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Fenestration

Adequate Ventilation of Low-Slope Roof Systems

IIBEC interface

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Considerations for Specifying Rigid, Cellular Polystyrene Insulations in Various Applications

Separating Fact from Fiction on Real-World Construction Projects

By Rob Brooks; Tiffany Coppock, AIA, NCARB, CSI, CDT, LEED AP; Matt Dillon; Mike Fischer; Meng Guo, PhD; and Valentina Woodcraft, PhD

RIGID, CELLULAR POLYSTYRENE (RCPS) foam boards are used as thermal insulation in assemblies for exterior walls and roofs, as well as cold-climate infrastructure.[1-3] Considering all these applications (**Fig. 1–3**), it is interesting that the number of generic "types" could be reduced to just 14 according to ASTM C578, *Standard Specification for Rigid, Cellular Polystyrene Thermal Insulation*.[4] This article addresses considerations surrounding different applications of various types of polystyrene insulation, including caveats related to specifying insulation thickness based solely on the *R*-values listed in ASTM C578.

The main purpose of ASTM C578 is to allow products from different manufacturers to be classified according to basic physical properties that can be measured in a laboratory using standardized test methods. ASTM C578 provides guidance for testing physical properties such as compressive resistance, flexural strength, and thermal resistance to ensure continued compliance with the product standard. However, specifying only as-manufactured physical properties is not adequate to ensure foam polystyrene performance in practice. Hence, this article examines how physical properties of insulation change as they interact with the environment.

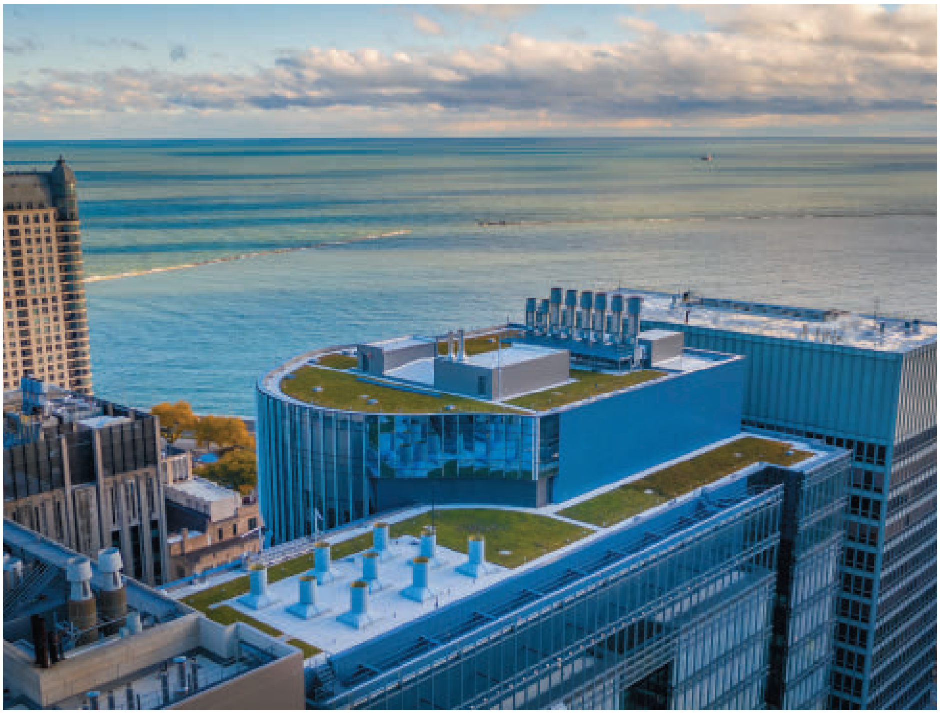

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Figure 1. *The architects of this building in downtown Chicago developed a protected membrane roof assembly (PMRA) blue roof, especially to meet the water detention requirements of their building permit. The 14-story base of the building accommodates storm water management requirements for the entire building through the design of blue and green (vegetative) PMRAs.*

CAVEATS FOR THE SPECIFIER

It is not possible for a designer to choose an *R*-value from a table without further consideration of end-use conditions. Designers

Figure 2. *Rigid, cellular polystyrene foam boards are often installed beneath airfields in cold climates.*

Figure 3. *Rigid, cellular polystyrene foam boards can be used in horizontal floor applications as well as vertical wall applications.*

also need knowledge of factors that affect the long-term performance of insulation. This knowledge can be gained from science, experience, and the industry's best practices.

Guidance from individual manufacturers and industry associations is useful, but such information can be limited. "Buyer Beware!" applies in the RCPS marketplace. There is no substitute for a detailed understanding of the long- and short-term material properties of insulations in specific applications.

These caveats are mentioned in Appendix X1 of the ASTM C578 material classification standard. While that appendix is designated as "nonmandatory information," it covers several vital topics, including the following, which will be discussed in this article:

- X1.3 Water Vapor Transmission
- X1.4 Water Absorption
- X1.7 Thermal Resistance Values at Additional Mean Temperatures

For a building enclosure consultant, engineer, or architect who is specifying the insulation, the advice in Appendix X1 may be as relevant as information from the body of ASTM C578, which provides mandatory testing information. The specifier should keep in mind that *R*-values are affected by in-use temperature changes, which occur daily and seasonally. Thermal performance of RCPS is also affected by moisture absorption and outgassing of blowing agents (and inward diffusion of air) over years and decades.

