EPS vs. XPS - Water Absorption

Insulation is an essential component of the building envelope which impacts both occupant comfort and energy efficiency. Specifying insulation which has consistent long-term thermal performance is essential. During the insulation's service life, it experiences fluctuations in moisture and temperature which can result in performance reduction and an increase in overall building energy consumption.

Expanded Polystyrene (EPS) and Extruded Polystyrene (XPS) are two types of rigid insulation which are commonly used to insulate walls, roofs, foundations, concrete slabs, etc. EPS is manufactured by expanding spherical beads in a mold using heat and pressure to fuse the beads together. XPS is manufactured via continuous extrusion process, with a blowing agent, at high temperature and pressure.

Water is able to absorb and transfer heat very well, and the presence of water inside the insulation diminishes the thermal resistance of the material. The amount of trapped moisture inside the structure of the insulation is inversely proportional to its thermal performance (R-Value) and as such, it is important to either keep the moisture out or allow it to quickly escape. This becomes important for below grade applications where the frequency of moisture coming into contact with insulation is much greater and overall drying potential is more limited.

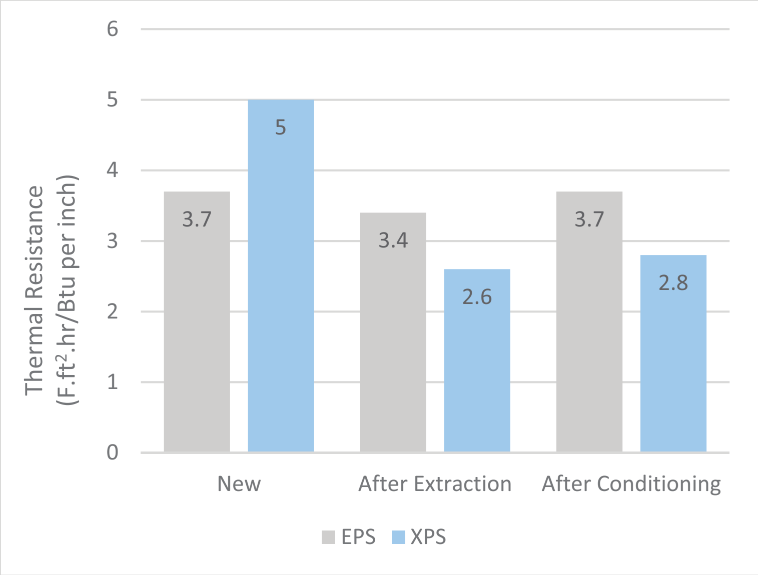
Current Standard Testing

The current industry standard testing for polystyrene rigid insulation products for water absorption are ASTM C578[1] and CAN/ULC S701[2]. Testing XPS under these protocols is shown to have lower water absorption and as such one would expect it to retain a higher R-value. The standard testing methodology utilizes a small sample size of 12x12" (305x305mm) with a thickness of 1" or 2" (25mm or 51mm). The samples are then fully submerged in a container of water for a period of up to 96 hours after which the samples are measured for water absorption by volume. This test is indicative of short-term water absorption but does not provide an accurate representation of what in-service, long term performance might be.

The testing methodology for these standards was developed as a measure for product performance, evaluation and quality control, but does not act as a good measure for real life performance. In-situ performance of the insulation after a period of time would show a difference in water absorption levels and thus potentially degraded thermal performance.

Long-term In-service Testing

Long term testing of EPS and XPS samples was performed by Element Materials Technology (Stork Twin City Testing), an accredited testing laboratory, by installing 2" (51mm) of Type I (1.0 lb/ft^3 (16 kg/m^3)) EPS and Type X (1.6 lb/ft^3 (26 kg/m^3)) XPS on concrete foundation wall in St. Paul, Minnesota (in 1993)[3]. The foundation wall was part of a full height basement with conditioned space on the interior. The boards were affixed without the use of additional adhesives and backfilled with native soils. The area near the building was subjected to typical local weather conditions.



