File photos

## Controlling air and water leakage

Building envelope enclosures are not continuous from material to material unless the gaps between them are connected. Most air intrusion occurs through the many joints and penetrations between wall products. Some polyurethane foam sealants have shown to be a durable and efficient seal for these discontinuous areas.<sup>1</sup>

Polyurethane foam sealants can assist in controlling air leakage through building envelope penetrations such as windows, utilities, or interfaces between building envelope materials. When used to complete a continuous air barrier plane, this further leads to an additional benefit—neutralizing the pressure difference across the building shell, which can help reduce water intrusion. Gap tests using a 0.58 kPa (12 psf) pressure difference have confirmed this air and water resistance in certain foam sealants.<sup>2</sup>

When seals are selected to join critical junctions in building envelopes, vapor diffusion should also be considered. Most foam sealants are semi-permeable, so they do not act as a vapor barrier; modeling can be employed for moisture accumulation predictions if desired.<sup>3</sup> Designers should consider both water and air intrusion issues for all components used in the building envelope.

## Additional advantages

Polyurethane foam plastic sealants can not only prevent air and water intrusion, but also offer myriad related advantages. These include the potential for energy savings, improved comfort, weather resistance, sound mitigation, and reduced exterior noxious gas infiltration.

### *Structural and adhesion advantages*

In certain cases, structural enhancements for building assemblies can be increased with polyurethane foam. Most foam sealants adhere well to nearly all substrates, adding structural strength in some sealing applications. Windows are one example where a polyurethane sealant can prevent side jamb rotation, raise window design pressure ratings, and help increase the anchorage of the window or door during high-



Polyurethane foam sealants can be used for myriad uses in design and construction, ranging from weather resistance to certain structural functions. For sound-sensitive spaces, such as a conference room, the material can help with acoustics, potentially reducing noise transmission through walls, floors, or roofs.

wind events.<sup>6</sup> Certain foam sealant products can perform these structural functions better than others; when these functions are critical, evaluations should be run using independent, third-party testing.

Adhesion and the attachment between building materials is another developing use for polyurethane foam adhesives. In the aftermath of recent hurricanes, foam roof tile adhesives were noted to perform well.<sup>7</sup>

A formal Notice of Acceptance (NOA) for these products also exists from Miami-Dade county. Roof insulation foam adhesives have also excelled in uplift tests for application on flat and low-slope roofs. Additionally, using polyurethane foam adhesive sealants for the attachment of drywall and subfloor panels is becoming popular—application can be fast, easy, and conform to the required codes, while usually reducing the mechanical fastener count and the associated thermal bridging.<sup>8</sup>

### Sound transmission

Plastic polyurethane foam sealants can be good for reducing sound transmission through gaps in wall, floor, or roof assemblies, helping minimize noise pollution. ASTM International C 919, *Standard Practice for Use of Sealants in Acoustical Applications*, quantifies sound reduction when gaps are sealed in building enclosure assemblies.

### Testing objectives and standards

Early polyurethane foam testing focused on product material properties borrowed from standard ASTM D 20 Committee on Plastics, tests intended for preformed cellular products. Current testing of foam sealants now focuses on building assemblies or subassemblies mirroring the actual end-use. Therefore, sample preparation for testing should be specific and simulate the foam sealant geometry evident in the final application.

### ASTM International

In 1997, the ASTM Committee on Aerosol Foam Sealants (C 24.61) began the task of developing germane standards for foam plastic sealants. So far, one test method, ASTM C 1536, *Standard Test Method for Measuring the Yield for Aerosol Foam Sealants*, and one specification, ASTM C 1620, *Standard Specification for Aerosol Polyurethane and Aerosol Latex Foam Sealants*, have been published. Two more tests are in ballot process and three more standards are in draft stage.

ASTM C 1620 provides:

- a maximum leakage limit per ASTM E 283, *Standard Test Method for Determining Rate of Air Leakage through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen*;
- a maximum allowed flame-spread index and smoke-developed index requirements per ASTM E 84, *Standard Test Method for Surface Burning Characteristics of Building Materials*;
- a minimum requirement for R-value; and
- mandates the reporting of several additional foam sealant properties (including a reporting requirement for foam sealant yield measured exclusively by ASTM C 1536).

The foam sealant industry has also participated in developing ASTM E 2112, *Standard Practice for Installation of Exterior Windows, Doors and Skylights*, which includes Annex A for foam plastic sealants and

For windows, polyurethane foam sealants can help prevent jamb rotation, raise design pressure ratings, and help increase anchorage during high-wind events.



Several different organizations work with polyurethane foam sealants to determine standards and specifications. Their work can help design professionals select the most appropriate foam plastic products for their projects.



When considering polyurethane foam sealants for fenestration applications, the design professional should consult both the prevailing codes and any relevant industry standards so the product is used appropriately and effectively.

foam tapes. A new standard for air leakage assembly testing has also received industry input, while standards for water intrusion are being reviewed. This author chairs a new ASTM task group in Committee E 06 for building performance (*Standard Practice for Measuring Air Leakage Rates for Air Barrier Components Used for Sealing Discontinuities in Air Barrier Materials*).<sup>9</sup>

#### AAMA

The American Architectural Manufacturers Association (AAMA) develops and publishes standards for fenestration products and installation practices, including AAMA 812-04, *Voluntary Practice for Assessment of Single Component Aerosol Expanding Polyurethane Foams for Sealing Rough Openings of Fenestration Installations*. The AAMA Foam Sealant Committee is now dedicated to developing a standard for the minimum moisture performance requirements for window and door installation foams. Foam sealants with pressure-build values as low as 0.55 kPa (0.08 psi) have recently been reported. When specifying this type, the pressure-build value should be quoted, per AAMA 812-04. Thus, the window manufacturer can select or specify a foam plastic suitable to his or her window/door product.