For example, extruded polystyrene (XPS) types of insulation are subject to long-term aging due to diffusion of blowing agents and air. The heavy molecules of the blowing agent slowly diffuse out of, and lighter air and water vapor molecules diffuse into, the insulation. As a result, the *R*-value typically decreases by a predictable amount of 1% to 2% over the product's life, which often spans several decades. This effect can be determined and reported in accordance with ASTM C1303, *Standard Test Method for Predicting Long-Term Thermal Resistance of Closed-Cell Foam Insulation,*[5] or CAN/ULC S770, *Standard Test Method for Predicting Long-Term Thermal Resistance of Closed-Cell Foam Insulation.*[6] ASTM C578 requires that the long-term thermal resistance (LTTR) be reported for five types of XPS (designated in the standard by roman numerals IV, V, VI, VII, and X). Expanded polystyrene (EPS) typically is not subject to this gas exchange mechanism and the associated accelerated testing to determine a LTTR value.

Compared with the gas exchange mechanism, moisture absorption more significantly influences the thermal resistance of polystyrene (EPS and XPS) insulations. ASTM C578 prescribes only short-term moisture absorption tests, using narrowly defined laboratory conditions. These tests can be informative for classification purposes, but they typically do not provide sufficient information to design a roof, wall, or cold-climate infrastructure assembly. This article discusses various aspects of moisture absorption in polystyrene (EPS and XPS) insulations and the pitfalls of relying exclusively on ASTM C578 *R*-values in real-world designs.

RCPS foam boards are used to manage the hygrothermal performance of roofs, walls, foundations, and cold-climate infrastructure. The thickness and physical properties of the foam boards influence the location of the dew-point temperature within the building enclosure elements. Moisture-absorption properties are especially important with respect to how moisture is transported through the insulation as well as the condensation of moisture within the bulk of the insulation.

Susceptibility to long-term moisture absorption is not quantified in ASTM C578. Short-term measurements of moisture absorption are based on submersion for 24 hours in a laboratory environment. As described in detail for cold climates,[3] the moisture absorption measured on samples retrieved from below-grade applications after several years are often much higher than the short-term maximum values specified in ASTM C578.

To ensure that appropriate environmental controls are sustained, an informed designer will strategically use neutral specifications and apply knowledge of how RCPS foam boards interact with the environment over long periods of time. ASTM C578 currently has no required test method to characterize the long-term effects of exposure to moisture. It is up to the designer to gain additional knowledge about these factors and develop an appropriate strategy.

The values given in ASTM C578 can be likened to the rules of a game such as basketball or chess. The rules of manufacturing and classifying the various types according to ASTM C578 are not in dispute. Nonetheless, how these specifications are applied has more to do with the talent of the designer in developing an optimal design in accordance with the end use and the environment.

BASICS OF THERMAL RESISTANCE

Basic thermal insulation knowledge begins with a fundamental understanding of heat flow. Arguably, from the viewpoint of a building enclosure consultant, engineer, or architect, the most important material property of RCPS foam board is its thermal resistance.

The heat flow Q per unit area A is directly proportional to the temperature difference ΔT divided by the thermal resistance R_{th}.

Heat flow per unit area: $q = Q/A = \Delta T/R_{th}$

In this equation, R_{th} equals the *R*-value. R_{th} values add in series, similar to electrical resistors. *R*-value is sometimes expressed as *R*-10, *R*-20, and so on, indicating the product of the *R*-value per inch and the thickness of the board in inches.

The Federal Trade Commission (FTC) requires home insulation manufacturers, professional installers, new home sellers, and retailers to provide *R*-value information, based on the results of standard tests, to help inform consumers. The FTC's "*R*-value rule" is formally known as the "Trade Regulation Rule Concerning the Labeling and Advertising of Home Insulation."[7]

The reciprocal of thermal resistivity is thermal conductivity.[8] See the sidebar p 31. "Converting Thermal Resistance Values from Imperial to Metric Units," for an explanation of units, including how to convert between imperial units (inch-pound) and metric units for thermal resistance.

MAKING SENSE OF ASTM TYPES

For projects involving polystyrene foam, a building enclosure consultant, engineer, or architect requires understanding the 14 RCPS classification types listed in Table 1 of ASTM C578. They are numbered I, II, and IV to XV. (Type III has been discontinued, which explains why the numbering goes to XV even though there are only 14 types.)

The columns in ASTM C578 Table 1 are not in numerical order by type but rather are arranged as follows:

- Types XI, I, VIII, II, IX, XIV, and XV are listed in the first seven columns. These are typically EPS insulations.
- Types XII, X, XIII, IV, VI, VII, and V are listed the next seven columns. These are typically XPS insulations.
- Within each set of seven columns, the types are then listed in order according to their specified minimum value for compressive resistance. The first row gives the compressive resistance for each of the 14 types, ranging from 5.0 to 60.0 psi (35 to 414 kPa) for the EPS types and from 15.0 to 100.0 psi (104 to 690 kPa) for the XPS types.

Note that ASTM C578 does not specify that EPS or XPS products must be assigned to specific types. For example, there is no requirement that only XPS products can be classified as Type X or that only EPS products can be classified as Type XII. As long as the product meets the standard's specifications for a type, it can qualify as that type. Realistically, however, there is widespread industry agreement regarding "EPS types" and "XPS types." Manufacturers rarely market an XPS product as one of the EPS types. This article ignores those rare exceptions and informally refers to EPS types and XPS types. (Note: Type XIII, a specialized type of pipe insulation, is not relevant to this article.)

The first row in Table 1 of ASTM C578 gives the standard for minimal compressive resistance because compressive resistance is an important physical property to specify in design documents. Compressive resistance determines how much load can be placed on the RCPS foam board. Although 100 psi is only a fraction of the compressive resistance of steel (25,000 psi [172 MPa]) or concrete (up to 10,000 psi [69 MPa]), the compressive resistance of the foam boards could be a key specification for a protected membrane roof assembly, a basement floor, or an airport runway, to give a few examples. Obviously, RCPS foam board is not meant to be a structural material. However, when the load is distributed, a compressive resistance of 100 psi could adequately support vehicular traffic in plaza decks or airplanes taking off from or landing on an insulated airport runway. ASTM C578 only gives the tensile and compressive stress values. It is not a design standard. It is up to the designer to calculate other structural effects, such as creep and foundation modulus, according to appropriate design standards.