Stork Twin City laboratory thermal resistance testing results

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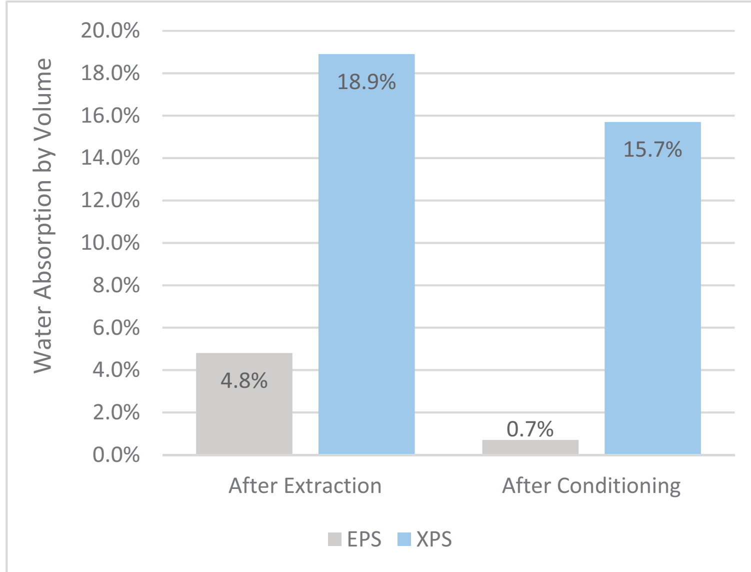
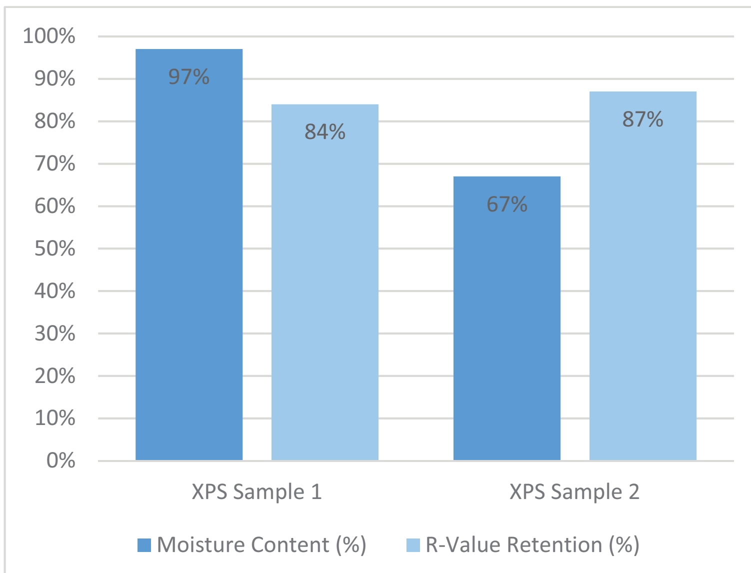
After a period of 15 years, the boards were dug out and 12x12" (305x305mm) samples from a depth of roughly 6' (1.8m) were extracted and immediately measured. It was found that XPS had 18.9% water absorption while EPS was only at 4.8%. This translated into a retention of only 52% of XPS's initial R-value while EPS retained 94% of it. After conditioning the samples for 30 days (at 72°F (22°C) and 50% RH), EPS has reached 0.7% moisture (by volume) while XPS dropped to 15.7%. Both the moisture content and thermal resistance values of the XPS samples would not pass the ASTM C578 to qualify as Type X boards.



Stork Twin City laboratory water absorption testing results

Another 15 year in-situ testing was conducted by the US department of Energy's Oak Ridges National Laboratory (ORNL) with final report released in 2012[4]. Several types of exterior insulation, including a 2" (51mm) XPS, were installed below grade (and above grade) in 1991 and were dug up in 2006 for testing. The samples were installed to a typical full basement height and the interior space of the basement was heated during the winter months.

