XPSA
EXTRUDED POLYSTYRENE FOAM ASSOCIATION
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Demystifying Rigid, Cellular Polystyrene Insulations

Figure 1. RCPS foam boards are often installed beneath airfields in cold climates. Photograph courtesy of DuPont.

Rigid, cellular polystyrene (RCPS) foam boards are used as thermal insulation in assemblies for exterior walls, basements and roofs as well as cold climate infrastructure [1-3]. Figures **1–3** show examples of just a few of the many applications for RCPS foam boards.

Considering there are so many different applications, it is noteworthy 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.

Figure 2. RCPS foam boards are often installed in below-grade applications for habitable basements. Photograph courtesy of Kingspan.

Why 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.

Let the Buyer Beware

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

Figure 3. RCPS foam boards can be used in underslab as well as vertical wall applications.

Guidance from individual manufacturers and industry associations is useful, but such information can be limited to specific applications or product properties rather than holistic application performance. “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.

Appendix X1

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:

- 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 outgassing of blowing agents (an inward diffusion of air) and moisture absorption over years and decades.

Small Effects of Gas Exchange Mechanism

It is true that 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.

The outgassing 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.

Gas Exchange Versus Moisture Absorption

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.

Hygrothermal Performance

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. 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.

A Winning 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. A winning strategy would be to specify products that resist moisture over time periods beyond the specifications of the standard. 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.

References

1. Brooks, R., T. Coppock, M. Dillon, V. Woodcraft, and J. Woestman. 2022. "Extruded Polystyrene in Protected Membrane Roof Assemblies." Extruded Polystyrene Foam Association (XPSA). https://xpsa.com/wp-content/uploads/2022/09/PMRA-XPSA-FINAL-APPROVED-with-Photos-Interleaved-2022-bylines.pdf.
2. Brooks, R., T. Coppock, M. Dillon, M. Guo, V. Woodcraft, and J. Woestman. 2022. "The Role of Insulation for Habitable Basements," XPSA. https://xpsa.com/wp-content/uploads/2022/11/IP-BG-03-Habitable-Basements.pdf.
3. Brooks, R, B. Fabian, J. Smith, G. Titley, and J. Woestman. 2019. "Extruded Polystyrene Delivers Higher R-Values than Expanded Polystyrene in Below-Grade Applications, According to New University of Alaska Fairbanks Study." XPSA. https://xpsa.com/wp-content/uploads/2020/05/XPSA-IP-BG-01_Nov.8.2019_Preprint.pdf.
4. ASTM International. 2023. *Standard Specification for Rigid, Cellular Polystyrene Thermal Insulation*. ASTM C578-23. West Conshohocken, PA: ASTM International.
5. ASTM International. 2022. *Standard Test Method for Predicting Long-Term Thermal Resistance of Closed-Cell Foam Insulation*. ASTM C1303/C1303M-22. West Conshohocken, PA: ASTM International.