#### Building codes

Since the *International Building Code (IBC)* does not specifically reference foam sealants (or other sealants and most adhesives), local codes are often left to various interpretations. Unlike the denser tube sealants or adhesives they resemble in use, some code officials treat foam sealants as if they were cellular plastic insulation. This can place excessive thermal barrier protection requirements on products for many sealant applications. Some manufacturers have employed Underwriters Laboratories (UL) 1715, *Fire Test of Interior Finish Material*, to obtain acceptance when this issue is in doubt. As such, diversified testing and International Code Council Evaluation Service (ICC ES) reports are used to confirm the fire safety of existing applications or help gain acceptance for new ones.

North of the border, the *National Building Code of Canada (NBC)* specifically references foam sealants. The Canadian National Standard, Underwriters Laboratories of Canada (CAN/ULC) S 710.1,

*Thermal Insulation—Bead: Applied One-component Polyurethane Air Sealant Foam, Part One: Material Specification*, is a foam sealant material requirement published in January 2005. Few construction products meet such rigid demands; CAN/ULC S 710.1 includes an air barrier assembly durability test using a full wall section with rapid thermal cycling from  $-20$  to  $66$  C ( $-4$  to  $150$  F) for 60 cycles. Pressure cycling is simultaneously employed from  $-1000$  to  $1000$  Pa ( $-21$  to  $21$  psf). However, the standard is still too new to be referenced by the Canadian code at this time. ☉

#### Notes

<sup>1</sup> For more information, see Canadian Construction Materials Centre (CCMC) 13074-R. Articles are online at the National Research Council of Canada (NRC) site, [www.nrc-cnrc.gc.ca](http://www.nrc-cnrc.gc.ca).

<sup>2</sup> These tests are in accordance with ASTM International E 331, Standard Test Method for *Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure Difference*.

<sup>3</sup> One example is WUFI—an advanced hygrothermal model that predicts heat and moisture transport (and accumulation) in building envelopes for many North American cities. Visit the Oak Ridge National Laboratory (ORNL) site at [www.ornl.gov/sci/btc/apps/moisture](http://www.ornl.gov/sci/btc/apps/moisture).

<sup>4</sup> For example, some manufacturers recommend products meeting the International Code Council National Evaluation Service (ICC-ES) Legacy Report (NER) 645 as appropriate for this application. Product acceptance research reports are prepared for construction products in compliance with requirements of the three-model codes and the International Code Series. Manufacturers specify if their product meets these specifications (*i.e.* *International Fire Code 2003*, Chapter 7, “Fire-resistance-rated Construction,” Section 703.1.1., “Fireblocking and Draftstopping.”)

<sup>5</sup> For more on the safety of plastics with regards to fire performance, see “Flammability Requirements for Plastic Materials” by Arthur J. Parker, PE, and Jesse J. Beitel in the April 2006 issue of *Modern Materials*. (See also Footnote 4.)

<sup>6</sup> The DP rating system measures the amount of pressure a window or door is designed to withstand when closed and locked, along with other performance factors, such as structural pressure, water penetration, and air infiltration. The higher the DP, the better the performance. This rating system is established in AAMA 101/I.S.2/NAFS-02 and AAMA/WDMA/CSA 101/I.S.2/A 440-05, *Voluntary Specification for Aluminum, Vinyl, and Wood Windows and Glass Doors*.

<sup>7</sup> For more, see “Shelter from the Storm: SPF and the Hurricanes of Florida” by Mason Knowles and Roger Morrison, PE, RRC, in the May 2005 issue of *Modern Materials*.

<sup>8</sup> As with all building materials, the specifier should check with the AHJ so all local codes are met.

<sup>9</sup> For more information on various ASTM activities, visit [www.astm.org](http://www.astm.org).

#### About the Author

Robert Braun is an R&D and Tech Service leader for the Dow Chemical Co. He has been the chair for the ASTM Subcommittee for aerosol foam sealants since its founding in 1999. Braun also chairs the AAMA Aerosol Foam Sealants Committee.



File photo

# PLASTICS

## AND the 2005 Energy Policy Act

POSSIBLE TAX  
CREDITS FOR  
FOAM INSULATION

by Jared Blum

With the price of oil hovering between \$60 and \$70 a barrel, energy costs could remain quite high for the foreseeable future. For architects, contractors, and building owners, there is some relief in the form of comprehensive energy legislation that offers tax incentives and deductions for the creation of more energy-responsible homes and buildings.

When it comes to specifying building materials that save owners money, it is important to know not only the thermal properties, but also the current legislation. Energy-efficient in both manufacture and performance, many types of plastics insulation products—from polyurethane to spray polyurethane foam (SPF) to polyisocyanurate (polyiso) to polystyrene—can help a project achieve tax incentives.



Photos courtesy Polyiso Insulation Manufacturers Association

*The Energy Policy Act (EPAct)* allows the possibility for tax credits to owners or design firms creating energy-efficient buildings. The proper specification and installation of plastic foam insulation, including polyisocyanurate (polyiso) products, can help pave the way for this sort of thermal resistance.

## Commercial buildings

Signed into law in August 2005, *the Energy Policy Act of 2005 (EPAct)* includes precedent-setting tax incentives for energy-efficient commercial buildings, public buildings, and homes to help combat the nation's growing energy problems.

