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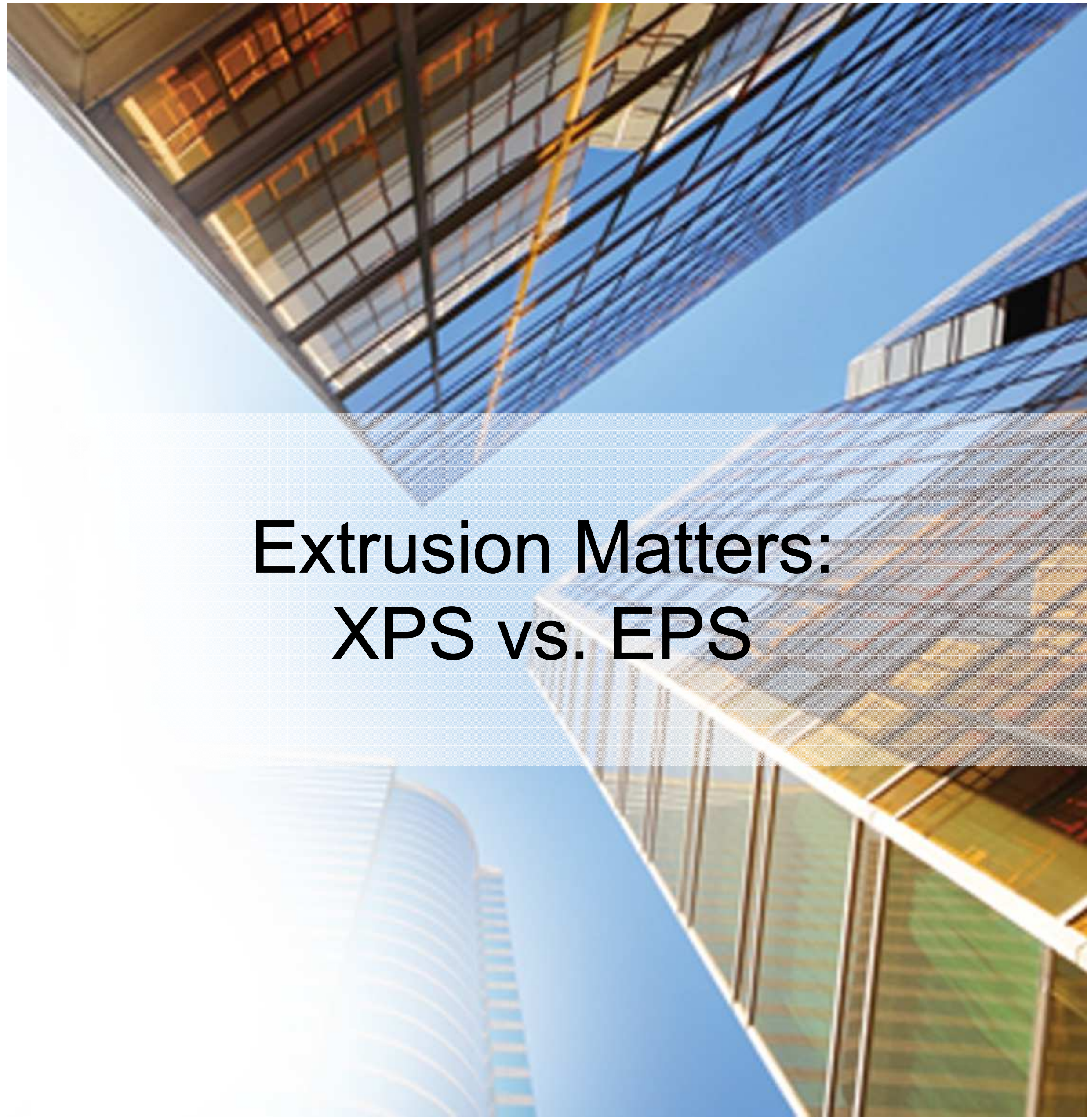

Extrusion Matters: XPS vs. EPS

Extrusion Matters: XPS vs. EPS

Presented by: Owens Corning
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Description: Extruded polystyrene (XPS) and expanded polystyrene (EPS) are both types of rigid foam plastic insulation; their different manufacturing processes produce wide-ranging performance attributes, especially in water absorption and R-value. This course discusses the negative impact of water absorption on R-value and structural integrity; explains why codes and standards are sometimes specific in requiring XPS in applications where prolonged exposure to water occurs; and concludes with a look at best specification practices for accurate bids.

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Purpose and Learning Objectives

Purpose: Extruded polystyrene (XPS) and expanded polystyrene (EPS) are both types of rigid foam plastic insulation; their different manufacturing processes produce wide-ranging performance attributes, especially in water absorption and R-value. This course discusses the negative impact of water absorption on R-value and structural integrity; explains why codes and standards are sometimes specific in requiring XPS in applications where prolonged exposure to water occurs; and concludes with a look at best specification practices for accurate bids.

Learning Objectives:

At the end of this program, participants will be able to:

- identify the physical differences between XPS and EPS rigid polystyrene insulation materials
- restate code and standard differences regarding the performance of XPS versus EPS
- discuss water absorption differences and the impact on the energy efficiency properties of EPS versus XPS, and
- describe best specification practices for rigid polystyrene insulation materials to produce accurate project bids.

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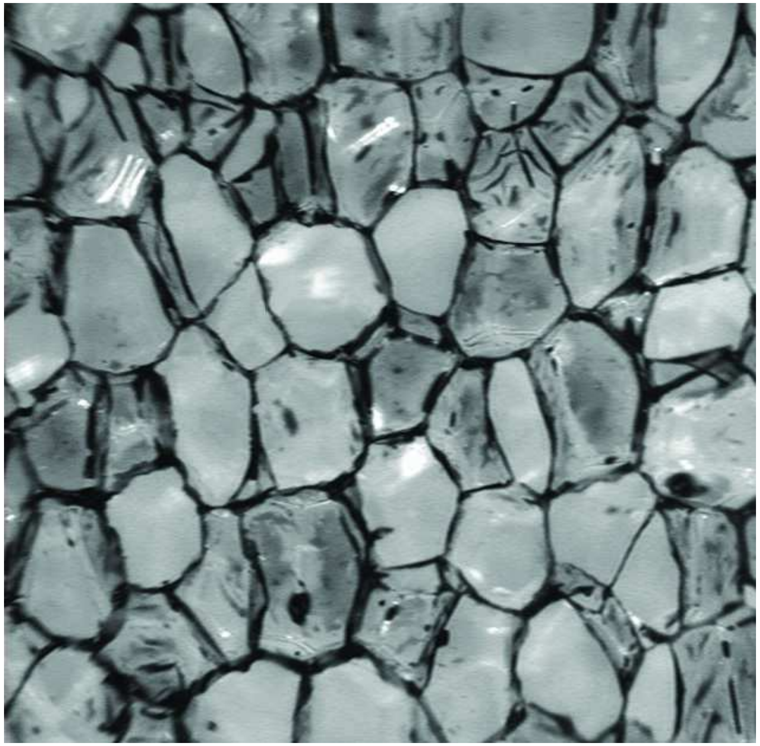
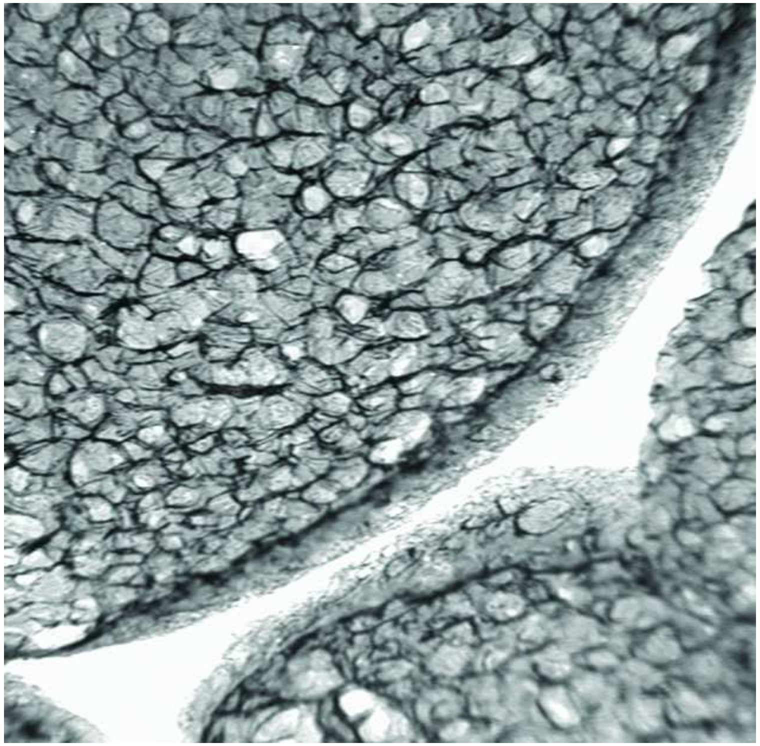


XPS



EPS

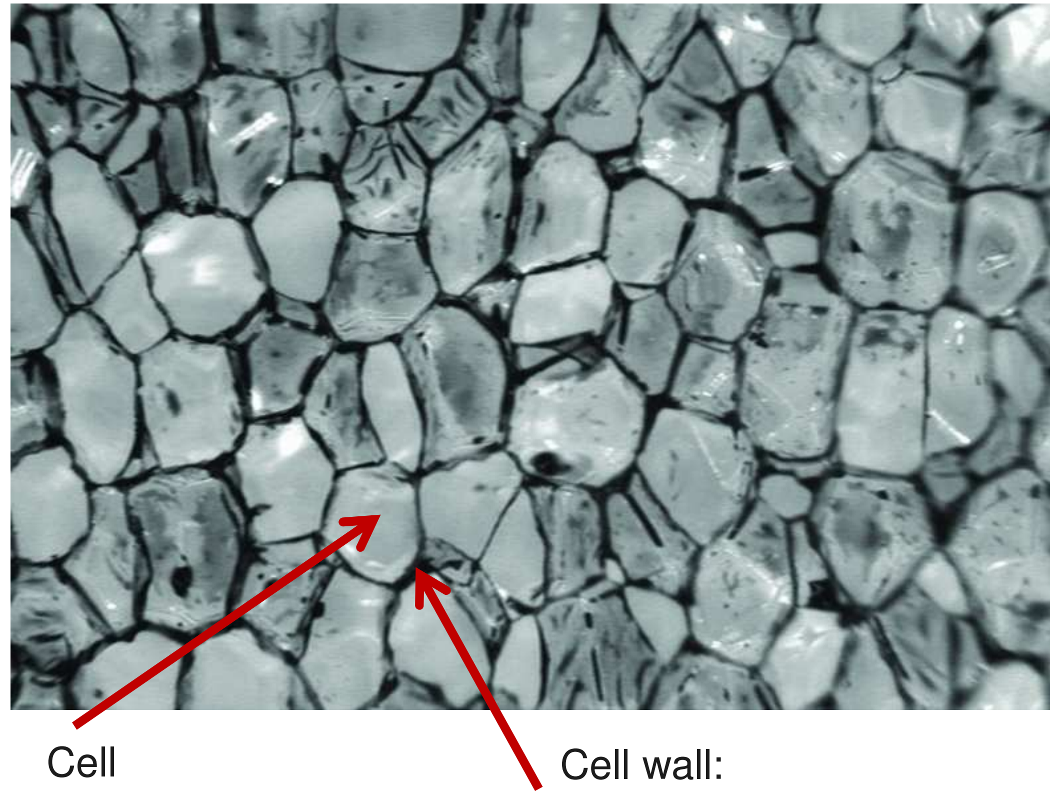
XPS vs. EPS

Polystyrene Insulation Types

Polystyrene is a hydrophobic polymer that repels water. There are two types of rigid polystyrene foam plastic insulation that are produced using different manufacturing processes:

- Extruded (XPS)
- Expanded (EPS)

XPS is manufactured in a continuous extrusion process that produces a homogeneous, closed-cell cross-section. Each cell is fully enclosed by polystyrene walls; therefore, very little water can be absorbed into the cell.