TYPICAL *R*-VALUES

The second row in ASTM C578 Table 1 lists the minimal thermal resistance as measured at 75°F (24°C). Thermal resistance varies significantly with temperature. In general, the *R*-value of RCPS decreases as the temperature increases. In other words, *R*-values are consistently higher at 25°F and 40°F (-4°C and 4°C) compared with 75°F and 110°F (24°C and 43°C) for both EPS and XPS types (**Fig. 4**). In ASTM C578, the table that recommends minimum *R*-values at 25°F, 40°F, and 110°F is Table X1.1 in Appendix X1. As noted earlier, that appendix is intended to collect "nonmandatory" information. However, these higher *R*-values at lower temperatures are relevant when specifying insulation for colder climate zones or environments.

At each of the test temperatures, five of the XPS types (X, IV, VI, VII, and V) are specified in ASTM C578 to have the same minimum *R*-values per inch, which plateau at 5.60, 5.4, 5.0, and 4.65 for temperatures of 25°F, 40°F, 75°F, and 110°F (-4°C, 4°C, 24°C, and 43°C), respectively. That is remarkable considering that other performance characteristics vary substantially for these five XPS types. This is because *R*-values have less correlation with density for XPS types and a much stronger correlation for EPS types. Furthermore, **Fig. 5** shows that the *R*-values for XPS types are consistently higher than the *R*-values for EPS types of similar densities.

Density is perhaps the least relevant material property of RCPS foam boards in terms of building enclosure design. The additional load on a building from the weight of RCPS foam boards is negligible. Density may only be

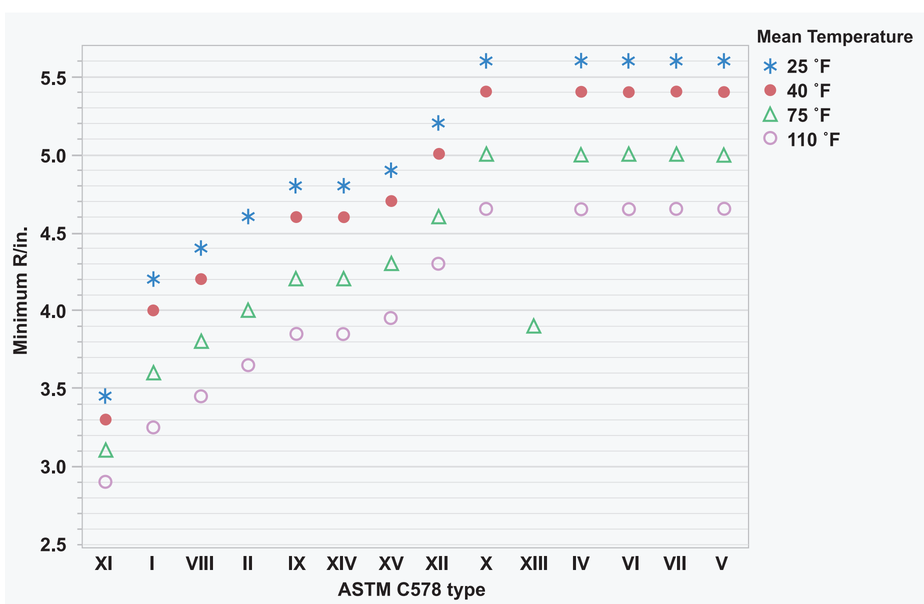
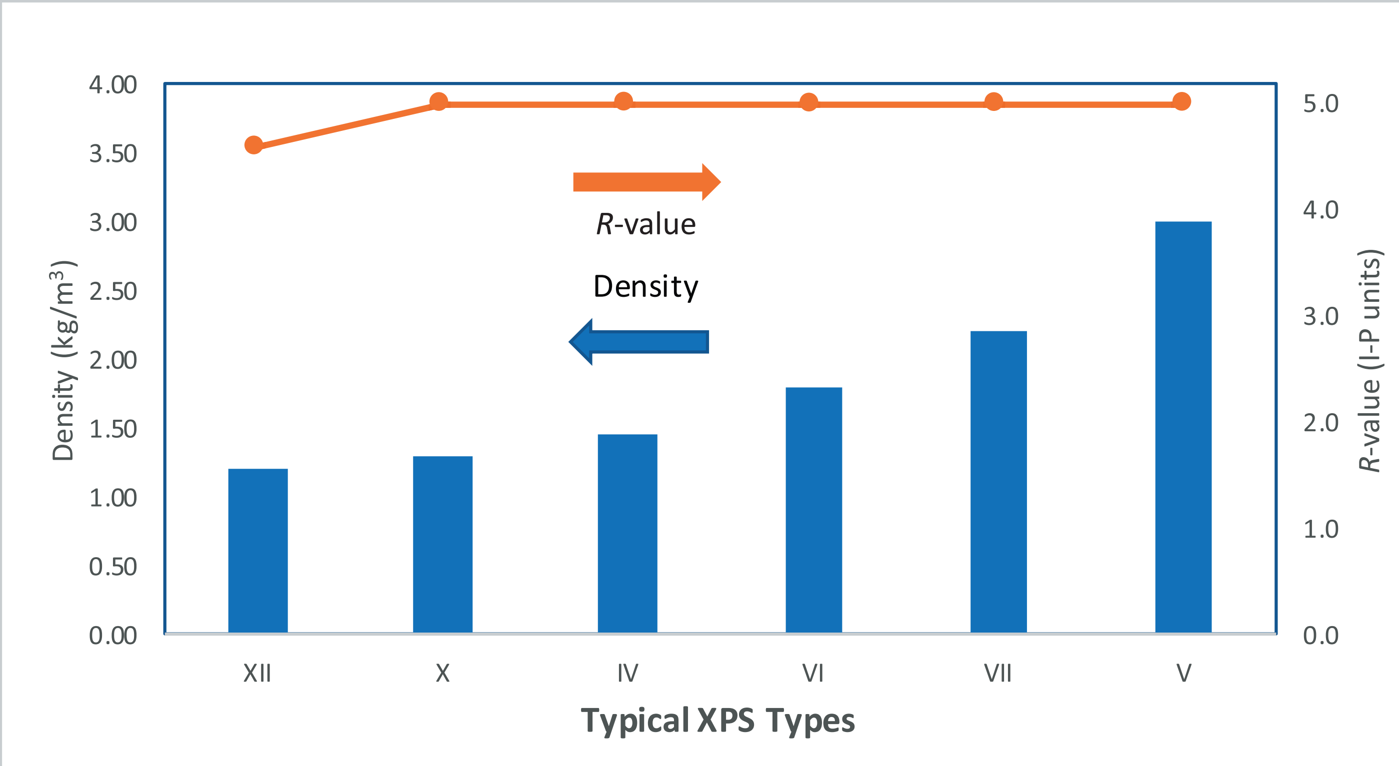


