XPSA
EXTRUDED POLYSTYRENE FOAM ASSOCIATION

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Limitations of Short Term Testing of XPS and EPS Polystyrene Foam Insulation

An Overview of Moisture Absorption in Polystyrene Foam Insulations

Expanded polystyrene (EPS) and extruded polystyrene (XPS) foam insulation are widely used in below grade applications under a variety of moisture conditions. The integrity of building foundations and infrastructure relies upon their long-term thermal performance despite frequent or continuous exposure to liquid water and moisture.

EPS is unlike XPS insulation. When EPS insulation is continuously exposed to water in below grade applications for many years, EPS absorbs and retains many times its own weight in water. Double-digit moisture content by percent volume is not unusual for EPS in such applications [1, 2]. With so much water uptake possible, the thermal conductivity of EPS varies significantly, depending on the moisture content percentage (by volume or by weight) and how that moisture is distributed in the EPS microstructure.

The effects of moisture absorption on thermal resistance have been carefully studied for both XPS and EPS insulations. Small-scale laboratory testing accurately predicts the relationship between moisture absorption and thermal performance for short time periods, e.g., on the order of days; but such testing does not predict the amount of moisture that will be absorbed in real world applications in the long term. Such tests were never intended to predict long-term moisture or thermal performance.

CLASSIFICATION OF POLYSTYRENE FOAM INSULATIONS

Rigid cellular polystyrene thermal insulations are standardized under material specifications such as ASTM C578 [3] and CAN/ULC S701 [4]. Material specifications are used to define performance requirements at the point of manufacture for quality control. The performance requirements in ASTM C578 and CAN/ULC S701 are intended to classify the various products/properties into "Types." Manufacturers are required to meet the performance requirements for each product Type. Thus, ASTM C578 and CAN/ULC S701 classify various insulations into Types that are based in part on moisture absorption performance. These Types are subsequently widely used in application specifications. Moisture absorption is just one of the physical properties specified for each polystyrene foam Type.

The water absorption test methods referenced by ASTM C578 and CAN/ULC S701 are ASTM C272 [5] and ASTM D2842 [6], respectively. ASTM C272 and D2842 are valuable as short-term test methods to measure the moisture absorption properties of different cellular polystyrene thermal insulations for the purpose of classification into the product Types mentioned above. Moisture absorption is measured after submerging the specimens in water for either 24 or 96 hours per C272 and D2842, respectively.

Nonetheless, ASHRAE 90.1 [7] and other building codes specify ASTM C578 and CAN/ULC S701 Types for certain below grade applications as a minimum criteria. Such specifications are necessary until long-term research provides adequate design information for R-value in lieu of moisture content. If the insulation is exposed to moisture for long periods of time then meaningful long-term testing is necessary to ensure adequate thermal performance for decades of exposure in wet environments.

Under slab application. (Courtesy of Owens-Corning.)

HISTORY OF LONG-TERM TESTING

There is a substantial history of research on the subject of moisture absorption in polystyrene insulation in below-grade applications. More than forty years ago, Dechow and Epstein noted that moisture absorption has a major negative effect on thermal resistance values, decreasing R-values as much as 50 percent [8]. Other factors such as aging and temperature can also negatively affect R-values but not nearly as much as moisture absorption.

Dechow and Epstein concluded that R-values determined from short term laboratory-scale tests do not account for aging (minor effects) or exposure to temperature and moisture (major effects).

> *"Much work has been done in Europe, Canada, and the United States with respect to the effect of moisture on the thermal efficiency of various insulations. However, very little work has been done to orient the laboratory test methods to the actual field conditions in which the various insulations will be used." [8]*

Below-grade wall application. (Courtesy of Kingspan.)

More recently, in 2010, in his discussion of the effective thermal resistivity values used in the design and construction of frost-protected shallow foundations, Crandell questioned the relevance of small scale laboratory tests in predicting performance under actual exposure conditions [9].

> *"Unfortunately, the standardized test conditions may have little relevance to actual environmental exposure histories expected in end use, particularly in below-ground environments." [9]*

The EPS Industry Alliance acknowledges the inadequacy of laboratory scale testing in a 19-page white paper as follows:

> *"Unfortunately, the R-values derived from these ASTM standard laboratory scale tests do not provide a full representation of the performance of insulation in buildings because the tests do not account for the age of the insulation or its exposure to other temperatures and moisture after installation in a building." [10]*

In the same paper, however, the EPS Industry Alliance then reverses its position and recommends using laboratory determined R-values with a 10 percent "adjustment factor" to account for moisture absorption.

> *"This document provides a methodology that uses short-term, laboratory-determined R-values with adjustment factors to account for the long-term conditions of buildings when a more detailed analysis is desired." [10]*
>
> [...]
>
> *The R-values for both EPS and XPS decreases by approximately 10% due to the absorption of water in below grade applications. [10]*

This 10-percent adjustment factor, based on averaged data from a handful of studies, is misleading and contradicts data from peer-reviewed literature. As Carl Sagan once said, "Extraordinary claims demand extraordinary proof." While such low values of moisture content may be valid for XPS in below grade applications, metadata studies on EPS in similar applications point to substantially higher moisture absorption and larger decreases in R-values.