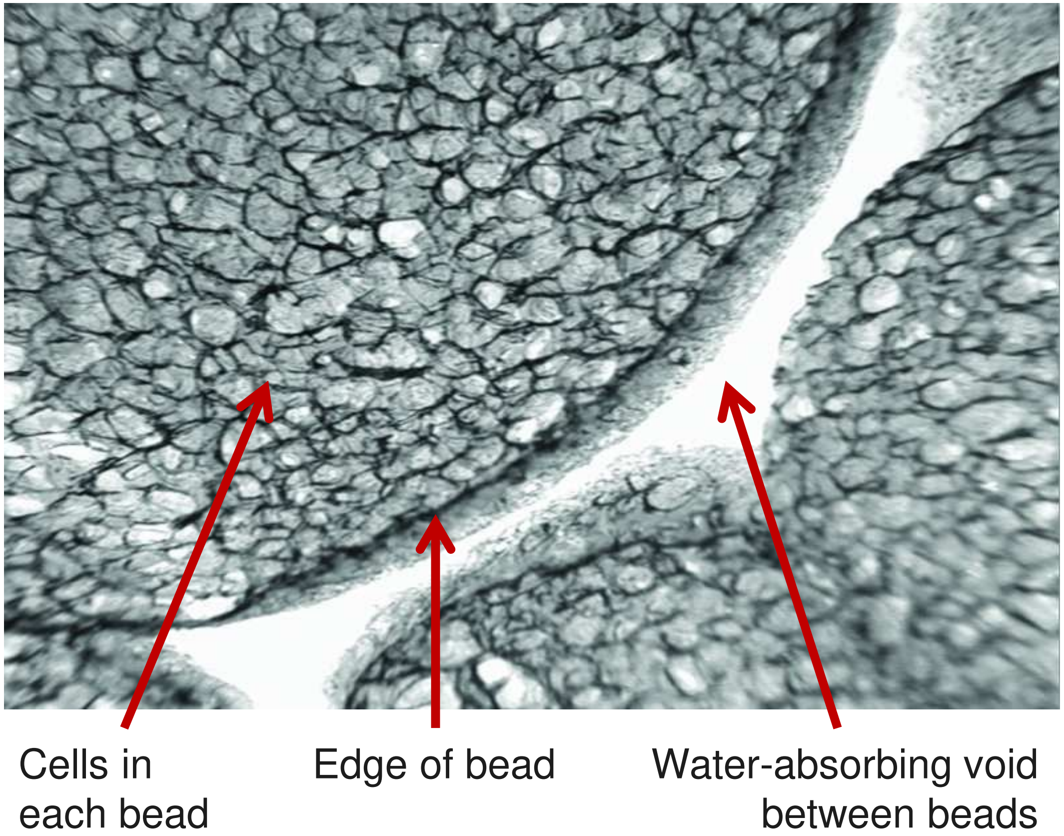


Polystyrene Insulation Types

EPS is manufactured by expanding spherical beads in a mold, using heat and pressure to fuse the beads together where they touch, and leaving voids between the beads where they don't touch.

While each individual bead is a closed-cell environment, there are significant open spaces between each bead where water may enter.

EPS is suitable for a variety of applications, but where water absorption is a concern, it is important to realize how EPS and XPS are different.



Polystyrene Insulation Standards and Applications

Although both types are composed of polystyrene, the two types of manufacturing processes produce finished products with very different performance properties. Both types are manufactured to meet the physical property specifications of:

- ASTM C578, “Standard Specification for Rigid, Cellular Polystyrene Thermal Insulation”
- ASTM D6817, “Standard Specification for Rigid Cellular Polystyrene Geofoam,” and
- AASHTO M230, “Standard Specification for Extruded Foam Board (Polystyrene).”

The standards are the basis of design for a variety of construction insulation applications for both building and geo-technical polystyrene foam or “geofoam.” For any type of construction, it is important that the rigid insulation chosen for the use possesses properties that are suitable for the application.

That is particularly critical when rigid insulation will be exposed to water, as in protected membrane roofing, or in below-grade uses including foundations, frost-protected shallow foundations, and geotechnical applications such as under pavement and lightweight fill applications.

ASTM C578

ASTM C578 defines all properties and ensures uniform product standards. Below is a portion of the chart that includes the main properties (gray columns=XPS; white=EPS).

Polystyrene Board Type	EPS	EPS	EPS	XPS	EPS	XPS	EPS	XPS	EPS	XPS	EPS	XPS
ASTM C578 Classification	Type XI	Type I	Type VIII	Type X	Type II	Type IV	Type IX	Type VI	Type XIV	Type VII	Type XV	Type V
Compressive resistance at yield or 10% deformation, whichever occurs first (with skins intact) min., psi (kPa)	5.0 (35)	10.0 (69)	13.0 (90)	15.0 (104)	15.0 (104)	25.0 (173)	25.0 (173)	40.0 (276)	40.0 (276)	60.0 (414)	60.0 (414)	100.0 (690)
Density, min., lb/ft^3 (kg/m^3)	0.70 (12)	0.90 (15)	1.15 (18)	1.30 (21)	1.35 (22)	1.55 (25)	1.80 (29)	1.80 (29)	2.40 (38)	2.20 (35)	2.85 (46)	3.00 (48)
Thermal resistance of 1.00-in. (25.4-mm) thickness, min., $hr•ft^2•°F/Btu$ ($K•m^2/W$) Mean temperature: 75.2° (24.1°C)	3.10 (0.55)	3.60 (0.63)	3.80 (0.67)	5.00 (0.88)	4.00 (0.70)	5.00 (0.88)	4.20 (0.74)	5.00 (0.88)	4.20 (0.74)	5.00 (0.88)	4.30 (0.76)	5.00 (0.88)
Flexural strength, min., psi (kPa)	10.0 (70)	25.0 (173)	30.0 (208)	40.0 (276)	35.0 (240)	50.0 (345)	50.0 (345)	60.0 (414)	60.0 (414)	75.0 (517)	75.0 (517)	100.0 (690)
Water vapor permeance of 100-in. (25.4-mm) thickness, max., perm ($ng/Pa•s•m^2$)	5.0 (287)	5.0 (287)	3.5 (201)	1.5 (86)	3.5 (201)	1.5 (86)	2.5 (143)	1.1 (63)	2.5 (143)	1.1 (63)	2.5 (143)	1.1 (63)
Water absorption by total immersion, max., volume	4.0	4.0	3.0	0.3	3.0	0.3	2.0	0.3	2.0	0.3	2.0	0.3

ASTM C578

The portion of the chart shown here highlights two properties that this course will focus on: R-value and water absorption.

Polystyrene Board Type	EPS	EPS	EPS	XPS	EPS	XPS	EPS	XPS	EPS	XPS	EPS	XPS
ASTM C578 Classification	Type XI	Type I	Type VIII	Type X	Type II	Type IV	Type IX	Type VI	Type XIV	Type VII	Type XV	Type V
Thermal resistance of 1.00-in. (25.4-mm) thickness, min., hr•ft^2 •°F/Btu (K•m^2/W) Mean temperature: 75.2° (24.1°C)	3.10 (0.55)	3.60 (0.63)	3.80 (0.67)	5.00 (0.88)	4.00 (0.70)	5.00 (0.88)	4.20 (0.74)	5.00 (0.88)	4.20 (0.74)	5.00 (0.88)	4.30 (0.76)	5.00 (0.88)
Water absorption by total immersion, max., volume	4.0	4.0	3.0	0.3	3.0	0.3	2.0	0.3	2.0	0.3	2.0	0.3

The industry standards separate EPS and XPS types so that important physical property differences like water absorption can be identified for specification purposes. XPS always has a maximum allowed water absorption of 0.3, while EPS ranges from 2.0 to 4.0.

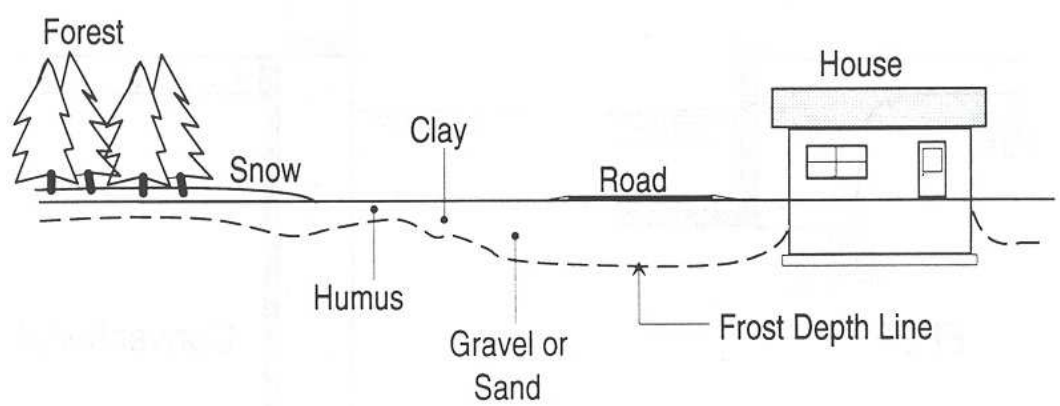
EPS R-value per inch varies with density because the higher the density, the smaller the spaces between beads, which results in a slightly higher R-value. XPS is a uniform 5 per inch regardless of density because the XPS cell structure is closed, so R-value is uniform and reliable.

XPS and EPS in Building and Design

Polystyrene Insulation and Building Codes

Design standards and building codes can be very specific in requiring XPS rather than EPS, reinforcing the fact that there are differences between the two.

A shallow foundation does not extend below the frost line, and has insulation around it to capture heat from the earth and prevent the frost line from achieving its normal depth. It essentially raises the frost line; therefore, it is called a frost-protected shallow foundation, or FPSF.



2012 IRC Table R403.3(1)

In order to maintain the structural integrity of a building for the life of the building, the building code has to be certain that frost has been adequately protected against. This is the International Residential Code prescriptive design table for frost-protected shallow foundations. Footnotes a–e are on the following slide.