The act provides tax deductions for owners of commercial buildings who make improvements that reduce energy and power costs by 50 percent over American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE) 90.1, *Energy Standard for Buildings Except Low-rise Residential Buildings*. Since it was developed in response to the energy crisis of the 1970s, ASHRAE 90.1 has been the basis for building codes and standard for building design and construction throughout the United States. The U.S. Department of Energy (DoE) established ASHRAE 90.1-2001 as the commercial building reference standard for



state building energy codes under the federal *Energy Conservation and Production Act*.

Insulation, HVAC systems, and lighting technologies can meet *EPAct* criterion. The tax deduction (not credit) is equal to the cost of energy-efficient improvements installed in a building, up to \$1.80 per square foot. To qualify, improvements must be installed as part of one or more of the following three building systems:

- interior lighting;
- heating, cooling, ventilation, and hot water; and
- the building envelope (including insulation).

In cases where the energy-efficiency improvements do not meet the overall 50 percent threshold, a partial tax deduction (of up to 60 cents per square foot) is allowed with respect to each of the three building systems. To qualify, the improvements must equal or exceed system-specific savings targets to be established by the secretary of the treasury. (As this article was written, targets had not yet been announced.<sup>1</sup>)

Another issue involving partial tax deduction relates to improvements to HVAC and the building envelope. In this case, it will be possible for building owners to obtain a \$1.20 deduction per square foot for upgrading these systems. To qualify, the improvements must also equal or exceed system-specific savings targets to be established by the secretary of the treasury (which, again, have yet to be announced). Roof systems on low-rise buildings with enhanced insulation levels may be instrumental in achieving a partial tax deduction. These roof systems can include the use of sealed extruded or expanded polystyrene (XPS or EPS; insulated concrete forms [ICFs] and structural insulated panels [SIPs]), spray polyurethane foam (SPF), and polyiso, among other plastic materials.

*EPAct* specifies guidelines for calculating, and obtaining certification of, energy savings. A list of software for this purpose is available in the 2005 *California Nonresidential Alternative Calculation Method Approval Manual*.<sup>2</sup> It outlines the requirements for individuals or companies wishing to design a calculation computer program to use with the energy standards. The new act also notes procedures will be defined for inspection and testing by qualified individuals to ensure compliance of buildings with energy-savings plans and targets.

## Public buildings

Public buildings, such as schools and other government-owned properties, can also be eligible for a tax deduction. In this case, the deduction can be allocated or transferred to the person primarily responsible for designing the property instead of the owner (i.e. the architect firm responsible for the public school). In addition to this federal legislation, many states—including California, Maine, North Carolina, Oregon, and Washington—are enacting laws requiring 'green' certification for state-owned buildings.

## Residences

In addition to commercial and public buildings, *EPAct* provides incentives to homebuilders and home manufacturers. An eligible contractor who constructs a qualified energy-efficient home can qualify for a credit of up to \$2000. The credit is available for all new homes, including manufactured units constructed in accordance with the Department of Housing and Urban Development's (HUD's) *Federal Manufactured Homes Construction and Safety Standards*.

With regard to site-built homes, the credit of \$2000 is available to those certified to have a level of annual heating and cooling energy consumption at least 50 percent below a comparable home constructed in accordance with the standards of the 2004 supplement to the 2003 *International Energy Conservation Code (IECC)*. This benchmark can potentially be reached through the proper use of plastic insulation.

Manufactured homes are eligible to qualify for the \$2000 credit in the case of a 50 percent efficiency improvement and \$1000 credit for a 30 percent improvement or compliance with Energy Star® criteria. For manufactured homes meeting the 30 percent standard, one-third the savings must come from the building envelope. For site-built and manufactured homes meeting the 50 percent standard, one-fifth the savings must come from the building envelope.

According to the Internal Revenue Service (IRS), tax deductions are effective for property placed in service from January 1, 2006 through December 31, 2007. Under the new provision, the home qualifies for the credit when:

- it is located in the United States;
- its construction is substantially completed after August 8, 2005;
- it meets the statutory energy-saving requirements; and
- it is acquired from the eligible contractor after December 31, 2005, and before January 1, 2008, for use as a residence.

## Beyond 2007

Although the *Energy Policy Act of 2005* will only be effective until December 31 of next year, the Polyisocyanurate Insulation Manufacturers Association (PIMA) and many other industry and energy-efficiency advocates are working to extend the new law beyond 2007. Due to the lead time it takes to design, contract, and build commercial buildings, the two-year length of the bill is inadequate to accommodate the typically 12- to 24-month design cycle. Those interested in further pushing the boundaries of the bill's duration should visit the PIMA Web site, [www.pima.org](http://www.pima.org), for more on the organization's grassroots efforts to maximize the benefits to the design and construction industries.

In the meantime, for more information about the act, visit:

- Tax Incentives Assistance Project Web site ([www.energytaxincentives.org](http://www.energytaxincentives.org)); and
- Commercial Building Tax Deduction Coalition Web site ([www.efficientbuildings.org](http://www.efficientbuildings.org)). ☺

## Notes

<sup>1</sup> As more information becomes available from the secretary of the treasury, it will be included on the Polyisocyanurate Insulation Manufacturers Association (PIMA) Web site, [www.pima.org](http://www.pima.org).

<sup>2</sup> For more information, visit [www.energy.ca.gov/ title24/2005standards/ nonresidential\\_acm](http://www.energy.ca.gov/title24/2005standards/nonresidential_acm).