Figure 4. *R-value per inch increases as temperature decreases for both "EPS types" and "XPS types" of rigid, cellular polystyrene insulation in the ASTM C578[4] classification. Note: EPS = expanded polystyrene; XPS = extruded polystyrene.*



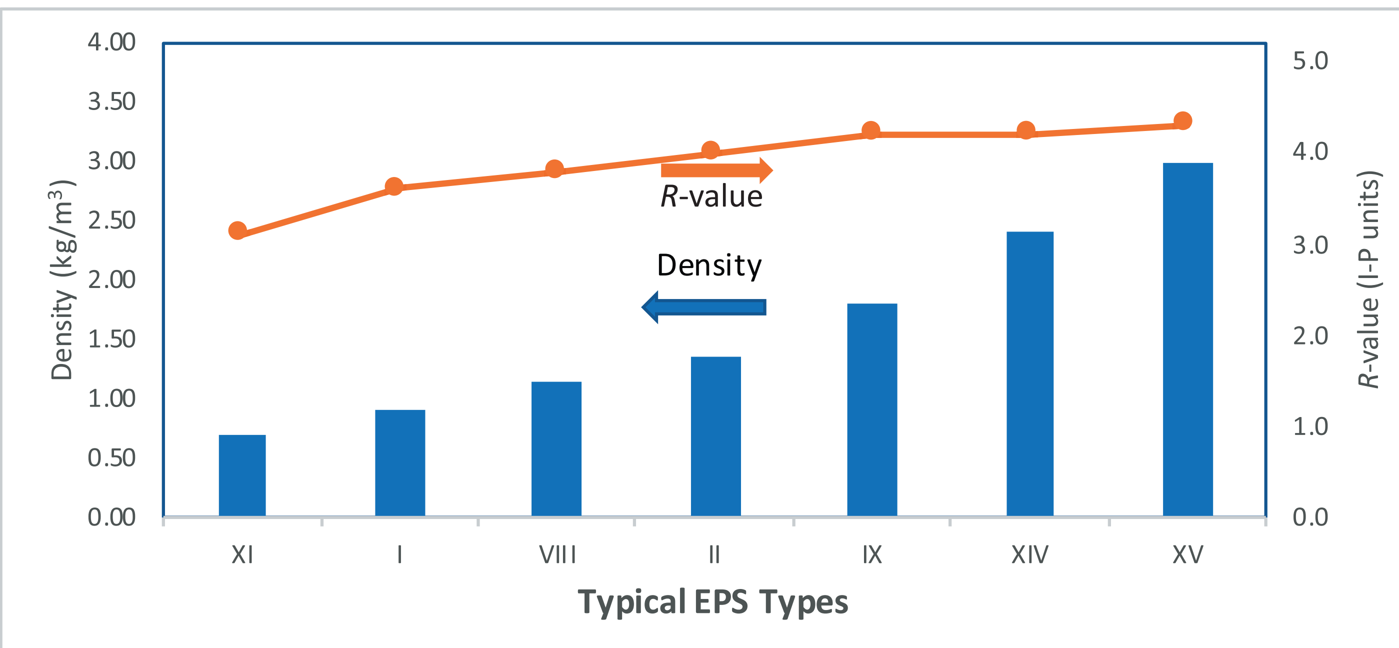


Figure 5. R*-value increases with density for both "EPS types" and "XPS types" of rigid, cellular polystyrene insulation in the ASTM C578*[4] *classification, although* R*-value peaks at higher values and relatively low density for XPS types. Note: EPS = expanded polystyrene; XPS = extruded polystyrene. Values are from ASTM C578.*

relevant when calculating the buoyancy of the foam boards used on a protected membrane roof assembly or a flotation device. In those cases, there will need to be enough ballast to keep the foam boards from floating. Also, the weight of the protected membrane roof assembly is relevant to the design for wind uplift resistance.

POROSITY AND STRENGTH

Although the density of RCPS foam boards may not be of much relevance in building enclosure design, it is noteworthy that the material's strength correlates well with density. There are two observations worth noting:

- Compressive strength and flexural strength generally correlate with density.
- For a given density, XPS types are stronger than EPS types.

For example, XPS Type V and EPS Type XV both must test to a minimal density of 48 kg/m^3 (3.0 lb/ft^3), but the compressive strength of the EPS type is 40% less than that of the XPS type.

How could two foam boards of the same material with the same density have such different strengths? One possible answer may involve the porosity, which can be subdivided into closed porosity and open porosity.

Porosity is defined as 1 minus the ratio of the density of the foam and the density of the solid: [1 - (ρ/ρ_{solid})]. According to the National Institute of Standards and Technology,[9] the density of solid polystyrene (not insulation) is 1060 kg/m^3 (66 lb/ft^3), which is slightly denser than water. (Of course, solid polystyrene has zero porosity.) In comparison, the density of polystyrene foam insulation boards ranges between 12 and 48 kg/m^3 (0.75 and 3.0 lb/ft^3). Hence, the total porosity of these types of insulation boards ranges between 0.99 (least dense) and 0.95 (most dense).