Minimum Footing Depth and Insulation Requirements for Frost-Protected Footings in Heated Buildings [a]

Air Freezing Index (°F-days) [b]	Minimum Footing Depth, D (inches)	Vertical Insulation R-Value [c,d]	Horizontal Insulation R-Value [c,e]		Horizontal Insulation Dimensions per Figure R403.3(1) (inches)		
			Along walls	At corners	A	B	C
1,500 or less	12	4.5	Not required	Not required	Not required	Not required	Not required
2,000	14	5.6	Not required	Not required	Not required	Not required	Not required
2,500	16	6.7	1.7	4.9	12	24	40
3,000	16	7.8	6.5	8.6	12	24	40
3,500	16	9.0	8.0	11.2	24	30	60
4,000	16	10.1	10.5	13.1	24	36	60

2012 IRC Table R403.3(1) Footnotes

Table R 403.3 (1)

For SI: 1 inch = 25.4 mm, °C = [(°F) - 32]/1.8.

a. Insulation requirements are for protection against frost damage in heated buildings. Greater values may be required to meet energy conservation standards.

b. See Figure R403.3(2) or Table R403.3(2) for Air Freezing Index values.

c. Insulation materials shall provide the stated minimum R-values under long-term exposure to moist, below-ground conditions in freezing climates. The following R-values shall be used to determine insulation thicknesses required for this application:

- Type II expanded polystyrene: 2.4R per inch
- Type IV extruded polystyrene: 4.5R per inch
- Type VI extruded polystyrene: 4.5R per inch
- Type IX expanded polystyrene: 3.2R per inch
- Type X extruded polystyrene: 4.5R per inch

d. Vertical insulation shall be expanded polystyrene insulation or extruded polystyrene insulation.

e. Horizontal insulation shall be extruded polystyrene insulation.

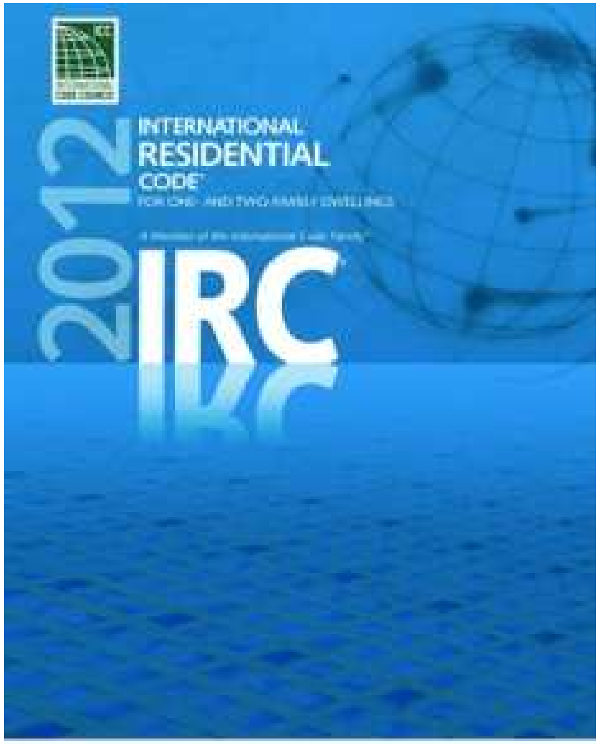
IRC: Polystyrene Insulation and FPSF

Two of the footnotes bear a closer look.

e. Horizontal insulation shall be extruded polystyrene insulation.

In the critical horizontal application where there will be maximum exposure to water, preserving the structural integrity of the building relies on preserving the ability of the insulation to insulate below-grade for the life of the building.

Recognizing the differences in water absorption properties between XPS and EPS, XPS is named in the code.



IRC: Polystyrene Insulation and FPSF

c. Insulation materials shall provide the stated minimum R-values under long-term exposure to moist, below-ground conditions in freezing climates. The following R-values shall be used to determine insulation thicknesses required for this application:

- **EPS Type II: 2.4R per inch**
- **XPS Type IV: 4.5R per inch**
- **XPS Type VI: 4.5R per inch**
- **EPS Type IX: 3.2R per inch**
- **XPS Type X: 4.5R per inch**

This footnotes acknowledges the moisture sensitive nature of the FPSF and specifies the long-term R-value that shall be used for each material with a built-in safety factor.

IRC: Polystyrene Insulation and FPSF

Compare the R-values on the prior slide with the ASTM C578 table.

Polystyrene Board Type	EPS	EPS	EPS	XPS	EPS	XPS	EPS	XPS	EPS	XPS	EPS	XPS
ASTM C578 Classification	Type XI	Type I	Type VIII	Type X	Type II	Type IV	Type IX	Type VI	Type XIV	Type VII	Type XV	Type V
Thermal resistance of 1.00-in. (25.4-mm) thickness, min., hr•ft^2 •°F/Btu (K•m^2/W) Mean temperature: 75.2° (24.1°C)	3.10 (0.55)	3.60 (0.63)	3.80 (0.67)	5.00 (0.88)	4.00 (0.70)	5.00 (0.88)	4.20 (0.74)	5.00 (0.88)	4.20 (0.74)	5.00 (0.88)	4.30 (0.76)	5.00 (0.88)

Even though XPS Types IV, VI, and X are recognized as having 5R per inch, the code requires only 4.5R per inch long-term, building in a 10% safety factor.

EPS Type II is prescribed at 2.4R, and IX is 3.2R per inch. Much larger safety factors are built in here: 40% for Type II and 24% for Type IX.

The importance of maintaining R-value below grade in the presence of intermittent ground water and freeze/thaw cycles results in the IRC adding in a larger safety factor for EPS, to protect the stability of the structure for its lifetime.

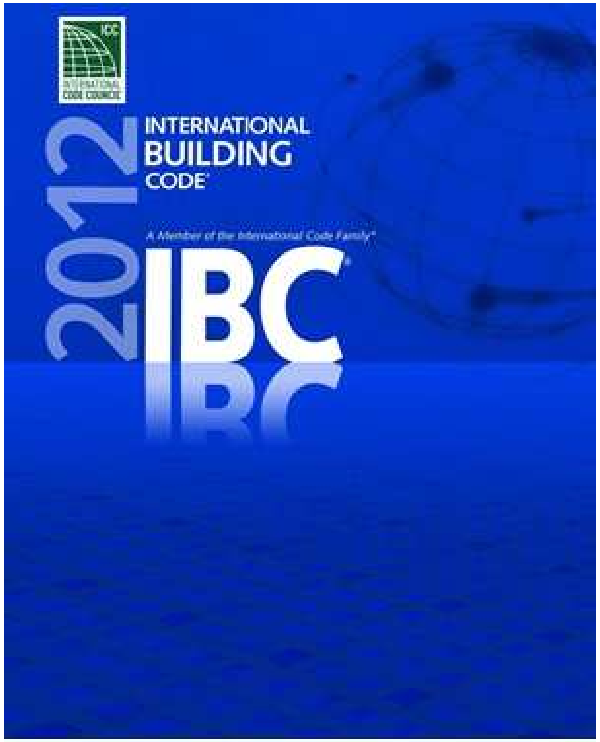
IBC: Polystyrene Insulation and FPSF

The International Building Code is similar to the Residential Code in frost-protected shallow foundations.

1809.5 Frost protection.

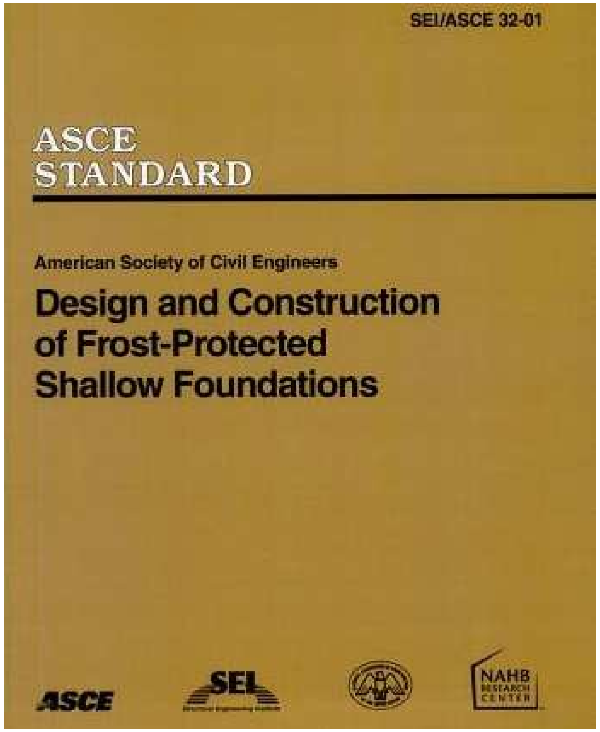
Except where otherwise protected from frost, foundations and other permanent supports of buildings and structures shall be protected from frost by one or more of the following methods:

1. Extending below the frost line of the locality;
2. Constructing in accordance with ASCE 32; or
3. Erecting on solid rock.



ASCE: Polystyrene Insulation and FPSF

The American Society of Civil Engineers' ASCE 32 is the consensus standard for frost-protected shallow foundations and contains the same provisions just described in the International Residential Code, differentiating between EPS and XPS.

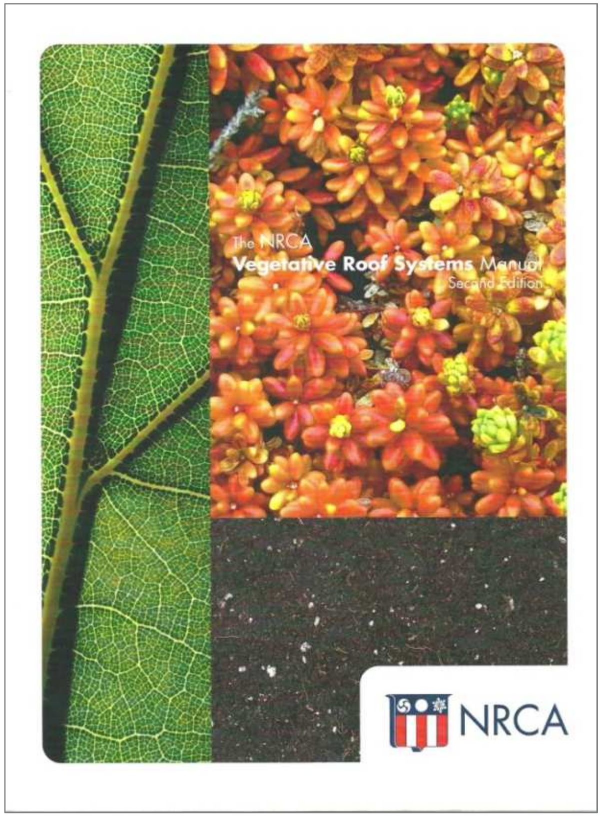


NRCA: Polystyrene Insulation and Green Roofs

We now move from foundations to the roof.

A vegetative roof system consists of an inverted, protected roof membrane assembly. The insulation is above the waterproofing membrane, so is exposed to water.

The National Roofing Contractors Association publishes a manual called the “Vegetative Roof Systems Manual,” describing the prescriptive design standards for vegetative green roofs.