## About the Author

Jared O. Blum is president of the Polyisocyanurate Insulation Manufacturers Association (PIMA), the Washington-based national trade association representing the manufacturers of polyisocyanurate (polyiso) foam insulation. The association is committed to working independently and with public and private organizations to provide education about the critical importance of national energy conservation.

# POLYISO BOARDS



Photo courtesy Polyiso Insulation Manufacturers Association

One way to help a commercial building owner earn *Energy Policy Act of 2005 (EPAct)* tax incentives is to provide education about certain materials that can help yield the necessary levels of energy efficiency. All types of foam plastic can apply. For example, polyisocyanurate (polyiso) is a rigid foam board product, which can deliver excellent insulation properties, strong performance in code-required fire tests, and compatibility with many roofing systems. Its benefits include:

- dimensional stability;
- compressive strength;
- moisture resistance; and
- virtually zero ozone-depletion potential and negligible global warming effects. ☺

# SPF ROOFING

## Practical solutions for impractical projects

by Mason Knowles



**I**ncreasing one's knowledge about the use of foam plastics involves more than merely learning about a building product's manufacture and performance characteristics. To truly understand how a modern material can best be used often requires a look at the innovation of other construction/design teams who have successfully employed it.

Some roofing projects are more challenging than others. Last year, West Roofing (a LaGrange, Ohio, contractor) was asked to bid on re-roofing a modified bitumen (mod-bit) system installed to a scalloped concrete roof deck at Saint Joseph Hospital in Chicago, Illinois. The task was complicated by a number of factors, but plastic spray polyurethane foam (SPF), helped provide an ideal resolution.

The design/construction team faced quite a few possible roadblocks, including:

- the roof section needing replacement was 21.3 m (70 ft) off the ground and only accessible through the building interior;
- there were no anchors to attach safety lines or fall arrest systems;
- the existing roof had to be completely removed because of the saturated insulation and deteriorated roof membrane;
- the windows next to the roof housed the 'new mothers and newborns' ward, making overspray, fumes, and odors major concerns; and
- since a hospital never shuts down, working after business hours was not an option.

Many contracting firms would not have considered this project a prime job for bidding. However, West Roofing seized the moment, seeing the opportunity to use SPF as a multifaceted solution to several potential pitfalls. First, they had to convince city officials.

Jack Moore, project manager for West Roofing, told the designers a spray polyurethane foam roofing system could provide virtually unique benefits, including a custom fit to the unusual scallop shape of the concrete. SPF could also be spray-applied at 76 mm (3 in.) thick to provide the needed insulation, and would not require additional counter flashings or perimeter edge metal. As another advantage, spray polyurethane foam generally does not need periodic

replacement, but only regular maintenance and a recoat every 15 to 20 years. The team was also ready to remedy potential problems with the removal of the old roof.

Once city officials were convinced spray polyurethane foam could meet the new roof's needs, city officials had to be assured the polyurethane application would not lead to overspray, odor, or fume problems for the hospital and surrounding areas (and that the job could be performed safely).

### Safety planning

Moore assisted in developing a comprehensive safety plan that took into consideration hospital workers, fall protection, and securing the area from overspray and minimization of fumes and odors.

West Roofing's crews installed 18 'spider' concrete anchors to fasten lifelines for fall prevention. They built a special corridor of plastic inside the hospital for the crews to access the roof from inside the building, separating the tradesworkers from the healthcare workers. This also prevented dust and debris from settling in the hospital. Hospital officials escorted the suited workers to the roof access.

On similar jobs, the contractor had performed area and personal monitoring of SPF spray applications. Outside a few feet of application, West Roofing knew the permissible exposure levels of fumes and mists were well within safe guidelines for the surrounding area. To protect the crew, personal protective clothing was used consisting of chemical-resistant protective coveralls, gloves, boots, spray hood, goggles, and suitable respiratory protection. Next, they sealed the building itself to prevent fumes, mists, and overspray from getting into the hospital. Windows adjacent to the roof were sealed with plastic 'shrinkwrap' (i.e. a 0.15-mm [6-mil] polyethylene film) and spray adhesive.

The crew then tackled the issue of overspray protection for the surrounding area. The project was located right next to an extensive city parks system, with many parked cars and pedestrian traffic. Since keeping the lightweight foam and coating from drifting onto

# Safety Course

## Plastics and Side-impact Car Safety

One of the most devastating types of traffic accidents is the side-impact crash. Unlike front-end or rear-end collisions, there is not a lot of space between the passenger compartment and the point of impact—this means there is not much time for safety restraints to function successfully. To make matters worse, these incidents can happen at high speeds, leaving unsuspecting passengers particularly vulnerable to injury. Thankfully, much like they have done in the built environment, plastic materials have helped bring automotive design into the 21<sup>st</sup> century.

For some cars, manufacturers are inserting lightweight polyurethane foam plastic into the hollow unibody door frame between the front and back seats. These foams can serve as localized reinforcement to help manage crash energy, and can provide the added benefit of offering acoustical management capacities. Additionally, the light material does not add much weight, helping keep the car efficient.