Table 1 of this article shows the density and calculated total porosity of various types of RCPS along with the compressive strengths as given in ASTM C578 Table 1. As density increases, the porosity decreases; however, that does not explain the strength differences between EPS types and XPS types of similar porosity.

Table 1. Calculated total porosity of "XPS types" and "EPS types" of rigid, cellular polystyrene insulation based on ASTM C578 minimum density values

EPS types							
Type	**XI**	**I**	**VIII**	**II**	**IX**	**XIV**	**XV**
Porosity, [1 - (ρ/ρ_{solid})]	0.989	0.986	0.983	0.979	0.972	0.964	0.954
Compressive resistance, minimum, psi	5	10	13	15	25	40	60
Flexural strength, minimum, psi	10	25	30	35	50	60	75
XPS types							
Type	**XII**	**X**	**IV**	**VI**	**VII**	**V**	
Porosity, [1 - (ρ/ρ_{solid})]	0.982	0.98	0.978	0.972	0.967	0.954	
Compressive resistance, minimum, psi	15	15	25	40	60	100	
Flexural strength, minimum, psi	40	40	50	60	75	100	

Note: EPS = expanded polystyrene; XPS = extruded polystyrene. 1 psi = 6.895 kPa. ρ = density of foam; ρ_{solid} = density of solid.

Total porosity is the sum of closed porosity and open porosity. Open porosity can be measured by the gas adsorption method: the more gas adsorbed, the greater the open porosity. Open porosity also explains the greater water absorption and permeability of EPS types compared with XPS types of the same density. Most of the porosity of XPS types is closed porosity. In contrast, when the resin beads in EPS are expanded into a closed mold, the channels between the beads provide a substantial proportion of open porosity. Thus, although the cell-wall thicknesses may be similar in EPS and XPS samples of similar density, the EPS sample would have a greater proportion of open porosity as seen in **Fig. 6**.

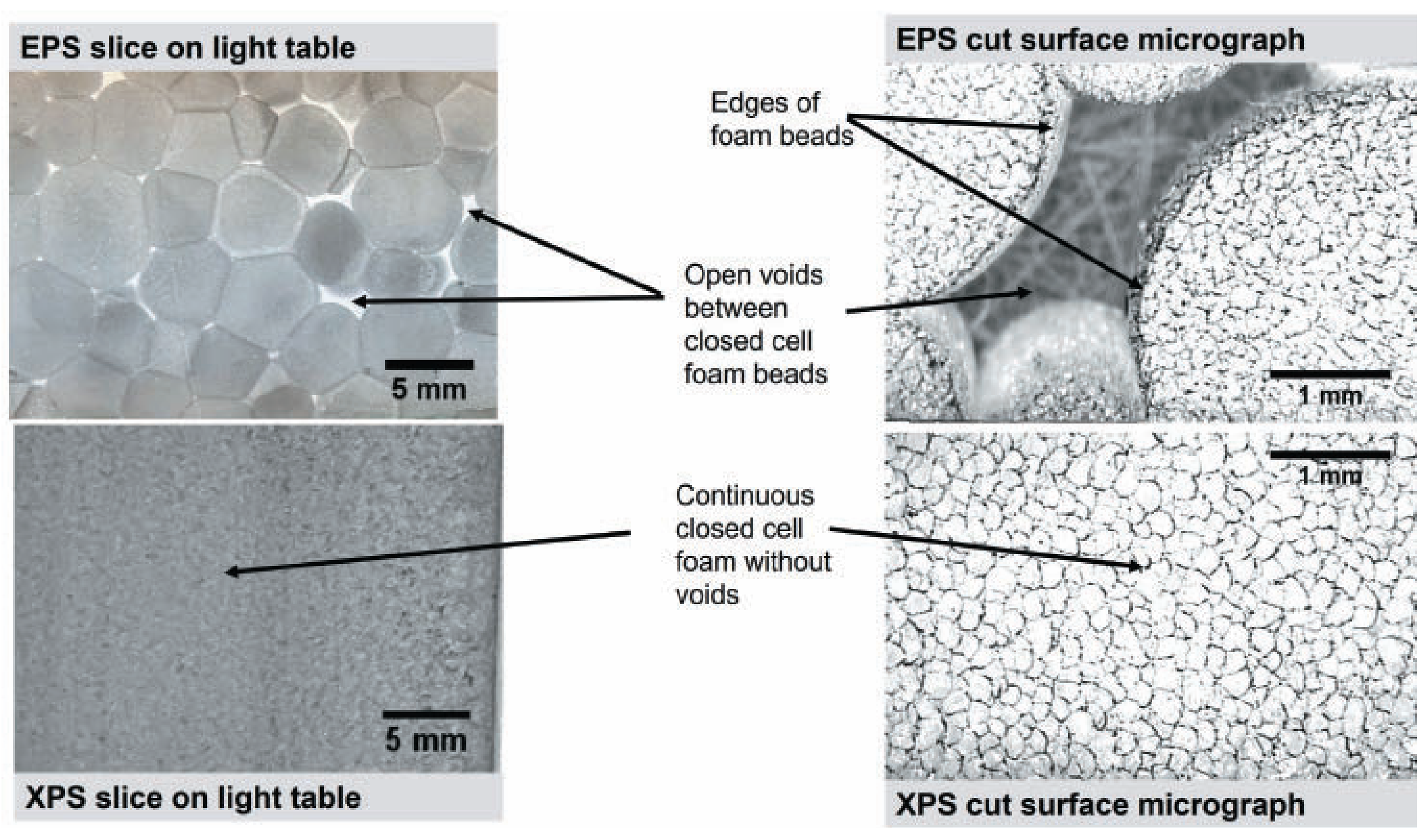


Figure 6. *EPS foam illustration has considerable open porosity compared with XPS foam insulation. Note: EPS = expanded polystyrene; XPS = extruded polystyrene.*