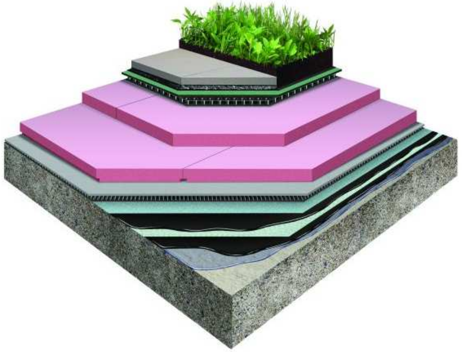


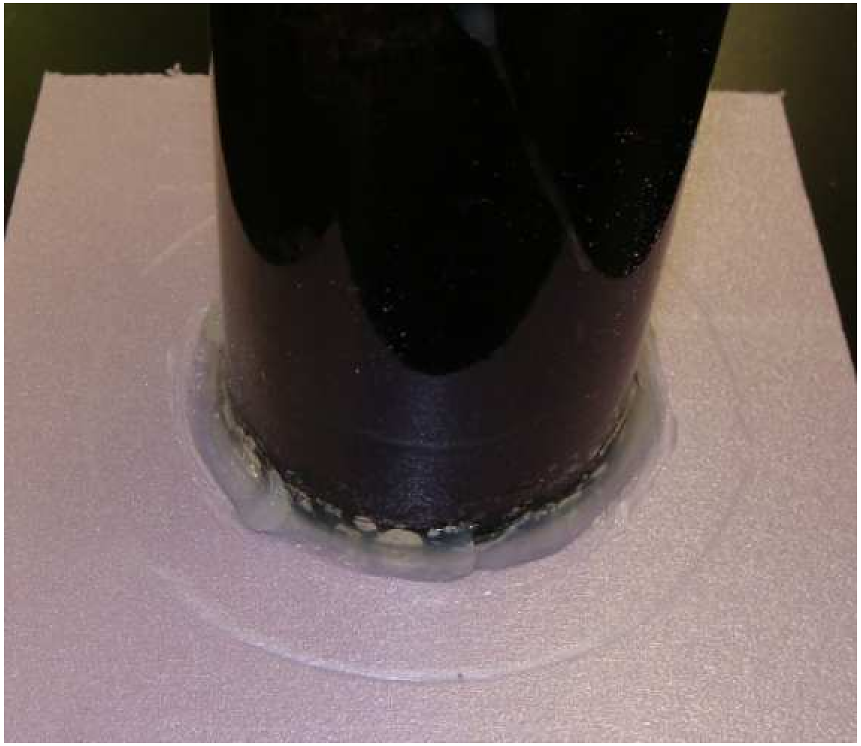
NRCA: Polystyrene Insulation and Green Roofs

In regards to moisture-resistant insulation, the manual states:

> "NRCA recommends XPS insulation be used as the thermal insulating material for vegetative roof systems..."
>
> "…EPS is sometimes used as fill material, not as the primary insulating material…"
>
> "If EPS is used…EPS will retain water, and, therefore, the additional weight should be accounted for when determining the total dead load of the system." (p. 46)

EPS is a viable insulation material and is appropriate for many applications. However, it is important to recognize its differences from XPS and account for them when using EPS.





XPS

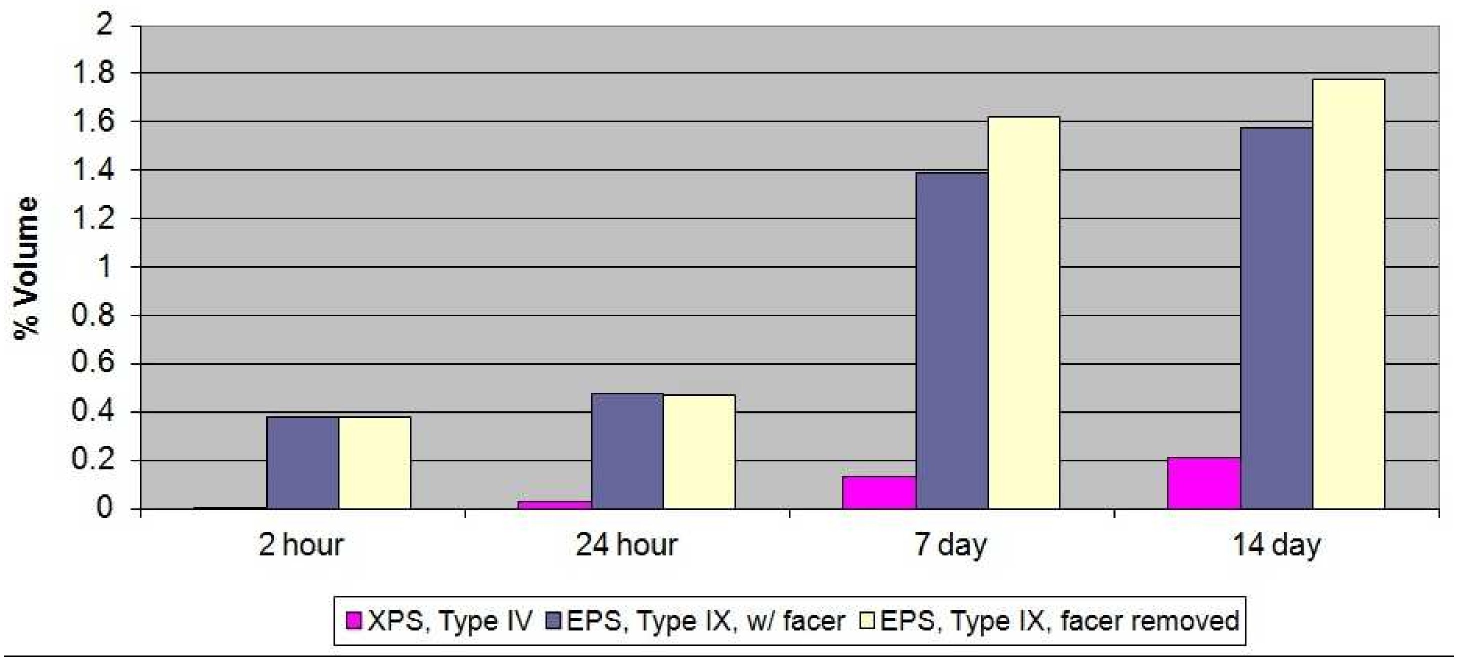
EPS

Water-Absorption Properties of XPS and EPS

Industry Mandated Testing

Both ASTM C578 and AASHTO M230 (for highway applications) require water absorption testing in accordance with ASTM C272, “Standard Test Method for Water Absorption of Core Materials for Sandwich Constructions.”

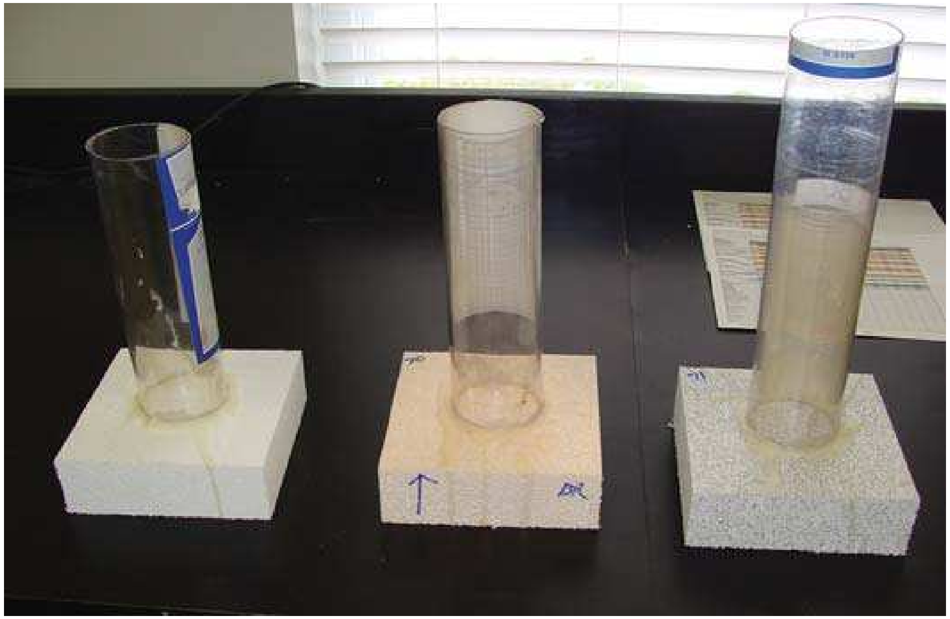
The test method requires that samples be fully immersed in water, so the results serve as a point of comparison for how different materials react to immersion. Water absorption is measured at 2 hours, 24 hours, 7 days, and 14 days. As shown in the table, XPS absorbs far less water than EPS does.



Capillary Action and Wicking

What if the boards are on foundations and are not fully immersed? Does EPS absorb moisture if it is not sitting in a pool of water?

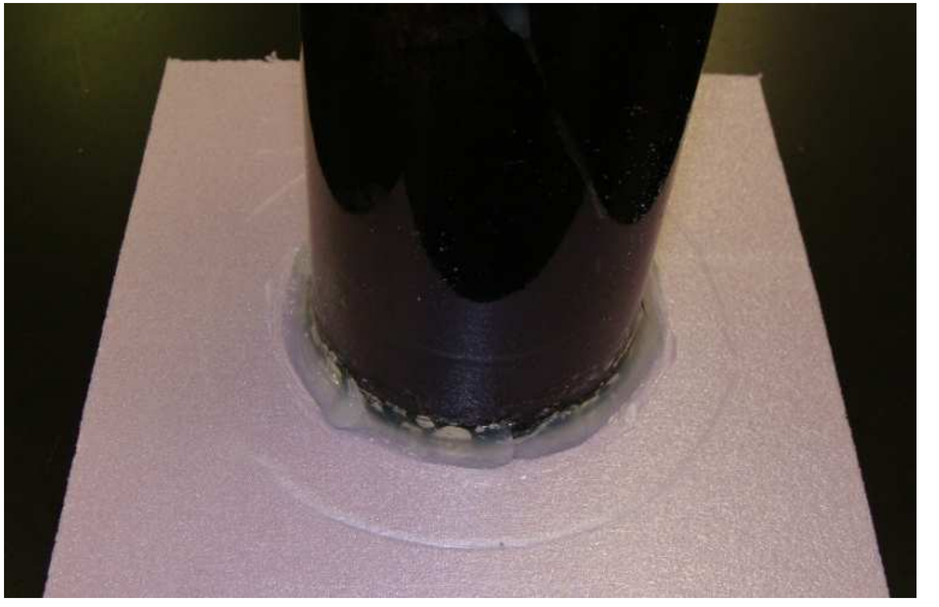
These photos demonstrate what happens when columns of colored water are sealed over three different densities of EPS. With only a small surface area of EPS exposed to the water column, the colored water traveled by capillary action through voids in the EPS, then wicked throughout the entire sample over the span of several hours.



Capillary Action and Wicking

Using the same method, the XPS showed no water movement into or through its closed-cell structure, neither by capillary action nor by wicking.

This demonstration again illustrates the important water absorption differences that result from the open-cell structure of EPS compared to the closed-cell structure of XPS.



XPS

Water Absorption in Actual Below-Grade Contact

Although laboratory test data enables controlled and repeatable comparisons, it is useful to compare EPS and XPS in ad-hoc ground contact experiments to support the differences found in the lab.