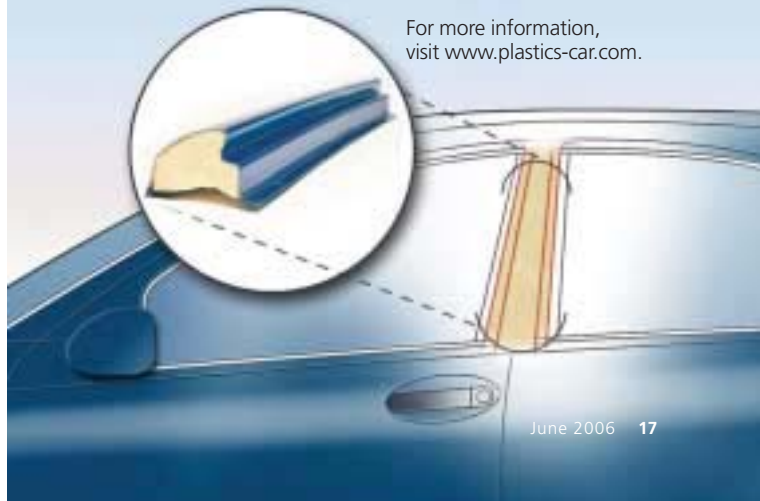
Other energy absorption (EA) plastic products include integrated knee bolsters, pillar trim, structural instrument panel systems, and further foam technologies and molded components enabled by polypropylene, polyurethane, and engineered plastic resins. For example, structural adhesives help stiffen areas of the vehicle and can add overall durability by reducing connection fatigue and failure of traditional fasteners.

In some cars, a two-part polyurethane foam is injected into body cavities (e.g. longitudinal rails, cowl/plenum area, between the passenger cabin and the engine) during vehicle assembly, where it cures almost immediately, providing an acoustical seal and near-immediate reinforcement of the body structure. Since the expanding foam has fluid-like properties, it flows into seams and crevices, helping provide adhesion to metal surfaces, and keeping the material in its designated location.

The polyurethane foam's performance can help automakers meet full frontal barrier and offset crash regulations. It is just one more use for a modern material that has already demonstrated its versatility in the building and construction industry. ☉

Inset photo courtesy Dow Automotive

For more information, visit [www.plastics-car.com](http://www.plastics-car.com).



Photos courtesy Scott Wanner and SPFA



- 1 The front of Saint Joseph Hospital in Chicago, Illinois. The scalloped roof edge required material that could form to irregular shapes.
- 2 Finished roof system with 0.5 mm (20 mils) of silicone coating.
- 3 View of the parked cars from the roof. Wind enclosures and screens prevented overspray from being a problem.
- 4 These windows were sealed with plastic 'shrink wrap' and foam sealant before spray polyurethane foam (SPF) and coating application to prevent fumes and mists from entering the building.

parked cars and passersby was important, West Roofing decided on two types of overspray protection. For the majority of the spraying, a movable, custom-designed booth was fabricated to precisely fit the curve of the scalloped roof. The crews sprayed inside the enclosure, effectively preventing virtually any overspray from drifting beyond the target area. When they came to the edge, a hand-held windscreen was employed.

A crane was used to lift small containers of tear-off construction debris from the roof to a container adjacent to the building. Within 10 days, West Roofing had performed the tear-off, substrate preparation, foam/coating application, and cleaned up the site, leaving the hospital with a high-performance, energy-efficient roof system. The project's speed was greatly appreciated by the hospital since it minimized inconvenience. Even more importantly, there were no reported overspray claims or complaints of odors or fumes from the application.

As a result of these efforts, West Roofing won one of the Spray Polyurethane Foam Alliance's (SPFA's) 2006 Excellence in Contracting Awards. ☉

### About the Author

Mason Knowles is the executive director of the Spray Polyurethane Foam Alliance (SPFA). He can be contacted via e-mail at [masonknowles@sprayfoam.org](mailto:masonknowles@sprayfoam.org).

# Performance the Board

ACROSS

XPS sheathing from  
manufacture to installation

By Susan Herrenbruck



Photo courtesy Extruded Polystyrene Foam Association

The most common components of a building envelope perform important functions, but they do not always meet their true potential. To that end, various types of plastic materials can help building owners achieve the efficiency they require. For example, extruded polystyrene (XPS) foam insulating sheathing offers many benefits due to the way this product is manufactured.

Energy-efficient, easy to install, lightweight, and recognizable in its blue, pink, or green colors, the specification of XPS sheathing may allow the use of a single product to create a continuous layer of thermal and moisture protection on a building's walls, thereby contributing to energy efficiency.

### Creating extruded polystyrene

XPS foam begins as a solid granule of polystyrene resin. The granules are fed into an extruder, where they are melted and mixed with critical additives to form a viscous fluid. Next, a blowing agent is injected to enable its expansion. Under carefully controlled heat and pressure conditions, the mixture is forced through a die into the desired shape. The rigid foam is then trimmed to the final product dimensions and is usually recognized as boards.

This continuous process produces a closed-cell structure that looks like a mass of uniform bubbles with common walls between them. A continuous smooth skin on the top and bottom also forms.

The closed-cell structure of XPS imparts excellent long-term strength and durability. (See "Message from the APC" on page 4 for more on foam plastics.) Products are available in a range of compressive strengths to suit varied application needs. Due to its inherent physical properties, this strength does not depend on the use of facers or laminates, which can sometimes be compromised during installation. However, XPS faced-products are available to add extra strength when specified for a particular application. Extruded polystyrene also comes in a wide variety of sizes, and up to a thickness of 102 mm (4 in.) to suit many applications.

### Energy efficiency

XPS sheathing can have positive energy and air emission benefits when used in residential buildings. A 2000 Franklin Associates' study shows far more energy is saved over the 50-year life of a home properly using XPS foam insulation than is consumed by manufacturing the insulation.<sup>1</sup> Another study, presented at the 2004 Earth Tech forum, shows that after less than three years, more greenhouse gas emissions are avoided due to heating/cooling energy consumption than are emitted during the manufacture of XPS insulating sheathing.<sup>2</sup>



Photo courtesy Extruded Polystyrene Foam Association

Extruded polystyrene (XPS) foam insulating sheathing can offer long-term strength, thermal resistance, and durability. The products can also offer a sense of sustainability—reports suggest far more energy is saved over the 50-year life of a home than is consumed in manufacturing the insulation.