After extraction, the XPS boards installed below grade had 67% higher moisture content when compared to the same boards when installed above grade. Below grade XPS boards were able to retain only 84% of their initial R-value. It took XPS samples 3 months to fully dry out. In addition, to maintain the thermal performance, XPS is greatly dependent on the moisture load in the adjacent soil and thus proper drainage is crucial for its performance.



Oak Ridges National Laboratory moisture content and R-Value retention results

Drying Potential

The same cell structure that allows XPS to have low short-term water absorption also causes it to retain more moisture in the long run. Although it takes moisture a long time to accumulate within the material, it also takes a long time to dry out due to the limited drying potential of the material. XPS has higher capillary suction forces, these capillary suction forces with the smaller pore sizes are much stronger than gravity and prevent moisture from draining out of the XPS to the water table[4]. Drying through vapor diffusion is also quite limited with the majority of XPS types at 2" (51mm) thickness landing below the vapor barrier threshold[5,6].

These factors contribute to slow drying time which could be as high as three months[4]. For below grade applications, the combination of environmental cycling and the long drying periods does not provide XPS with a sufficient amount of time

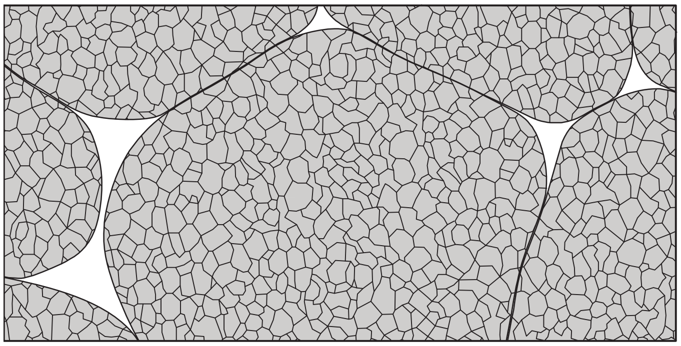
[1] *ASTM C578-18, Standard Specification for Rigid, Cellular Polystyrene Thermal Insulation*, ASTM International, West Conshohocken, PA, 2018, www.astm.org

[2] *CAN/ULC-S701.1, Standard for Thermal Insulation, Polystyrene, Boards and Pipe Covering*, Standards Council of Canada, Ottawa, ON, 2017, www.scc.ca

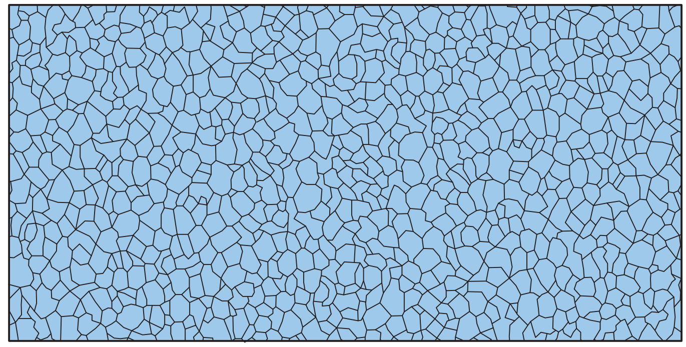
[3] *15-Year In-Situ Research Shows EPS Outperforms XPS in R-Value Retention*. 2008, Retrieved https://www.epsindustry.org/

[4] Kehrer, Manfred, & Christian, Jeff. *Measurement of Exterior Foundation Insulation to Assess Durability in Energy-Saving Performance*. United States. doi:10.2172/1050900. Retrieved http://www.tbcca.com/images/professionals/SGI/techdata/US%20Dept%20Energy%20XPS.pdf

to dry causing a net gain of moisture. EPS absorbs moisture more quickly but its high vapor permeance allows moisture to dry out over time. This permits EPS to maintain its thermal performance over a long period of time.