Samples of XPS and EPS were buried and exposed to ambient ground water. After three weeks, the samples were tested. Results show that the EPS samples quickly absorbed the ground water, while the XPS samples absorbed virtually no water through the three weeks. The table below illustrates the water absorption differences between EPS and XPS.

Water Absorption, Limited Ground Contact

Sample	Density (pcf)	Water Absorption (% volume)		
		Week 1	Week 2	Week 3
EPS	1.62	1.77	3.50	3.57
EPS	2.71	0.86	0.65	0.88
XPS	1.60	0.0	0.0	0.0

Below-Grade Freeze/Thaw Resistance

Wet soil and below-grade insulation is subject to dozens—if not hundreds—of freeze/thaw cycles each winter.

When EPS absorbs that water into its voids, frozen expansion further breaks down the bonds between the beads and opens up the EPS structure to even more water intrusion during the next cycle.

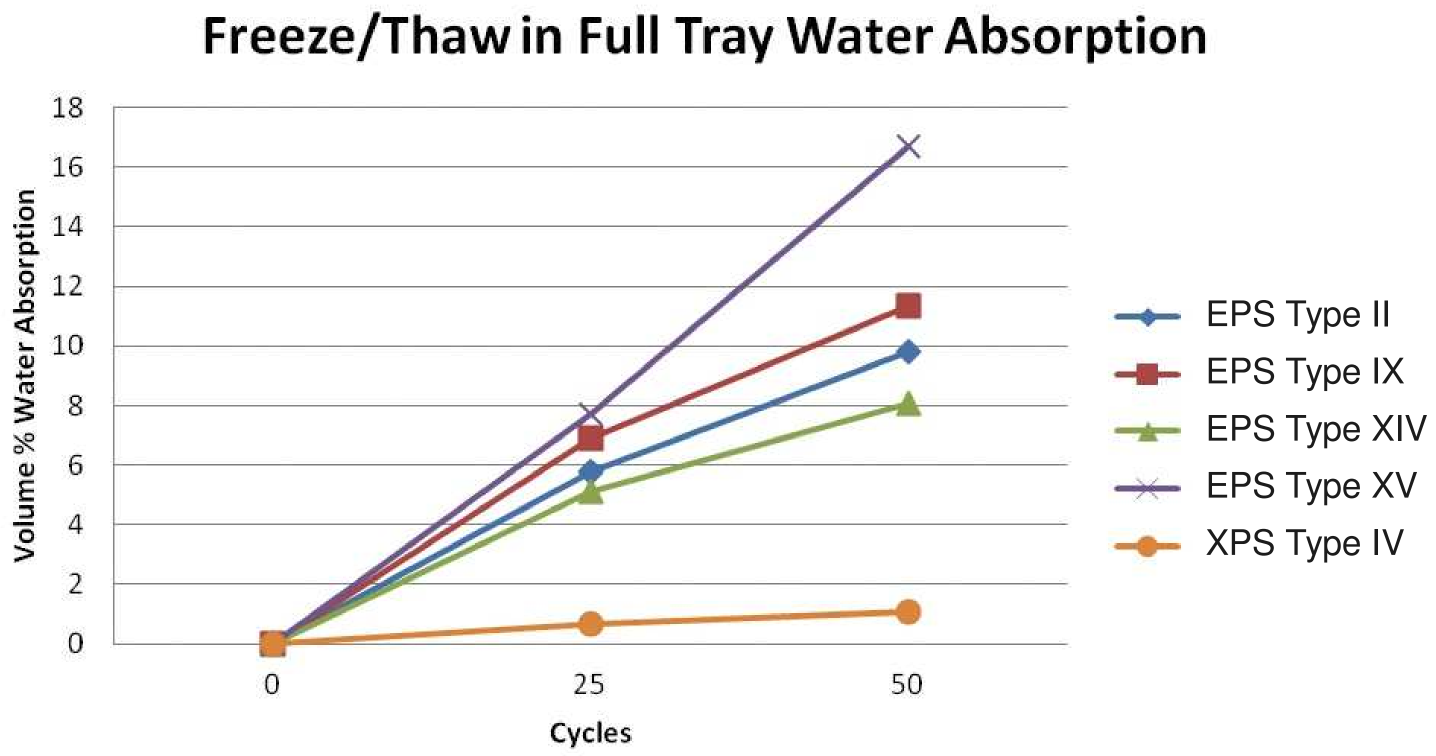
This process continues building on itself over time, leading to greater expansion and further reductions in R-value over the life of the product.

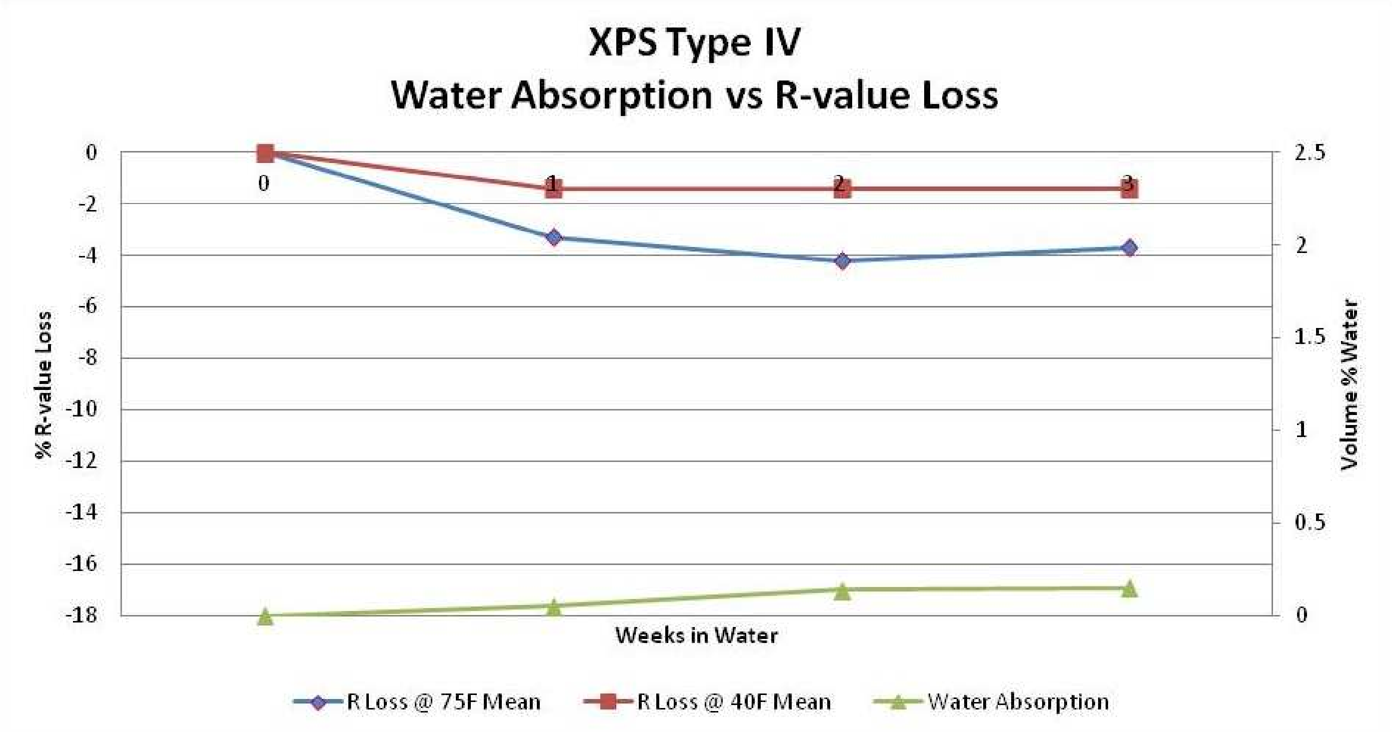
EPS

Below-Grade Freeze/Thaw Resistance

This does not happen to XPS, because it maintains its closed-cell structure and resistance to water absorption even during very punishing freeze/thaw cycles.

The chart shown here compares the water absorption of XPS and various densities of EPS as they are put through the number of freeze/thaw cycles shown at the bottom.





Water Absorption and R-Value

The Effect of Water Absorption on R-Value

Generally, for all installations of insulation, the R-value goes higher as it gets colder within a certain temperature range. The molecular activity slows down, and the ability to conduct energy becomes less efficient—so the R-value goes up.

Under dry conditions, the R-values of both EPS and XPS increase in cold temperatures. But the construction world is not always a dry environment. Over the lifetime of a building or paved surface, water get into, and lingers in, the soil around construction. Therefore, where the purpose of the insulation is to insulate, the most important characteristic of the insulation is its ability to retain R-value and continue to insulate even when exposed to water for long periods of time.

What is the impact of water on insulation performance?

The Effect of Water Absorption on R-Value

- Water is an excellent conductor of heat. If insulation becomes water-soaked, the water itself is conductive and causes R-value to be lost.

- Not only that, if the insulation material becomes waterlogged and then goes through freeze/thaw cycles, such as those seen in a shallow foundation application, the expansion and contraction of the water has the ability to break down insulation if it is actually inside its structure.

- As the insulation breaks down, more water gets in, and the R-value is further compromised in a repeated downward progression of performance.

In every instance the most important characteristic of insulation is its ability to retain R-value, and there is a difference between the ability of EPS and XPS to do this.

The Effect of Water Absorption on R-Value

Water absorption is a key detriment to thermal performance. There are two keys to resisting water absorption:

- The plastic itself must be hydrophobic (repels water), not hydrophilic (attracts water). Both XPS and EPS are manufactured using polystyrene, a hydrophobic polymer that repels water.
- The cell structure must be continuous and closed.

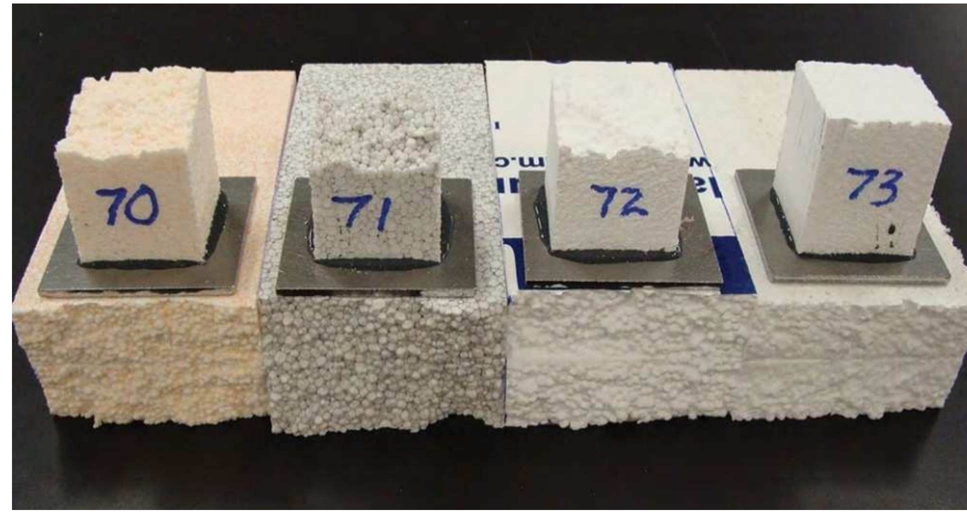
It has been demonstrated that EPS absorbs significantly more water than XPS. Although the individual beads of EPS are closed cells, the voids between the beads absorb measurable amounts of water, which reduces the already lower in-service R-value of EPS compared to XPS.