Properly installed XPS can also improve a building's energy efficiency by providing a complete layer of insulation on the wall. This reduces air movement through the wall that can rob energy. Insulation between studs does not necessarily offer complete insulation value because wood studs and other framing members are not insulated. (See "Plastics Takes Improvement to the Wall," page 5.) This phenomenon is called thermal bridging and can dramatically decrease thermal performance of the building.

Since residential wood framing typically makes up about 25 percent of the wall area (taking into account window and door framing), a quarter of the wall is uninsulated when only cavity insulation is used. As such, XPS sheathing can provide insulating value to the entire wall area. Aside from its inherent insulating performance, XPS sheathing, when properly installed and seams taped, can also greatly reduce air leakage through walls, which can improve energy efficiency and comfort.

An essential attribute for sustainable building products, especially insulation, is the ability to function properly over its useful life without physical property performance degradation. In fact, good long-term insulation performance is needed to correctly design a building's heating and air-conditioning systems.

XPS can also have advantages due to its ability to assist with moisture management, resisting both water absorption and freeze-thaw cycles. When traditional insulation absorbs water, its thermal performance can be compromised over time.

### Reduce, reuse, recycle

Three strong environmental principles are to reduce, reuse, and recycle.<sup>3</sup> Since insulating sheathing can reduce energy loss in buildings, it can lower (*i.e.* reduce) the amount of energy (gas and electric) required to maintain comfortable living environments.



Properly installed and taped XPS can improve a building's efficiency by providing a complete layer of insulation on the wall, reducing air movement that robs energy. Residential wood framing typically makes up a quarter of the wall, and the insulation protects more than just the cavities.



Photos courtesy Extruded Polystyrene Foam Association

The more widespread the use of insulating sheathing, the more profound its effect can be on reducing consumption of natural resources, such as coal, oil, and gas.

Polystyrene resin is a thermoplastic material, which means it can be melted and re-inserted (*i.e.* reused) into the manufacture of new XPS insulation. Extruded polystyrene manufacturing plants create virtually no scrap or waste materials because nearly 100 percent is recovered, ground up and re-pelletized for the production system (*i.e.* recycled). Some companies even seek outside sources of scrap polystyrene resin to reuse.

Additionally, XPS can be created from post-consumer material. However, there is currently no infrastructure in the United States that makes it economically sound to collect construction material contaminated with nails, glue, etc. Should the situation change, XPS could be readily recycled once contaminants are removed from the product.<sup>3</sup>

Another choice for reducing post-manufactured material involves incineration, which is not widely used in the United States. Nevertheless, XPS could be feedstock for this technology, should it gain support. In any case, because XPS is used in structures with 15-to 50-year life spans, its effect on landfills tends to be small compared to traditional materials that may require more frequent replacement.

## Installation guidelines

As more sheathing insulating options are made available, builders are constantly seeking easier and better installation methods. While traditionally following ongoing trends in residential building systems installation, changes in local codes and new product introductions challenge builders to erect better homes that offer more resistance to moisture and increased energy efficiency.

Properly installed XPS insulating sheathing can provide excellent moisture and insulating properties. As mentioned, extruded polystyrene products are light, versatile, and easily installed on residential walls as illustrated in the following step-by-step guide:

1. The first step is to mark the XPS insulation boards by dragging the hook of a measuring tape along the surface of the board, while holding the other end of the tape at the desired measurement. This creates a small mark to follow when cutting.
2. The board should then be placed on a flat, sturdy surface for cutting ease and safety. A pair of sawhorses is usually sufficient for waist-high work. Following the mark left by the tape edge, a deep impression should be made with a knife held low against the board (without cutting through). Once the entire measured line has been scored, the piece is simply snapped over the edge of the work surface. It is best to use a utility knife and straight edge to trim the insulation board to conform to irregular wall angles, projections, or wall surfaces less than board width or height.
3. Code-acceptable corner bracing (e.g. diagonal metal strapping, let-in wood, or wood structural sheathing) is then installed. If wood sheathing is used as a structural component, the building can be covered with XPS insulation boards to provide for full wall insulation.
4. XPS insulation boards that are 1.2 m (4 ft) wide should be installed vertically with long joints butted tightly together and bearing directly on the framing members. Horizontal joints should be minimized between boards, unless joints are positioned directly over a horizontal framing member. Taping the insulation board joints seals them against air infiltration for improved energy efficiency.
5. It is preferable to secure XPS insulation boards with 25.4-mm (1-in.) head plastic cap nails long enough to penetrate framing measuring at least 19 mm (0.75 in.). Another option is to use 9.5-mm (0.375-in.) head-galvanized roofing nails long enough to penetrate framing a minimum of 19 mm. Additionally 25.4-mm crown, 16-gauge wire staples long enough to penetrate framing a minimum of 12.7 mm (0.5 in.) can also be used. Nail heads or staples should not be over-driven.
6. The field of the board is then secured 406 mm (16 in.) on-center (oc) and around the perimeter 305-mm (12-in.) oc, or as required by the building code authority having jurisdiction.

