XPSA
EXTRUDED POLYSTYRENE FOAM ASSOCIATION

Technical **INSIGHTS**

Winter-Spring 2021 Below Grade, Number 3

Moisture Absorption Mechanisms in Polystyrene Foams Are Keys to Predicting Long-term Performance

XPS and EPS Behave Differently in Moist Below-Grade Applications

Moisture absorption is a familiar concept (Fig. 1). Although moisture absorption mechanisms in polystyrene insulation are well known and easy to understand, claims about insulation performance can be misleading. Marketing claims often are made based on test results from a few field samples or small scale laboratory tests of limited duration and exposure.

Smart specifiers are well versed in the basic mechanisms for moisture uptake and moisture absorption. They know that there are key physical differences between XPS and EPS and these differences dramatically affect the long-term R-value performance.

Figure 1 *- Moisture absorption is a familiar concept.*

THREE NEED-TO-KNOW MECHANISMS

Moisture uptake is dictated by the properties of the materials. Just as polystyrene insulation microstructure affects heat transfer so, too, it affects moisture transport. This relationship between microstructure and moisture uptake especially holds true for insulation materials. The moisture uptake potential of an insulation material, therefore, is an important property to consider when designing with XPS or EPS.

The three mechanisms that the specifier needs to know and understand are as follows in order of importance:

- Liquid-water capillary action
- Water diffusion
- Water adsorption

These mechanisms are best understood with reference to Figure 2, which shows schematics of these mechanisms superimposed on actual micrographs of XPS and EPS.

All polystyrene insulation products are susceptible to water-vapor diffusion. Specific to expanded polystyrene (EPS) however, water in liquid or vapor form travels through the network of channels between the fused EPS beads. These fine capillaries are capable of transporting water deeply into the EPS insulation in a very short period of time.

Water vapor molecules from air are adsorbed onto exposed foam surfaces; although the available exposed surface is far larger for EPS compared to XPS, the amount is inconsequential for building applications.

DRIVING FORCES

Moisture uptake is the increase in water content of a material, typically reported as volume percentage or a weight percentage. For moisture to move into and through polystyrene insulation, a driving force and a pathway to travel are required (Fig. 3). The driving force could be a greater pressure of liquid water on one side of the insulation than the other, or a greater pressure of water vapor on one side than the other.

The greater the pressure difference, the greater the driving force for moisture to travel through the insulation

Driving force + Pathway = Transport

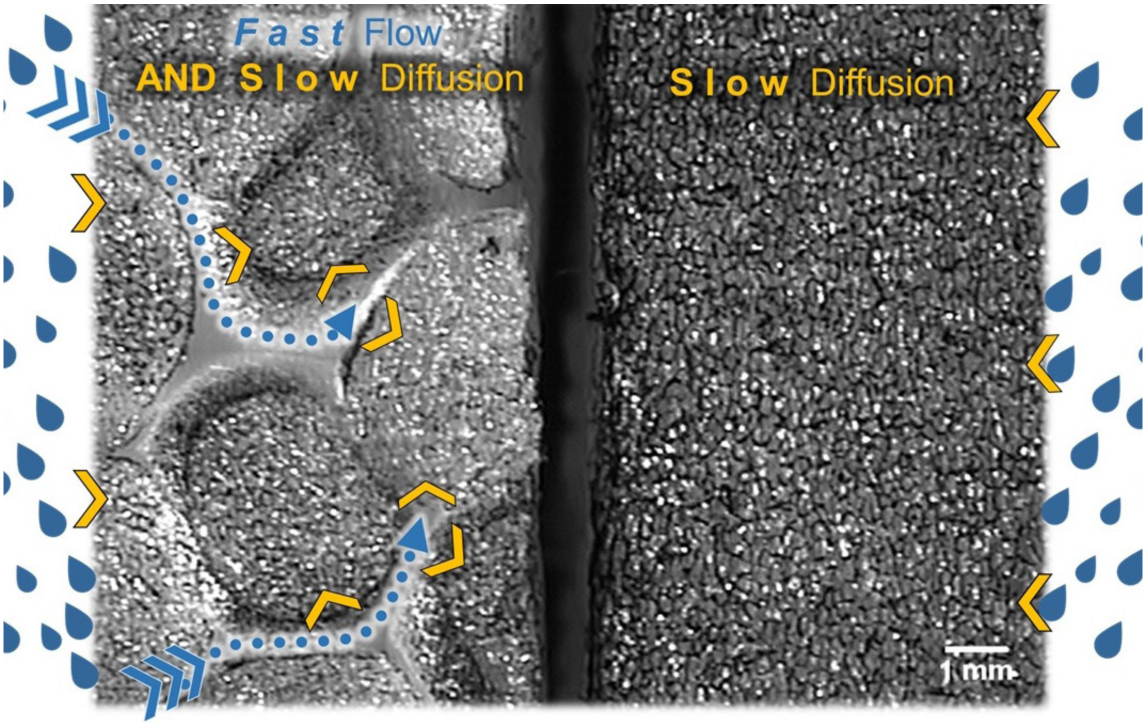

Figure 2 *- Micrograph of side-by-side EPS (Type XIV, left) and XPS (Type IV, right) foam specimens. A continuous mass of closed foam cells is seen on the right. Interstitial channels are evident on the left. The cut surface of both foam specimens highlighted using black ink to enhance imaging contrast; areas not coated with ink are out of the cut surface plane. Incident moisture transport paths are depicted as droplets and arrows.*