Water Absorption and R-Value Testing

The following slides present charts demonstrating the results of tests performed by an XPS manufacturer.

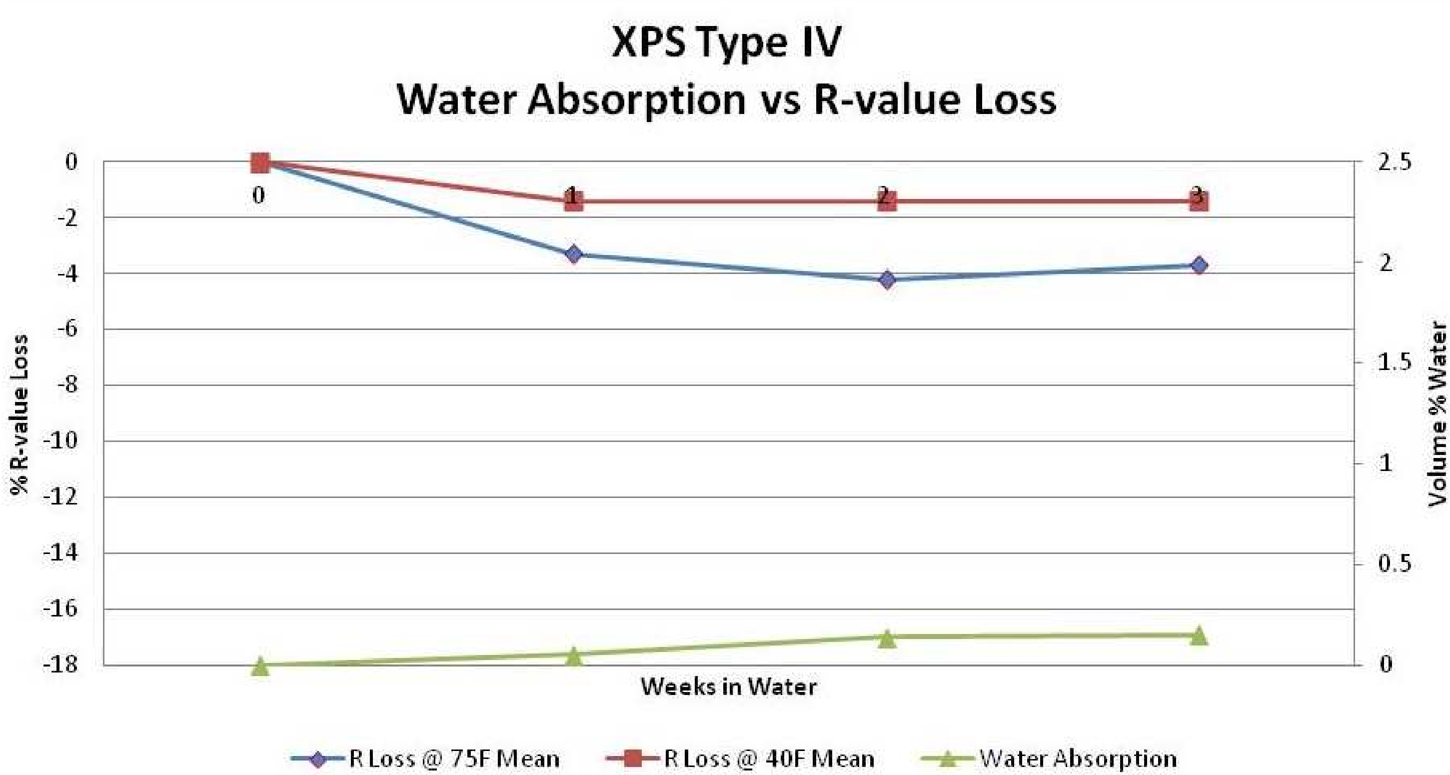
Samples were half-submerged in a tray of water for three weeks. The samples were periodically removed from the water tray and weighed to determine the amount of water absorbed. The R-value losses were also measured at 40°F and 75°F mean temperature.

All the charts show a red line for R-value loss at 75°F mean, a blue line for R-value loss at 40°F mean, and a green line for water absorption over the three weeks.



XPS: Water Absorption and R-Value

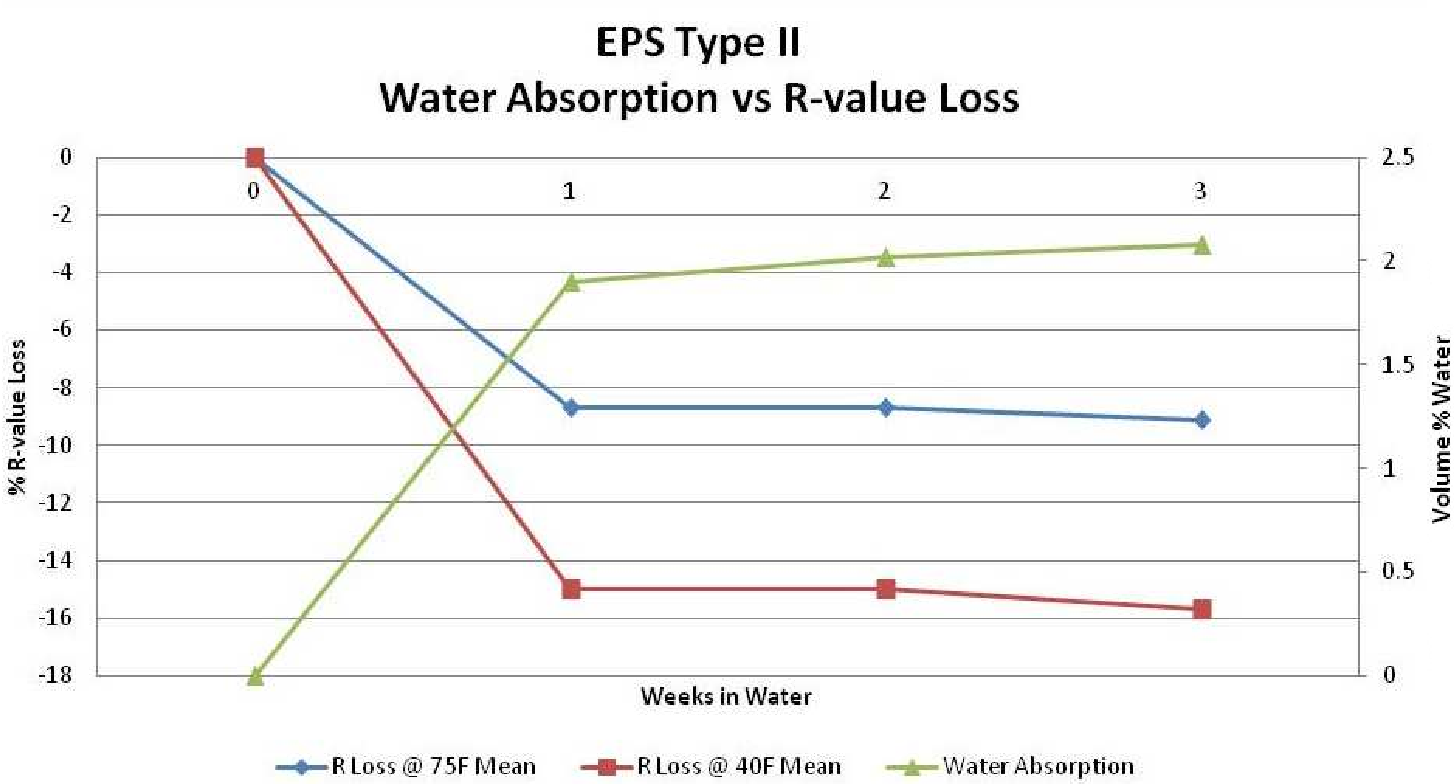
You can see that the XPS absorbed very little water over the three weeks. Note that the red line always stays higher than the blue; this means that it lost less R-value and is more thermally efficient at a colder mean temperature than at a warmer one.



At Week 3		
Temp.	R-Value	% R Lost
75°F	4.82	-3.7
40°F	4.93	-1.4
Water Absorption: 0.15%		

EPS: Water Absorption and R-Value

When EPS is dry, everything just stated applies to EPS. But when it is wet, the results turn upside down: green is now topmost, followed by blue, then red. More water is absorbed as the weeks progress compared to XPS. The R-value shows a much greater loss at a colder temperature, so the red line is now below the blue line.



At Week 3		
Temp.	R-Value	% R Lost
75°F	3.64	-9.1
40°F	3.37	-15.7
Water Absorption: 2.08%		

EPS: Water Absorption and R-Value

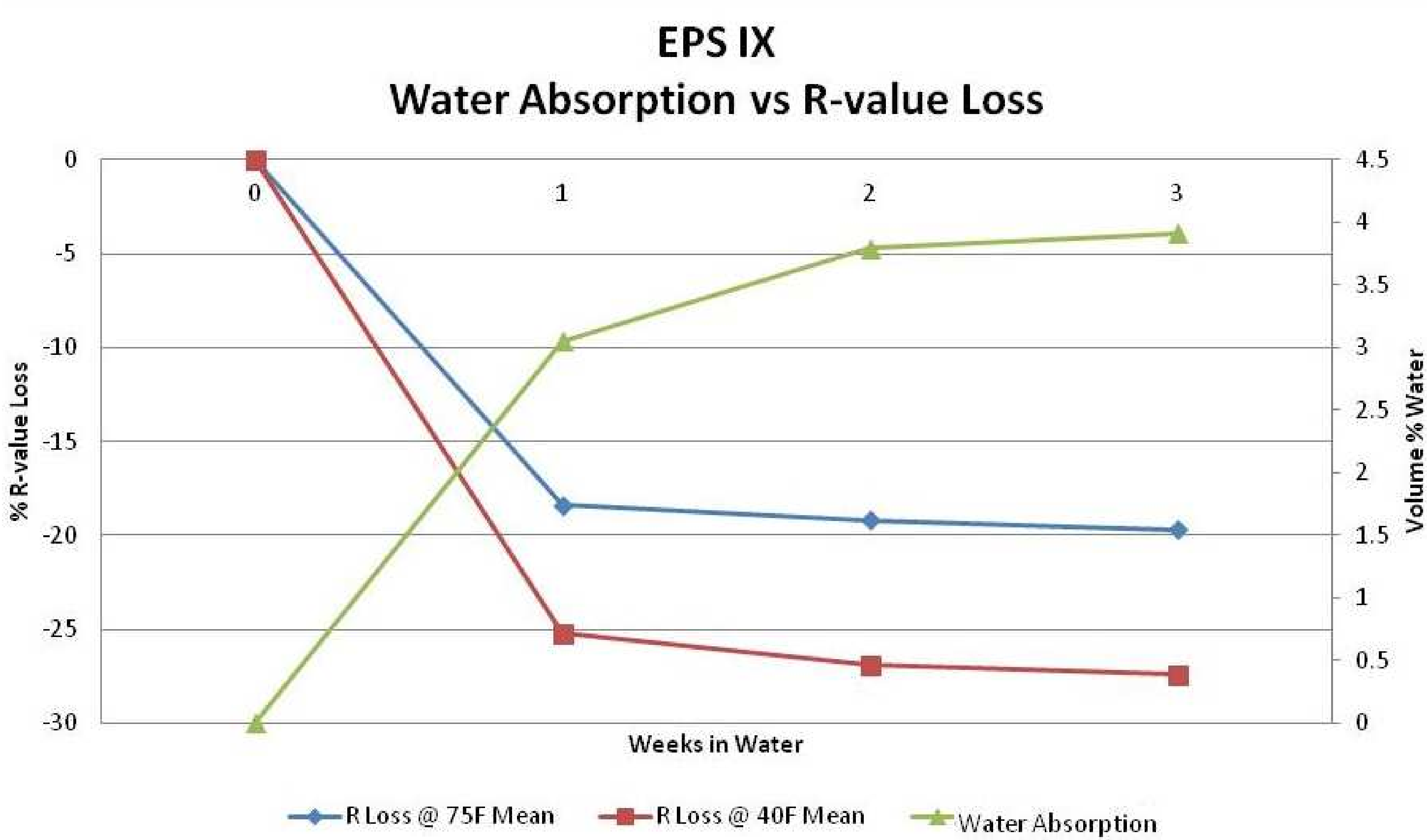
Remember, the phenomenon of “lower mean temperature, higher R-value” generally holds true for all insulation products unless water is absorbed into the sample. When the insulation boards are dry, free of absorbed water, EPS and XPS R-values get higher as the mean temperature gets colder.