Expanded Polystyrene (EPS) foam cell structure (25x)



Extruded Polystyrene (XPS) foam cell structure (25x)

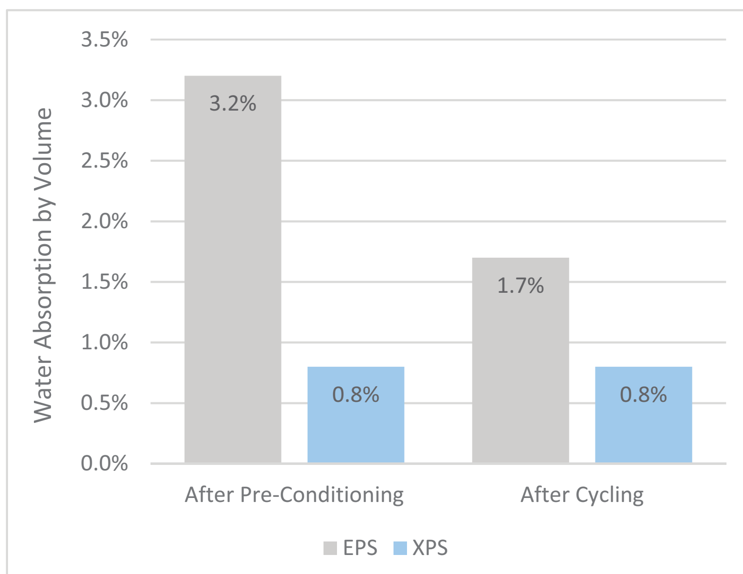
Freeze-Thaw Resistance

The low thermal conductivity gas used in the XPS manufacturing process escapes over time as the boards slowly come to an equilibrium with the environment. This phenomenon is reflected with the need to disclose Long Term Thermal Resistance (LTTR) value by the XPS industry. Since the current testing standards do not provide an accurate representation of actual water absorption performance over time an alternative standard should be used to show the long term performance and impact on thermal performance.

One test method which was developed to demonstrate long term thermal performance for building insulation is ASTM 1512[7]. This standard was developed specifically for freeze-thaw testing for insulation products as opposed to other materials such as concrete. Utilizing this protocol, Intertek Testing Services laboratory[8] has tested 1" (25mm) samples of EPS Type I, II and IX (equivalent to Type 1,2 and 3) and XPS Type X. The samples were pre-conditioned for 28 days to allow for artificial moisture ingress into the samples.

The next step was to temperature cycle the samples over 20 days to simulate common field exposure conditions (ranging from -15°C to 15°C (5°F to 59°F)). XPS showed 0.8% water absorption during the pre-conditioning stage (by volume) and 0.8% after cycling while EPS samples absorbed more moisture, ranging from 2.1-4.7% but also have lost more moisture (0.5-2% respectively) after the cycling period.

Based on this testing, it is evident that in the long run, EPS does not absorb excessive amounts of moisture. Furthermore, even during freeze-thaw conditions, EPS is able to dry, allowing it to maintain its compressive strength and thermal performance[9].



Intertek Testing Services laboratory water absorption testing results

[5] Vapor barrier defined as 60ng/Pa.s.m^2 (1.05 perms) in section 9.25.4.2. (1) of the National Building Code of Canada 2015 (NBC).

[6] Class II vapor retarder defined as 57ng/Pa.s.m^2 (1 perm) by the International Building Code (IBC) and International Residential Code (IRC)

[7] ASTM C1512-10(2015)e1, *Standard Test Method for Characterizing the Effect of Exposure to Environmental Cycling on Thermal Performance of Insulation Products*, ASTM International, West Conshohocken, PA, 2015.

[8] *Drying Potential of Polystyrene Insulations Under Extreme Environmental Cycling Conditions*. 2014, Retrieved https://www.epsindustry.org/

[9] *Freeze-Thaw Cycling Tests Show No Loss of R-Value or Strength*. 2008, Retrieved https://www.epsindustry.