Recently, new research on the performance of XPS and EPS in below grade applications was presented by Billy Connor, P.E., from the University of Alaska at Fairbanks (UAF) [11]. The Connor study presents data on moisture content as well as thermal conductivity as measured on XPS and EPS samples extracted from roads and airfields in cold regions of Alaska. Considering the unreliability of short-term laboratory testing as a predictor of long-term moisture uptake, the Connor study focuses on moisture content data obtained from specimens extracted after many years of below grade exposure in cold regions, including measurements made on extracted samples in two earlier studies [12, 13].

Cai, Zhang and Cremaschi from Auburn University concur that moisture measurement methods for samples extracted from real-world applications simply do not correlate well with short-term laboratory tests [1, 2]. They critically reviewed data from 56 test reports on the relation between moisture ingress and thermal conductivity in XPS and EPS. The metadata collected from multiple reports shows that moisture content in below grade service becomes unpredictable after about six years especially for EPS.

Highway geofoam application. (Courtesy of DuPont.)

These Auburn University researchers systematically evaluated laboratory testing, such as ASTM Standard C272 and other similar tests. They concluded that short-term tests do not reliably predict moisture content in the long-term. Ultimately, after an exhaustive review of historical data from many sources, the Auburn University researchers came to the following conclusions:

> *"[...] there is not yet a single laboratory test that can adequately replicate moisture conditions for EPS and XPS insulations." [1]*
>
> *"No standard test method currently exists that can correlate the moisture content derived from laboratory methods with the long-term performance for XPS and EPS used as soil insulation." [2].*

CONCLUSION

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. Moreover, long term studies predicting the thermal performance of a polystyrene insulation even after decades in service are scarce. Reliance on real-world application data is vital if premature failures of building foundations or infrastructure are to be avoided.

REFERENCES

1. Shanshan Cai, Boxiong Zhang, Lorenzo Cremaschi, "Review of moisture behavior and thermal performance of polystyrene insulation in building applications," *Building and Environment*, Volume 123, (2017) Pages 50-65
2. Shanshan Cai, Boxiong Zhang, Lorenzo Cremaschi, "Moisture behavior of polystyrene insulation in below-grade application," *Energy and Buildings*, Volume 159 (2018) Pages 24-38
3. ASTM C578: Standard Specification for Rigid, Cellular Polystyrene Thermal Insulation. Standard by ASTM International, 2019.
4. CAN/ULC-S701.1: Standard for Thermal Insulation, Polystyrene Boards. Standard by Underwriters Laboratories of Canada (ULC), 2017.
5. ASTM C272 / C272M: Standard Test Method for Water Absorption of Core Materials for Sandwich Constructions. Standard by ASTM International, 2018.
6. ASTM D2842: Standard Test Method for Water Absorption of Rigid Cellular Plastics. Standard by ASTM International, 2019.
7. ANSI/ASHRAE/IES Standard 90.1-2019: Energy Standard for Buildings Except Low-Rise Residential Buildings. https://www.ashrae.org/technical-resources/bookstore/standard-90-1
8. F.J. Dechow and K.A. Epstein, "Laboratory and Field Investigations of Moisture Absorption and its Effect on Thermal Performance of Various Insulations," *Thermal Transmission Measurements of Insulation, ASTM STP 660*, R.P. Tye, Ed., American Society for Testing and Materials, 1978, pp. 234-260.

   <https://doi.org/10.1520/STP35747S>

   https://www.astm.org/DIGITAL_LIBRARY/STP/PAGES/STP35747S.htm
9. Jay H. Crandell, *Journal of Cold Regions Engineering*, Volume 24 (2010) Pages 35-53.
10. EPS Insulation Advancements & Technology Innovations, TECHNICAL BULLETIN, EPS Below Grade Series 103 (2008).
11. Billy Connor, April 2019. "Comparison of Polystyrene Expanded and Extruded Foam Insulation in Roadway and Airport Embankments". Alaska University Transportation Center, University of Alaska Fairbanks, (INE/AUTC 19.08).

    http://autc.uaf.edu/projects/2019/comparison-of-polystyrene-expanded-and-extruded-foam-insulation-in-roadway-and airport-embankments/
12. David C. Esch, December 1986. Insulation Performance beneath Roads and Airfields. Highway Research, Fairbanks, Alaska: Alaska Department of Transportation and Public Facilities, 10. (AK-RD-87-17).

    http://dot.alaska.gov/stwddes/research/assets/pdf/ak_rd_87_17.pdf
13. Nadia Pouliot and Yves Savard, 2003. High Density Expanded Polystyrene Boards as Road Insulation, Phase I, Performance Evaluation of Expanded Polystyrene on Road 161 in St-Martyrs-Canadiens. Performance Follow-up Report, Quebec: Ministry of Transport Quebec.
14. John Woestman. "XPS Delivers High R-values in Below-grade Applications," *The Construction Specifier*, August 2020.

    https://xpsa.com/wp-content/uploads/2020/10/XPSA08-2020-ePrint.pdf

XPSA represents all major extruded polystyrene (XPS) foam insulation manufacturers in North America. The association and its members are committed to the safety and integrity of XPS products. They invite interested parties seeking additional information to visit XPSA online at www.xpsa.com or to email office@xpsa.com