Characteristically, specifically to EPS, water in liquid or vapor form can and does travel through the network of channels between the fused EPS beads. Capillary transport of liquid water is much faster than vapor diffusion through the closed cell foam structure. Large amounts of liquid water can be transported through the interstitial channel network with little restriction within seconds. Capillary action can accomplish in seconds what takes years by vapor diffusion.

Although capillary action is limited to the volume of the channel network, water from the interstitial channel network also contributes to diffusion of water into the body of the beads.

Capillary action can accomplish in seconds what takes years by vapor diffusion.

Moisture sources include water vapor in the air or soil surrounding the insulation and liquid water in direct contact with the insulation surfaces. Constant exposure to water leads to absorption of water in the polystyrene insulation and results in a proportional reduction in thermal resistivity (R-value) as measured on samples extracted from below-grade applications.

The water trapped in the channel network conducts heat very well (25 times more efficiently than the foam), thereby bypassing the insulation and reducing the effective R-value of the EPS insulation.

In the case of continuous exposure to below-grade liquid moisture, the insulation may be further compromised by contaminants in the soil and repeated cycles of freezing and thawing. Adjustments to design R-values are required to account for long-term moisture absorption in the real world.

Figure 3 *- Gravity drives river water to flow downward finding pathways of least resistance between obstacles along the way.*

~~WHAT IS NEXT?~~ GET INFORMED

Extruded polystyrene (XPS) insulation and expanded polystyrene (EPS) insulation are both used in applications with high potential for moist or wet service exposure, such as below-grade foundations, slabs, and geofoams, as well as protected membrane roof assemblies (PMRAs).

While proper drainage is recommended in all applications, in below-grade cases, insulations may still be exposed to liquid water and water vapor over many years.

Likewise, PMRAs may be exposed to intermittent water over wet seasons. XPS and EPS insulations both absorb some moisture from exposure to water for extended periods of time; however, research—from the 1970s to the present day—has consistently shown that XPS absorbs significantly less moisture than EPS with the differences becoming most apparent after about six years.

Ideally, engineers and specifiers would have access to peer-reviewed data from known scientific institutions and they could sort through the marketing claims. Furthermore, sophisticated mathematical modeling is emerging to help predict polystyrene insulation performance in a range of climate conditions. In the meantime, long-term field research studies are the best resource for reliable information.

More detailed information about moisture absorption mechanisms, including references to technical literature and real-world case studies, is provided in an XPSA technical paper by technical staff from three XPSA member companies [1] as well as a feature article by John Woestman appearing in *IIBEC Interface* [2].

The following conclusions can be made based on a basic understanding of the fundamental mechanisms as described here.

- It is critical to understand the effects of continuous exposure to water on the thermal performance of polystyrene insulations in various below-grade applications.
- Understanding moisture transport mechanisms in polystyrene foams allows material specifiers to select materials wisely for service in wet applications.
- Accurate predictions of in-service moisture absorption are vital in making decisions about design R-values for polystyrene insulation in moist or wet service below-grade applications.

In summary, short-term testing is presently unreliable for predicting in-service moisture absorption of polystyrene foam insulations. Study after study reached the same conclusion: Current short-term laboratory test methods are weak predictors of long-term thermal performance [3]. Moreover, long term studies predicting the thermal performance of a polystyrene insulation even after decades in service are scarce. The physical structure of XPS is better suited for retaining R-value in moist environments than EPS.

REFERENCES

1. XPSA, Insulation Performance, Below Grade Series, Number 2, "Effects of Moisture Absorption Mechanisms on In-Service Design R-Values of Polystyrene Insulation. PDF available for download from https://xpsa.com/technical-information/
2. John Woestman, "Moisture Absorption in Polystyrene Insulation: Effects on In-Service Design R-Values," IIBEC Interface, November 2020. PDF Available for download from XPSA Technical Information Page. https://xpsa.com/technical-information/ Download PDF: https://xpsa.com/wp-content/uploads/2020/11/2020-11-Woestman.pdf
3. XPSA, Insulation Performance, Below Grade Series Number 1, "Extruded Polystyrene Delivers Higher R-Values than Expanded Polystyrene in Below-Grade Applications, According to New University of Alaska Fairbanks Study," PDF available for download from https://xpsa.com/technical-information/