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ABSTRACT:
Through an examination of two case studies and a discussion of key factors such as cost-effectiveness, durability, and environmental impact, this tech tip provides valuable insights for architects, engineers, and construction professionals seeking to make informed decisions for choosing when to use Expanded Polystyrene (EPS) and Extruded Polystyrene (XPS) foam board insulation for below-grade applications.

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REFERENCES:
ASTM C272 - Standard Test Method for Water Absorption of Core Materials for Structural Sandwich Materials

ASTM C518 - Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Apparatus

ASTM C578 - Standard Specification for Rigid, Cellular Polystyrene Thermal Insulation

ASTM D2842 - Standard Test Method for Water Absorption of Rigid Cellular Plastics

Foundation Wall Insulation: EPS or XPS

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Foundation Wall Insulation

Below grade insulation is recognized for its ability to enhance a building structure's energy efficiency and temperature stability. Incorporating insulation in the below grade assembly improves thermal performance, increases moisture control, reduces interior condensation, and prevent freeze-thaw cycling damages.

Of insulating materials, polystyrene is one of the most common. Polystyrene has a stable R-Value and its structure inherently contains gaps within the material. The material is flammable and melts at temperatures above 250 degree F. It can be incompatible with certain thermoplastics, so polystyrene may remove plasticizers from thermoplastic membranes.

Polystyrene board insulation is readily available as Expanded Polystyrene (EPS) Foam Board and Extruded Polystyrene (XPS) Foam Board. Both EPS and XPS are recyclable products that can be utilized in projects pursuing LEED accreditation and share material qualities. They are good for below-grade applications due to their resistance to mold and mildew growth. They can be utilized over membranes, but the material will deteriorate with sun exposure. With these similarities and their easy convenience as a construction material, the question is, is EPS or XPS more preferable for project use?

EPS: Expanded Polystyrene Foam

In comparison to XPS, EPS has lower cost, weight, and global warming potential due to the pentane blowing agents. EPS typically has a 4.0 R-Value per inch of thickness, and is capable of being recycled into new EPS products. The polystyrene structure of EPS contains larger gaps of air. This allows it to absorb and release great amounts of water easily. In addition to its susceptibility to water absorption, it's also vulnerable to pest and installation damage. The EPS Industry Alliance has published many technical bulletins as available resources.

One of those bulletins is a case study completed in 2008. The study focuses on the R-Value retention differences between EPS and XPS. After being installed continuously for 15 years, EPS Type I and XPS Type X test samples were excavated from the exterior of a commercial building in St. Paul, MN, situated approximately 6 feet below grade. Both samples were tested using ASTM C518. Results showed EPS Type I still provided 94% of its R-value, reducing to R3.38 from the original R3.6; meanwhile the XPS Type X decreased its R-value to 52% with a 25 percent performance drop, reducing to R2.6 from the original R5.0.

Image 1: XPS (left) and EPS (right) samples before being excavated.

XPS: Extruded Polystyrene Foam

In comparison to EPS, XPS is resistant to water absorption, pests, and installation damage. XPS typically has a 5.0 R-Value per inch of thickness except for types VII and XIII. The polystyrene structure of XPS contains smaller gaps of styrene. This allows it to retain more absorbed water, but lesser amounts absorbed overall. Its greater density and weight provides a higher compressive strength, making it useful in structural applications such as supporting overburden and vehicular traffic on tunnel lids. XPS has a higher cost and global warming potential due to the hydrofluorocarbon blowing agents. Its coatings make it difficult to recycle. The Extruded Polystyrene Foam Association is an additional resource for technical information.

A study of in situ EPS and XPS moisture absorption for foundation wall applications was conducted by the University of Alaska. This multi-year study compared insulating materials that had been in place for over twenty years. The evaluation included previously and newly extracted samples.

The results emphasize that EPS absorbs more water over time when compared to XPS. Since water is a good conductor of heat, its infiltration into insulation diminishes the insulation's effective R-value.

Standards

ASTM C578 provides a classification system for cellular polystyrene boards. EPS has the following classification types: I, II, VIII, IX, XIV, and XV. XPS has the following classification types: IV, V, VI, VII, X, XII, and XIII. EPS Type VIII and IX, and XPS Type VI, VII, XII, and XIII, are commonly preferred for below-grade foundation wall insulation applications. Product selections made with this standard will specify the physical performance criteria. Physical requirements include thermal resistance, compressive resistance, flexural strength, water vapor permeance, water absorption, dimensional stability, and oxygen index specified.

Table 1: Water Absorption by Total Immersion Over Time

Region, Method	Immersion Period	Water Absorption max. % by vol.	
		EPS Types 2/II & denser***	XPS most Types
USA, ASTM C578	**1 day** (ASTM C272)	2-3	**0.3-1**
Canada, CAN/ULC-S701	**4 days** (ASTM D2842)	2-4	**0.7** (Type 4)
Europe, EN13164	**28 days** (EN12087)	3	1.5
Worldwide, Long-Term Studies[13]	**2-3 years**	**3-7**	**2-5.5**

*** Since EPS is available at lower densities than XPS, results for EPS Types with min. densities of less than 19kg/m³ [1.2PCF] are omitted

Summary

Buildings are comprised of systems and assemblies. Products and materials must be compatible and sufficiently integrate into those systems and assemblies to support performance. Building performance goals are dependent on the project and its typology. Different projects will require different systems and assemblies. With that caveat in mind, products and materials are not wholly bad nor good, only bad or good for the project applications and circumstances.

EPS might be more suitable for projects if high compressive strength isn't necessary, as is often the case in residential or light commercial buildings.

XPS insulation's superior resistance to moisture absorption and dimensional stability may make it a preferable choice for long-term performance in locations characterized by high water tables or frequent moisture exposure, as well as temperature fluctuations.

In the situation of selecting below grade insulation, the selection should be dependent on the project performance goals and the insulation roles and relations to its adjacent materials. Gaps and holes in the insulation will allow for passage of water to the foundations regardless of insulation type. Well-designed drainage, utilizing freely draining backfill and foundation drains that lead to open air, will move bulk water away from the insulation and minimize water retention and material degradation.

13. Moisture Behavior of Polystyrene Insulation in Below-Grade Application, S. Cai, B. Zhang, L. Cremaschi, Energy and Buildings 159 (2018), 24-38.