Water is a much more effective conductor of energy at colder temperatures, so a board loses much more R-value as it loads up with water. Water is one of a few materials for which thermal resistance gets worse rather than better when it gets colder.

The prior as well as the next few charts show EPS has more R-value loss at 40°F mean temperature compared to the loss at 75°F mean temperature—a reversal of the behavior of XPS in water.

EPS: Water Absorption and R-Value

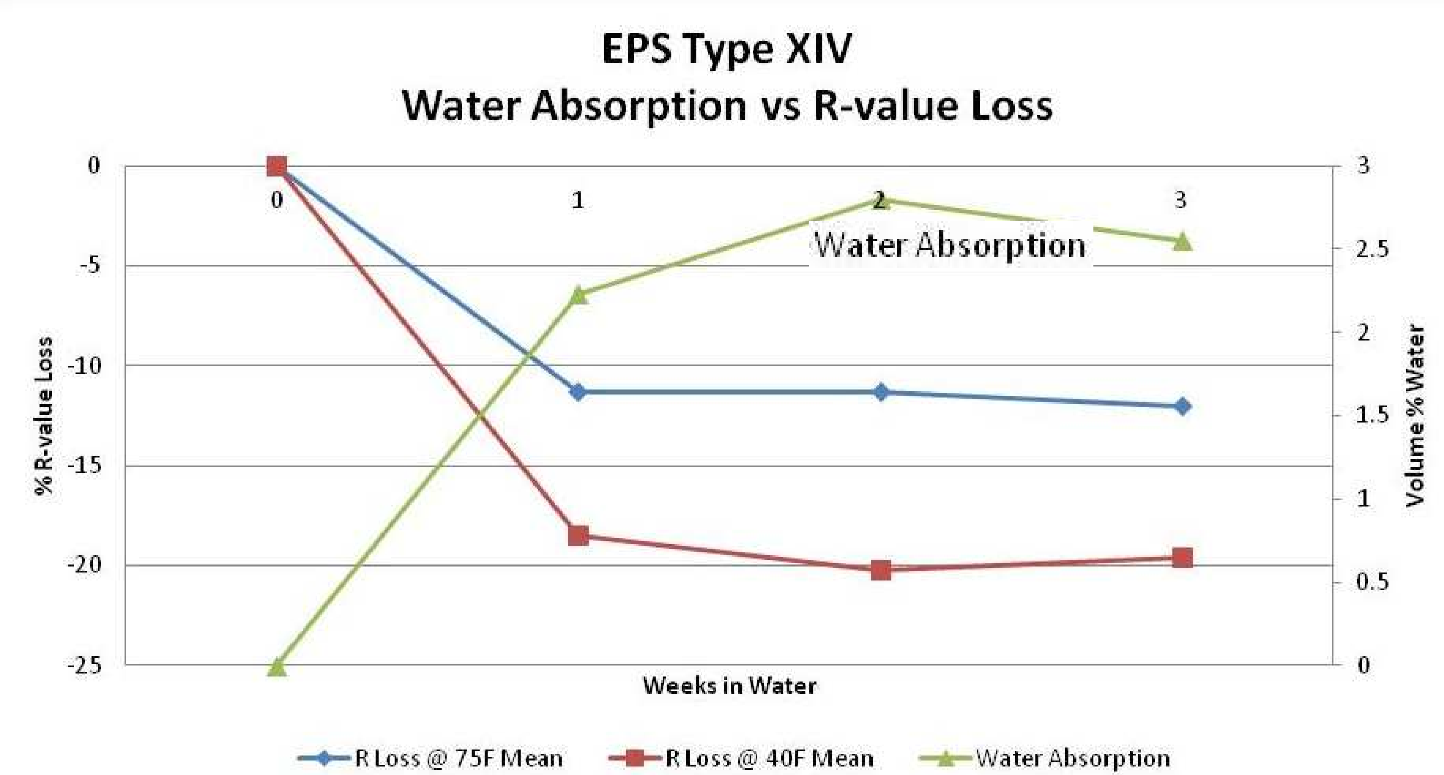
The performance relationship is true even in higher densities: water absorption increases while R-value decreases.



At Week 3		
Temp.	R-Value	% R Lost
75°F	3.37	-19.7
40°F	3.05	-27.4
Water Absorption: 3.91%		

EPS: Water Absorption and R-Value

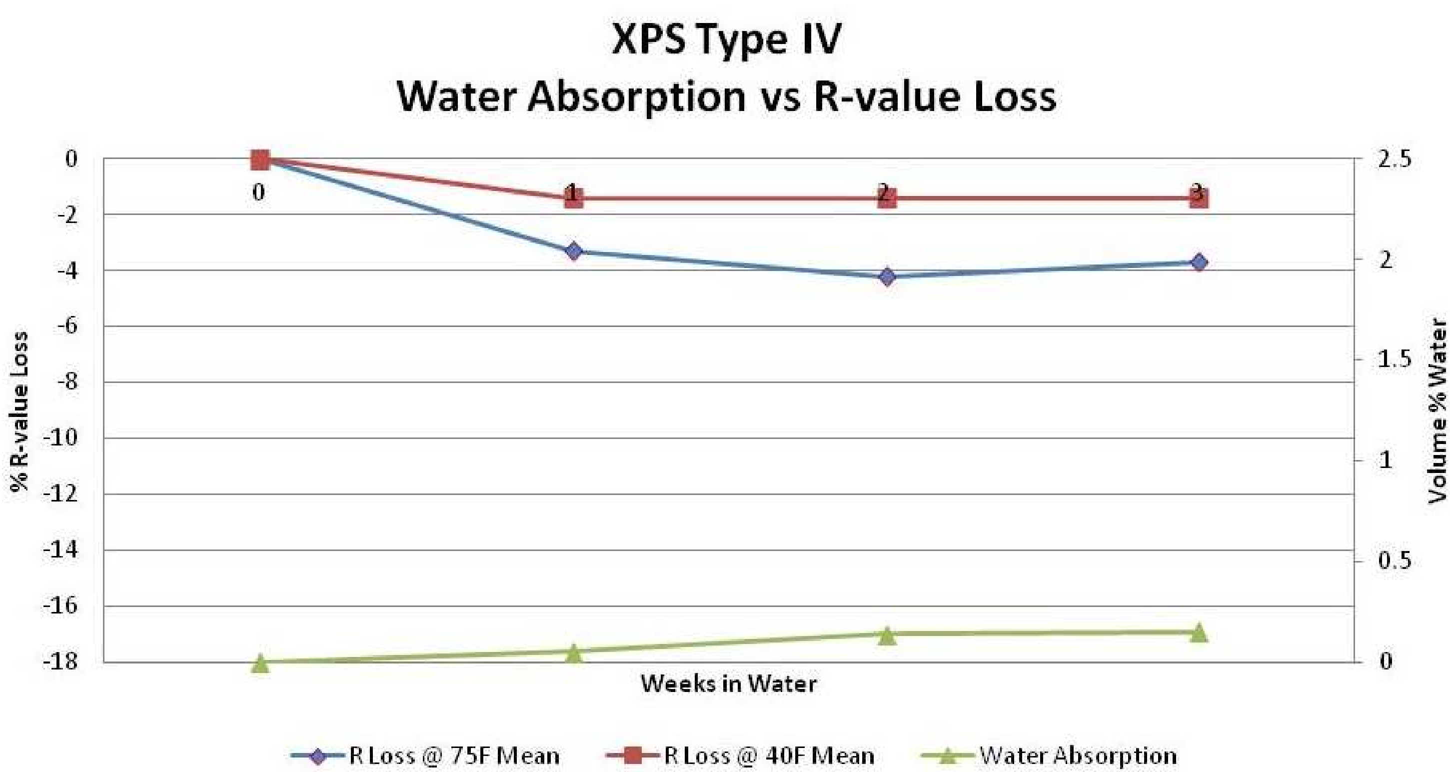
Even though the space between beads is smaller at higher densities, it still exists, so water can still get in.



At Week 3		
Temp.	R-Value	% R Lost
75°F	3.70	-12.0
40°F	3.38	-19.6
Water Absorption: 2.55%		

XPS: Water Absorption and R-Value

Re-examining the XPS chart, note that the R-value for wet XPS at 40°F mean temperature remains higher than the R-value at 75°F mean temperature. Why? Because the XPS absorbed virtually no water.



At Week 3		
Temp.	R-Value	% R Lost
75°F	4.82	-3.7
40°F	4.93	-1.4
Water Absorption: 0.15%		

Warranty Comparison

A typical EPS warranty is for 100% of the R-value, while an XPS warranty is for 90%. At first glance, it seems that 100% must be better than 90%, but it is important to look further than these initial numbers.

EPS is blown with pentane, which escapes and is replaced with air shortly after molding. Air is the means by which EPS achieves its insulating values, but it is not as effective an insulator as gas.

XPS cells contain a low-conductivity gas that does not efficiently conduct energy across the cells; the ability to contain the insulating gas in the cells is what gives XPS its high R-values. Almost all the insulating gas stays captive in the XPS cells for the life of the product. The very small amount that escapes is the reason that XPS has a 90% warranty, at which point the R-value stabilizes and equalizes with the air pressure.

Warranty Comparison

Instead of looking at the 100% versus 90%, looking at the R-values is more revealing. The example in this table shows that the R-value of XPS not only starts out higher than that of EPS, but also remains higher even at 90%. Warranties can be confusing when comparing R-value claims, so make sure you know what is being compared.