Figure 7. *Aerial view of US Coast Guard Headquarters. XPS insulation must resist compressive loads from the weight of vegetative or "green" roofs. Note: The appearance of US Department of Defense (DoD) visual information does not imply or constitute DoD endorsement. EPS = expanded polystyrene; XPS = extruded polystyrene.*

The open porosity of the EPS bulk matrix has a deleterious effect on strength and explains why EPS foam board absorbs more water than XPS foam does. Porosity is not the only factor underlying strength. Foam structure on the scale of the cells also is a factor. Mechanical strength is believed to come from polystyrene struts, which offer greater strength than the cell windows. A detailed discussion of how struts can strengthen RCPS is beyond the scope of this article. Interested readers are referred to the technical literature on this topic.[10] What is important to note here is that the strength of foam board is important for many applications of RCPS, and manufacturers are continually seeking to improve this property (**Fig. 7**).

THE TRUTH ABOUT WATER ABSORPTION

The most startling numbers in ASTM C578 Table 1 are found in the row on water absorption. These numbers represent the maximum water absorption allowed to meet the standard for each of the RCPS types. There is no question that EPS absorbs much more water than XPS, specifically in short-term testing by total immersion. Maximum water absorption values of 2%, 3%, or even 4% by volume are seen for EPS types. In general, for EPS types, as density increases, the maximum *R*-value is reduced but it does not drop below 2% by volume (**Fig. 8**).

Water weighs 1,000 kg/m^3 (60 lb/ft^3). When 2% of the volume of a cubic meter of Type XV foam is occupied by water, 20 kg (44 lb) of water are added to the 48 kg (106 lb) of foam. Values for water absorption per ASTM C272, *Standard Test Method for Water Absorption of Core Materials for Sandwich Constructions*,[11] for EPS Types XI and I (maximum 4% by volume), EPS Types VIII and II (maximum 3% by volume) and EPS Types IX, IV, and XV (maximum 2% by volume) are in sharp contrast to the maximum water absorption for XPS Types XII, X, IV, VI, VII, and V (maximum 0.3% by volume). In other words, depending on the specific type, EPS can absorb 7 to 10 times as much water as XPS and still meet the ASTM C578 product standard. See **Table 2**.

Table 2. Water absorption for various "EPS types" and "XPS types" of rigid, cellular polystyrene insulation

	Water absorption by total immersion, 24-hour maximum absorbed (% by volume)
EPS types	
XI, I	4.0
VIII, II	3.0
IX, XIV, and XV	2.0
XPS types	
XII, X, IV, VI, VII, V	0.3
XIII	1.0

Note: EPS = expanded polystyrene; XPS = extruded polystyrene.

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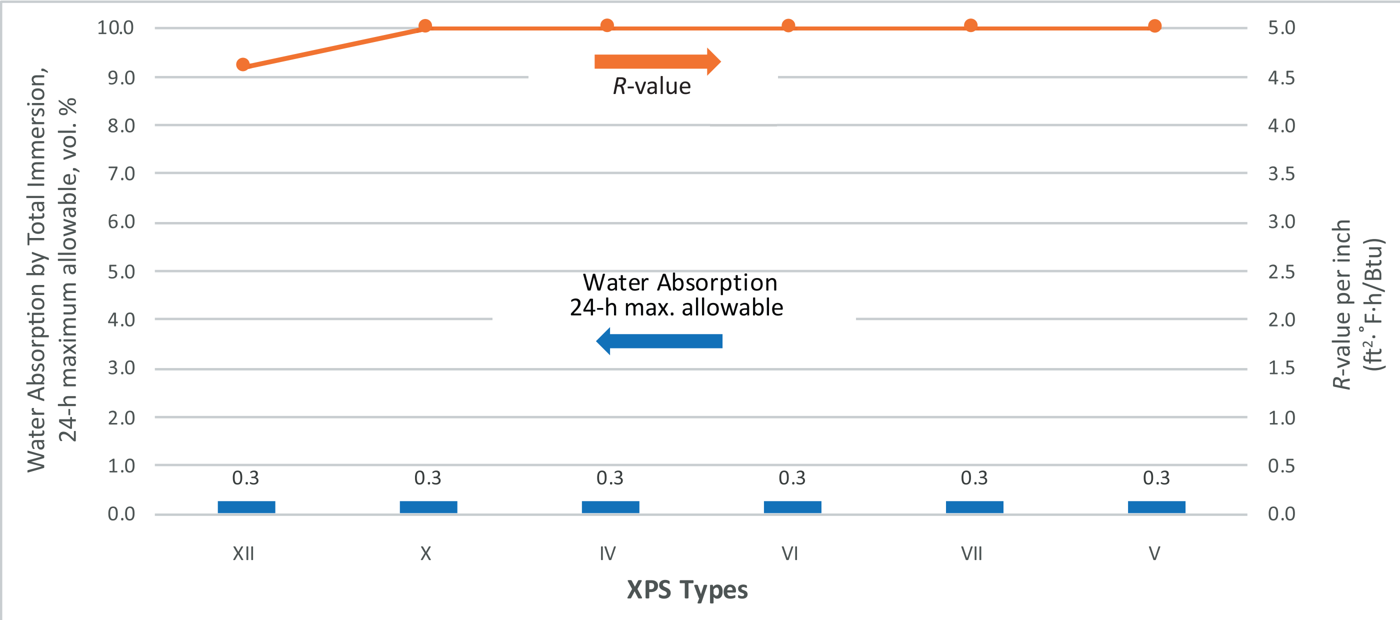