In stick-built construction, one should consider using 1.2 x 2.7-m (4 x 9-ft) XPS insulation boards to effectively cover the sill plates, floor/ceiling junctures, bandbox, and headers in one application with fewer horizontal joints. Brick, wood, hardboard, aluminum, or vinyl sidings are fastened to the wood frame construction through the insulation in accordance with the siding manufacturer's instructions. Shakes or shingles can also be applied by installing furring strips or



XPS can be a good choice for home insulation because it functions over its useful life without physical property performance degradation—a useful asset in maintaining heating and air-conditioning systems.

a plywood nailer base over the insulation and attaching the shakes or shingles. The manufacturer should be consulted on the most appropriate methods.

XPS foam insulation materials are available in either rigid board stock or fanfold sheet versions. The properties of XPS board stock are outlined in ASTM International C 578, *Standard Specification for Rigid, Cellular Polystyrene Thermal Insulation*. They are available in ASTM types IV, V, VI, VII, and X with square-edge, ship-lap, or tongue-and-groove edge treatments to minimize air leakage through the joints. Other board options include slotted edge and boards with plastic, reflective, or perforated facers.<sup>4</sup>

## Notes

<sup>1</sup> See Franklin Associates' *Plastics Energy and Greenhouse Gas Savings Using Rigid Foam Sheathing Applied to Exterior Walls of Single-family Residential Housing in the U.S. and Canada—A case study* (September 2000). Visit [www.plasticsresource.org/s\\_plasticsresource/docs/400/390.pdf](http://www.plasticsresource.org/s_plasticsresource/docs/400/390.pdf).

<sup>2</sup> See "Energy and Environmental Benefits of Extruded Polystyrene Foam and Fiberglass Insulation Products in U.S. Residential and Commercial Building" by Merle F. McBride, PhD, PE. This paper was presented at the 2004 International Earth Tech forum.

<sup>3</sup> Recycling is not available in all areas. Check to see if recycling is available in your community.

<sup>4</sup> For more information on XPS insulating sheathing, visit [www.xpsa.com](http://www.xpsa.com).

## About the Author

Susan Herrenbruck is the executive director of the Extruded Polystyrene Foam Association (XPSA), a trade association representing manufacturers of XPS foam insulation products and its raw material suppliers. XPSA members collectively manufacture more than 95 percent of all extruded polystyrene sold in North America.

# Finding Plastics Resources Online

## Polystyrene insulation

Expanded Polystyrene [EPS] Molders Association (EPSMA)  
[www.epsmolders.org](http://www.epsmolders.org)

Insulating Concrete Form [ICF] Association  
[www.formsof.org](http://www.formsof.org)

Structural Insulated Panel [SIP] Association (SIPA)  
[www.sips.org](http://www.sips.org)

Exterior Insulation Finish Systems [EIFS] Industry Members Association (EIMA)  
[www.eima.com](http://www.eima.com)

Expanded Polystyrene Resin Suppliers (ERSC)  
[www.americanplasticscouncil.org/apcorg/about\\_apc/ersc.html](http://www.americanplasticscouncil.org/apcorg/about_apc/ersc.html)

Extruded Polystyrene Association  
[www.xpsa.com](http://www.xpsa.com)

## Polyurethanes

Adhesives and Sealant Council (ASC)  
[www.ascouncil.org](http://www.ascouncil.org)

Alliance for the Polyurethanes Industry (API)  
[www.polyurethane.org](http://www.polyurethane.org)

Metal Construction Association (MCA)  
[www.mca1.org](http://www.mca1.org)

Alliance for Flexible Polyurethane Foam (AFPF)  
[www.afpf.com](http://www.afpf.com)

European Diisocyanate and Polyol Producers Association (ISOPA)  
[www.isopa.org](http://www.isopa.org)

Polyisocyanurate Insulation Manufacturers Association (PIMA)  
[www.pima.org](http://www.pima.org)

Polyurethane Foam Association (PFA)  
[www.pfa.org](http://www.pfa.org)

International Isocyanate Institute (III)  
[www.diisocyanates.org](http://www.diisocyanates.org)

Polyurea Development Association (PDA)  
[www.pda-online.org](http://www.pda-online.org)

Polyurethane Manufacturers Association (PMA)  
[www.pmahome.org](http://www.pmahome.org)

## Plastic piping

Plastic Pipe Institute (PPI)  
[www.plasticpipe.org](http://www.plasticpipe.org)

American Society of Mechanical Engineers (ASME)  
[www.asme.org](http://www.asme.org)

American Water Works Association (AWWA)  
[www.awwa.org](http://www.awwa.org)

Canadian Institute of Plumbing and Heating (CIPH)  
[www.ciph.com](http://www.ciph.com)

International Association of Plumbing and Mechanical Officials (IAPMO)  
[www.iapmo.org/iapmo](http://www.iapmo.org/iapmo)

American Society of Plumbing Engineers (ASPE)  
[www.aspe.org](http://www.aspe.org)

Plastic Pipe and Fittings Association (PPFA)  
[www.ppfahome.org](http://www.ppfahome.org)

Uni-Bell PVC Pipe Association  
[www.uni-bell.org](http://www.uni-bell.org)

## Vinyl

The Vinyl Institute  
[www.vinylbydesign.com](http://www.vinylbydesign.com) or  
[www.vinylinfo.org](http://www.vinylinfo.org)

Vinyl Siding Institute  
[www.vinylsiding.org](http://www.vinylsiding.org)

Resilient Floor Covering Institute  
[www.rfci.com](http://www.rfci.com)

Vinyl Council of Canada  
[www.cpia.ca/vinyl](http://www.cpia.ca/vinyl)