Warranted R-Value Comparison (at 75°F mean temperature)		
	Published R	Dry R Warranty
XPS	5.0	90% = 4.5
EPS (2.4 pcf)	4.2	100% = 4.2

Another important point is that typical EPS warranted R-values are based on the assumption that the EPS never gets wet and thus retains 100% of its claimed R-value. It is important to consider real in-service conditions that may result in wet insulation. As we have discussed, the data shows that when EPS get wet, its R-values fall, and in doing so, the value of the warranty is diminished.

Warranty Comparison

Shaded columns added to the same table as on the prior slide are not based on actual warranty claims, but are projections of what warranty claims might be if actual in-service wetting was considered.

Not only does the XPS have a higher warranted dry R-value, the projection for its wet R-value is 30% greater than that of wet EPS. In other words, a 90% R-value warranty is better than 100% especially when using real world conditions to assess performance.

Warranted R-Value Comparison (at 75°F mean temperature)				
	Published R	Dry R Warranty	Wet R	Wet R Warranty
XPS	5.0	90% = 4.5	4.92	90% = 4.43
EPS (2.4 pcf)	4.2	100% = 4.2	3.36	100% = 3.36

Note: Lower density EPS will have a lower R-value than shown in this table.

Specification Best Practices

XPS Specification: Understanding ASTM C578

Specifying EPS or XPS is simplified by ASTM C578. Calling out the ASTM classification will result in specifying a number of critical properties according to the type.

Polystyrene Board Type	EPS	EPS	EPS	XPS	EPS	XPS	EPS	XPS	EPS	XPS	EPS	XPS
ASTM C578 Classification	Type XI	Type I	Type VIII	Type X	Type II	Type IV	Type IX	Type VI	Type XIV	Type VII	Type XV	Type V
Compressive resistance at yield or 10% deformation, whichever occurs first (with skins intact) min., psi (kPa)	5.0 (35)	10.0 (69)	13.0 (90)	15.0 (104)	15.0 (104)	25.0 (173)	25.0 (173)	40.0 (276)	40.0 (276)	60.0 (414)	60.0 (414)	100.0 (690)
Density, min., lb/ft^3 (kg/m^3)	0.70 (12)	0.90 (15)	1.15 (18)	1.30 (21)	1.35 (22)	1.55 (25)	1.80 (29)	1.80 (29)	2.40 (38)	2.20 (35)	2.85 (46)	3.00 (48)
Thermal resistance of 1.00-in. (25.4-mm) thickness, min., $hr•ft^2•°F/Btu$ ($K•m^2/W$) Mean temperature: 75.2° (24.1°C)	3.10 (0.55)	3.60 (0.63)	3.80 (0.67)	5.00 (0.88)	4.00 (0.70)	5.00 (0.88)	4.20 (0.74)	5.00 (0.88)	4.20 (0.74)	5.00 (0.88)	4.30 (0.76)	5.00 (0.88)
Flexural strength, min., psi (kPa)	10.0 (70)	25.0 (173)	30.0 (208)	40.0 (276)	35.0 (240)	50.0 (345)	50.0 (345)	60.0 (414)	60.0 (414)	75.0 (517)	75.0 (517)	100.0 (690)
Water vapor permeance of 100-in. (25.4-mm) thickness, max., perm ($ng/Pa•s•m^2$)	5.0 (287)	5.0 (287)	3.5 (201)	1.5 (86)	3.5 (201)	1.5 (86)	2.5 (143)	1.1 (63)	2.5 (143)	1.1 (63)	2.5 (143)	1.1 (63)
Water absorption by total immersion, max., volume	4.0	4.0	3.0	0.3	3.0	0.3	2.0	0.3	2.0	0.3	2.0	0.3

XPS Specification: Understanding ASTM C578

By simply specifying "ASTM C578 Type IV," the listed properties are also specified:

- Compressive resistance at min. 25.0 psi
- Density min. of 1.55 lb/ft^3
- Thermal resistance at 5R/inch
- Flexural strength of min. 50 psi
- Water vapor permeance max. 1.5/inch
- Water absorption max. of 0.3

Polystyrene Board Type	EPS	EPS	EPS	XPS	EPS	XPS
ASTM C578 Classification	Type XI	Type I	Type VIII	Type X	Type II	Type IV
Compressive resistance at yield or 10% deformation, whichever occurs first (with skins intact) min., psi (kPa)	5.0 (35)	10.0 (69)	13.0 (90)	15.0 (104)	15.0 (104)	25.0 (173)
Density, min., lb/ft^3 (kg/m^3)	0.70 (12)	0.90 (15)	1.15 (18)	1.30 (21)	1.35 (22)	1.55 (25)
Thermal resistance of 1.00-in. (25.4-mm) thickness, min., hr•ft^2 •°F/Btu (K•m^2/W) Mean temperature: 75.2° (24.1°C)	3.10 (0.55)	3.60 (0.63)	3.80 (0.67)	5.00 (0.88)	4.00 (0.70)	5.00 (0.88)
Flexural strength, min., psi (kPa)	10.0 (70)	25.0 (173)	30.0 (208)	40.0 (276)	35.0 (240)	50.0 (345)
Water vapor permeance of 100-in. (25.4-mm) thickness, max., perm (ng/Pa•s•m^2)	5.0 (287)	5.0 (287)	3.5 (201)	1.5 (86)	3.5 (201)	1.5 (86)
Water absorption by total immersion, max., volume	4.0	4.0	3.0	0.3	3.0	0.3

XPS Specification Examples

What is the material being specified in this real-life example?

- Type IV properties, but does not need to be extruded

ASTM C578 defines the properties of Type IV, and they are the properties of an extruded product. Therefore, there is no non-extruded product that is also Type IV, so the above specification is incorrect.

Be sure to note that some EPS products may be labeled Type IV as a name but not because they have met the ASTM C578 Type IV standards.

★ Please remember the **exam password EXTRUDED**. You will be required to enter it in order to proceed with the online examination.

XPS Specification Examples

What is the material being specified in this real-life example?

- ASTM C578 Type IV, 40 psi, 1.3 pounds per cubic foot density

Type IV XPS is called out, but:

- Type IV is 25 psi while Type VI is 40 psi, and
- Type IV is 1.55 pcf while Type X is 1.3 pcf density.

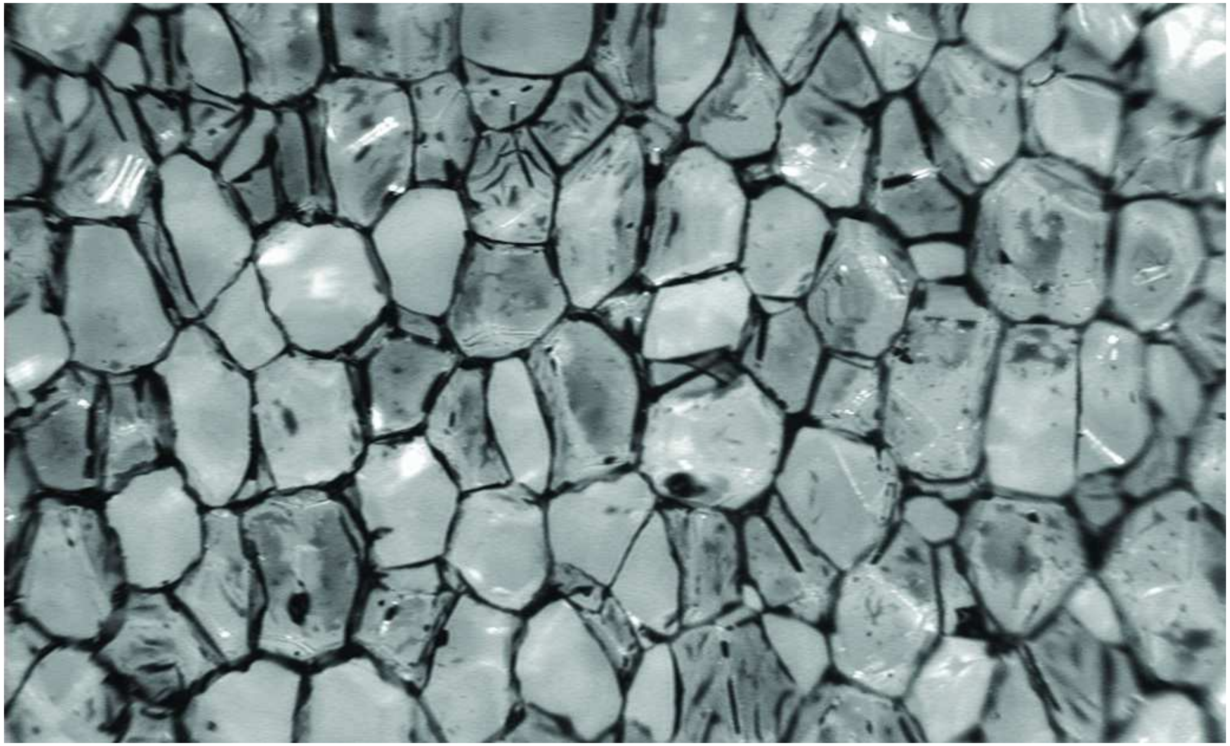
To avoid a confusing mixture of properties and types, it is best practice to specify the ASTM C578 type. This greatly simplifies specifications and avoids mistakes.

XPS Specification: Best Practices

Keep specification simple by using the ASTM C578. This is the best way to ensure that your project gets built to your specifications. Once the material properties are ensured, you can then define the important value-added properties not included in C578.

Value added properties include the following:

- Indoor air quality
- GREENGUARD certified
- 20% recycled content for points in green building programs



Summary

Summary

Water can migrate under pavement from above, and it can migrate through soil from below. Although soil moisture content varies seasonally, moisture is always present to some degree in soil.

Among the reasons that projects have under-pavement insulation is that the underlying soil is poorly drained or holds moisture, resulting in a high moisture content that makes it—and the pavement above it—susceptible to freeze/thaw cycling and heaving.

Dry soil is not as susceptible to freeze/thaw driven heaving because there is no or little water to freeze. Generally, dry or well-drained road bed projects have little reason to insulate. However, where it is impractical or impossible to de-water or drain the existing soil bed, insulation will extend the time it takes to reach a freeze thereby limiting freeze/thaw cycling.

Summary

When insulation R-value and structural durability are important for your below-grade, rooftop, or under pavement project, then water resistance is vital. An insulation's ability to perform under punishing conditions depends on its ability to effectively resist water absorption.

When water resistance is vital, the extrusion process is important. The open-cell structure of EPS absorbs significantly more water than XPS, degrading both R-value and the structural integrity of the EPS.

Unlike XPS, water-soaked EPS loses even more of its performance attributes at lower temperatures—when insulation is needed most.

It is important to understand the ramifications of the extrusion versus the expansion processes, and closed- versus open-cell structures. Be sure you know what is being compared, because there is a difference between EPS and XPS.

Resources

ASTM C578, “Standard Specification for Rigid, Cellular Polystyrene Thermal Insulation.” West Conshohocken, PA: ASTM International, 2015.

“FOAMULAR® Extruded Polystyrene Insulation: ASTM C578 Types and Physical Properties.” Pub. No. 10015702. Owens Corning, 2011.

“For Foam Plastic Insulation, Extrusion Matters.” Pub. No. 10018681-A. Owens Corning, 2015.

Conclusion

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