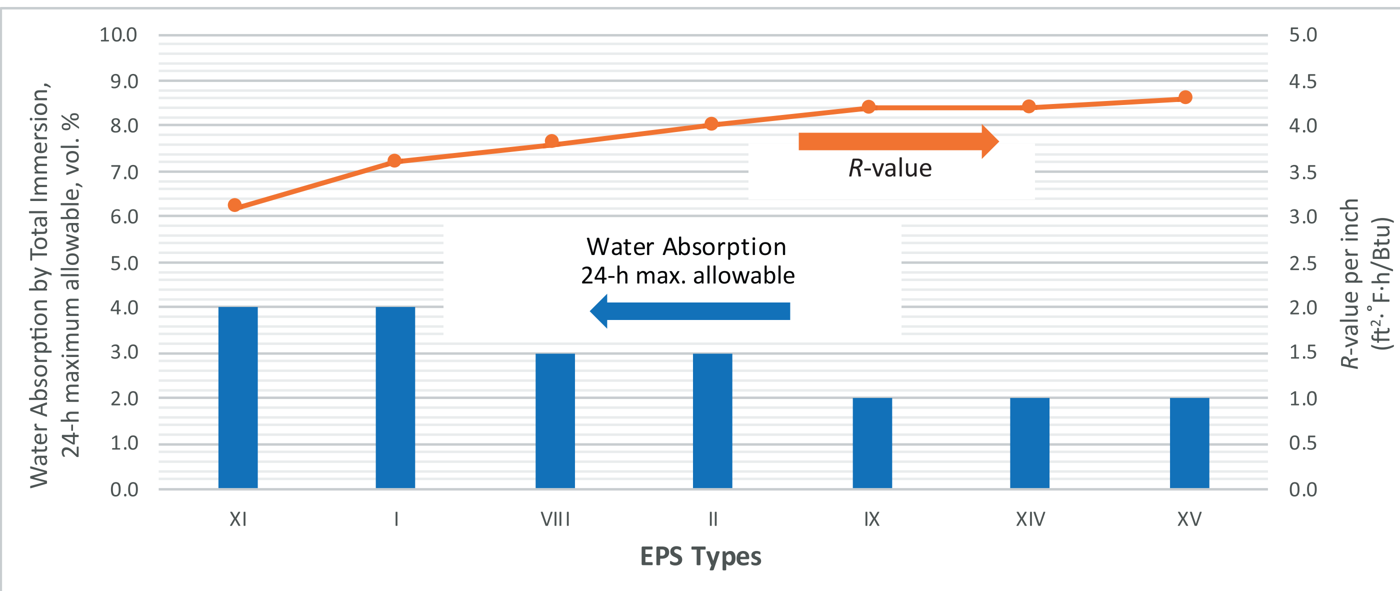

Figure 8. R-*value per inch increases as water absorption decreases. The high* R-*values for XPS could be attributed in part to its low values of water absorption. Water absorption is measured in percentage by volume. Note: EPS = expanded polystyrene; XPS = extruded polystyrene. Values are from ASTM C578.*[4]

The water absorption rates for short-term testing represent a major difference between EPS and XPS types of RCPS foam. ASTM C578 requires manufacturers to meet the water absorption limits for relatively short periods of immersion. Additionally, ASTM C578 mentions in the Appendix X1.4, "Water Absorption," that "this characteristic may have significance when this specification is used to purchase material for end-uses requiring extended exposure to water." The appendix is considered "nonmandatory" information, and ASTM C578 does not quantify the effects of this water absorption on the thermal performance of the materials. Designers are left to their own resources.

The reason for this disparity in water absorption rates has to do with the discontinuous structure of EPS foam boards, which results in significant open porosity (as described in the previous section). The capillary pathways allow water to enter the EPS types throughout the bulk of the material, depending on the capillary sizes. Smaller bead sizes—such as those used in food-grade EPS—result in smaller and less permeable capillaries but also limit the density reduction. On the contrary, relatively little water enters the bulk of the XPS samples because the high proportion of closed-cell porosity inhibits the absorption of water. XPS insulation has a smooth microstructure that is not interrupted by the millimeter-scale "bead structure" prevalent in EPS types.

The consequences of water absorption can be substantial, depending on the application. Its water absorption rate is one of the main reasons why EPS is unsuitable for protected membrane roofing assemblies.[1] It also explains why XPS is preferred in below-grade applications. Also, XPS is preferred over EPS for habitable basements, where polystyrene insulation is commonly applied exterior to the basement walls and floor slabs (and thus is often in contact with groundwater or moist soil).[2]

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The mechanisms of water absorption are reviewed in considerable detail in Brooks et al.[12] See also Pakkala and Lahdensivu.[13]

MYTHS ABOUT TESTING FOR WATER ABSORPTION

Aside from the water absorption mechanisms, which in general are not disputed, several myths and misinterpretations have developed concerning water absorption testing. Most experts readily acknowledge that *R*-values of RCPS foam boards drop as water is absorbed. This is based on simple physics. The thermal conductivity of water or ice is much greater than the thermal conductivity of air or blowing agents. Performance has been simulated using computer models.[14,15] Nonetheless, the prediction of water absorption depends on the application, the climate zone, and other factors. It is incorrect to assume that water absorption does not really matter because the insulation quickly dries out. This is untrue in many cases, especially for below-grade applications.[3]

Also, it is incorrect to assume that "maximum" water absorption according to ASTM C578 represents a "maximum possible" value of long-term water absorption, or that it places an upper limit on the amount of water that can be absorbed. This is also not true, according to findings reported by Cai et al.[16,17] The crux of these misunderstandings is the conflation of the ASTM C578 standard with performance expectations. ASTM C578 does not dictate the thickness of insulation required to achieve long-term design *R*-values. That is based on engineering judgment using various thickness-correction guidelines.