Chemical Fabrics and Film Association  
[www.chemicalfabricsandfilm.com](http://www.chemicalfabricsandfilm.com)

European Council of Vinyl Manufacturers  
[www.ecvm.org](http://www.ecvm.org)

Wallcoverings Association  
[www.wallcoverings.org](http://www.wallcoverings.org)

## Spray polyurethane foam

Spray Polyurethane Foam Alliance (SPFA)  
[www.sprayfoam.org](http://www.sprayfoam.org)

Insulation Contractors Association of America (ICAA)  
[www.insulate.org](http://www.insulate.org)

National Roofing Contractors Association (NRCA)  
[www.nrca.net](http://www.nrca.net)

Roof Consultants Institute (RCI)  
[www.rci-online.org](http://www.rci-online.org)

Roof Industry Educational Institute (RIEI)  
[www.riei.org](http://www.riei.org)

## Life cycles and modeling

Building Environment and Thermal Envelope Council (BETEC)  
[www.nibs.org/betechm.html](http://www.nibs.org/betechm.html)

National Institute of Building Sciences (NIBS)  
[www.nist.gov](http://www.nist.gov)

Building for Environmental and Economic Sustainability (BEES) provides users with direct comparisons between environmental performance and life-cycle cost.  
[www.bfrel.nist.gov/oae/bees.html](http://www.bfrel.nist.gov/oae/bees.html)

The Consortium for Moisture Management for Exterior Wall Systems (MEWS) is developing guidelines for wall systems to meet long-term performance and durability for various climate zones.  
[irc.nrc-cnrc.gc.ca/bes/mews/index.html](http://irc.nrc-cnrc.gc.ca/bes/mews/index.html)

MOIST predicts the one-dimensional transfer of heat and moisture, allowing users to investigate the effects of various parameters on moisture accumulation within layers of construction.  
[www.bfrel.nist.gov/863/moist.html](http://www.bfrel.nist.gov/863/moist.html)

WUFI is an advanced hygrothermal model that solves the coupled heat and moisture transport in building envelope systems, such as walls and roofs.  
[www.eere.energy.gov/buildings/tools\\_directory/software/wufi-ornl-ibp.html](http://www.eere.energy.gov/buildings/tools_directory/software/wufi-ornl-ibp.html)

## Related associations and organizations

American Architectural Manufacturers Association (AAMA)  
[www.aamanet.org](http://www.aamanet.org)

Canadian Plastics Industry Association (CPIA)  
[www.plastics.ca](http://www.plastics.ca)

Plastics Technology  
[www.plastics-technology.com](http://www.plastics-technology.com)

American Chemistry Council (ACC)  
[www.americanchemistry.com](http://www.americanchemistry.com)

Chlorine Chemistry Council (CCC)  
[www.c3.org](http://www.c3.org)

Partnership for Advancing Technology in Housing (PATH)  
[www.pathnet.org](http://www.pathnet.org)

ASTM International  
[www.astm.org](http://www.astm.org)

International Code Council (ICC)  
[www.iccsafe.org](http://www.iccsafe.org)

Society of Plastics Engineers (SPE)  
[www.4spe.org](http://www.4spe.org)

FM Global  
[www.factorymutual.com](http://www.factorymutual.com)

National Association of Home Builders (NAHB)  
[www.nahb.org](http://www.nahb.org)

Society of the Plastics Industry (SPI)  
[www.plasticsindustry.org](http://www.plasticsindustry.org)

British Plastics Federation (BPF)  
[www.bpf.co.uk](http://www.bpf.co.uk)

NSF International  
[www.nsf.org](http://www.nsf.org)

Underwriters Laboratories  
[www.ul.com](http://www.ul.com)

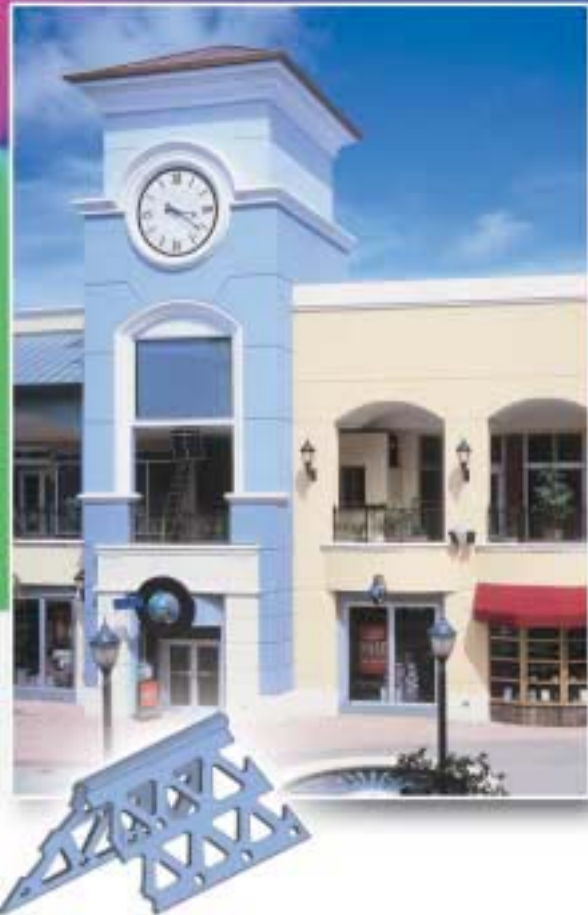
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[www.greenbuildingsolutions.org](http://www.greenbuildingsolutions.org)



[www.plastics.org](http://www.plastics.org)

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