Specifiers must keep in mind that the short-term testing for moisture absorption used in ASTM C578 does not predict how moisture absorption affects performance in different applications. There is a heavy energy-waste penalty due to reduced *R*-value when insulation is incorrectly used in wet environments such as building foundations, protected membrane roofing assemblies, infrastructure in cold regions, and other below-grade applications. It is up to the specifier or consultant to account for the consequences of material choices in any given application.

ASTM C578 only gives basic properties of the various types of EPS and XPS at the time of manufacture. In the final analysis, the building enclosure consultant, architect, engineer, or specifier must exercise "engineering judgment" in the design of insulation systems suitable for a particular application and environment. Thermal stability, moisture control, thickness factor, long-term *R*-values, and so on are all relevant to the design of below-grade structures.

CONVERTING THERMAL RESISTANCE VALUES FROM IMPERIAL TO METRIC UNITS

A full understanding of *R*-value (in imperial units) or RSI-value (in metric units) is essential to the application of ASTM C578. The following is a review of the basics of thermal resistance values and how to convert from imperial units to metric units.

Heat flow per unit area: $Q/A = \Delta T/R$

where

$R = R_{th}$ = thermal resistance

Q = heat flow

A = unit area

ΔT = temperature difference

Rearranging the heat flow equation gives the following equation:

$R = (\Delta T/Q) \times A$

In imperial units:

Q has units of energy per unit time (Btu/h)

ΔT has units of degrees Fahrenheit (°F)

Area has units of square feet (ft^2)

Therefore, the units for *R*-value per unit length are ($ft^2 \times$ °F)/(BTU/h) = (°F $\times ft^2 \times$ h/BTU)

In SI units, RSI has units of (°C $\times m^2$)/W or, equivalently, K $\times m^2$/W.

Converting from Imperial Units to SI Units

To convert from imperial units to SI units, apply the following conversions.

1°F = (5/9)K

1 Btu/h = 0.2931 W

1 ft^2 = 0.0929 m^2

°F $\times ft^2 \times$ h/Btu = (5/9) $\times$ 0.0929/0.2931 K·m^2/W

(°F $\times ft^2 \times$ h/Btu)/(K $\times m^2$/W) = 0.176

(K $\times m^2$/W)/(°F $\times ft^2 \times$ h/Btu) = 5.678

R-value (in imperial units) ≈ RSI-value (in SI) × 5.678

RSI-value (in SI) ≈ *R*-value (in imperial units) × 0.176

To convert to an RSI value in SI units an *R*-value in imperial units, multiply by 5.678. To convert an *R*-value in imperial units to an RSI value in SI units, multiply by 0.176.

About Thermal Conductivity

The *U*-value for an insulator is a measure of thermal conductivity. The inverse of the *R*-value is also known as the overall heat transfer coefficient.

U-value = (1/*R*-value) = heat flux/(temperature difference)

For a given temperature difference, a high *U*-value signifies a high heat flux. The heat flux in imperial units is expressed as Btu/h/ft^2. In SI units, the heat flux is expressed as W/m^2. The total heat transferred would be the heat flux multiplied by the area. Heat flow is greatest through areas with low *R*-values. The *U*-value of an assembly such as a wall or entire building enclosure accounts for individual *U*-values and interplay of the assembly components.

A Simple Example

The *R*-value for 1 in. (25 mm) thickness of many common building materials (such wood, brick, or concrete) is less than 1 °F × ft^2 × h/Btu. Consider a 1 ft × 1 ft (0.3 m × 0.3 m), 1 in. (25 mm) thick block of material with a 10°F (5.5°C) temperature differential on either side of the block. If the *R*-value per inch of this hypothetical building material has a value of 1 °F × ft^2 × h/Btu, this block would transfer 10 Btu (10.6 kJ) every hour. If the block area were 10 ft × 10 ft (3 m × 3 m), the heat loss would be 1,000 Btu/h (1,055 kJ/h). Increasing this example to 1,000 ft^2 (equivalent to the wall area of a small double-wide mobile home) results in 10,000 Btu/h (10,550 kJ/h) or 240,000 BTU (253,000 kJ) per day. Poorly insulated homes are notoriously expensive to heat and cool for this reason. In our example, energy loss could add up to $3 to $7 per day ($1,000 to $10,000 per year), accounting for seasonal, fuel type, and regional variability.

At the other extreme, an XPS foam board typically has a thermal resistance five times greater than our hypothetical material. So, in the example, instead of transferring 1,000 Btu/h (1,055 kJ/h), it would only transfer 200 Btu/h (211 kJ/h). Moreover, 5 in. (125 mm) would only transfer 40 Btu/h (42 kJ/h). It is easy to see how polystyrene insulation can dramatically inhibit heat transfer through walls, floor slabs, and roofs, and reduce energy use and waste. Few building materials offer values of thermal insulation as high as those for polystyrene insulation.

CONCLUDING REMARKS: FACTS AND CAVEATS

Insulation products are essential for improving the energy efficiency and service life of buildings. Polystyrene foam insulation boards are among the most versatile insulation materials available. However, all types of polystyrene insulation are not created equal. ASTM C578 has raised awareness that there are two distinct types of polystyrene insulation boards, EPS and XPS, and, in general, these two classes of insulation have very different properties.

ASTM C578 provides key facts but leaves the door open for logical fallacies. *Caveat emptor* (Buyer Beware!) rules the marketplace. Some nontechnical product representatives may incorrectly assume that the short-term moisture absorption values in ASTM C578 represent an upper limit on moisture absorption, or that long-term moisture absorption doesn't matter because the insulation dries out. However, without standard testing and in-field observations, marketing campaigns may advance anecdotal "evidence" of performance in insulation-friendly environments. Until reliable long-term testing and modeling can be developed, engineering judgment will continue to play a vital role in the specification of insulation.

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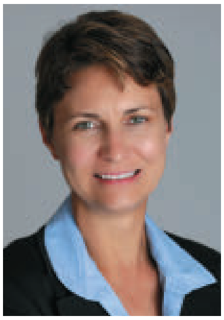

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