EXTRUDED POLYSTYRENE (XPS) RIGID FOAM INSULATION IN FOUNDATION APPLICATIONS

By NAHB Research Center Staff

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MAKING THE SWITCH

Extruded polystyrene (XPS) is a rigid foam board that can be placed on the interior or exterior of foundations. Installation of XPS foundation insulation is simple, and no training or special techniques are necessary. However, for most interior foundation applications, XPS cannot be left exposed. Unfinished basement construction must be covered by a suitable thermal barrier, such as gypsum wallboard, or with an ignition barrier when used on the interior of a crawlspace. For exterior applications on foundations, exposed portions of XPS must be protected by a suitable covering to prevent physical damage or degradation due to UV radiation (sunlight). Some exceptions apply (see Code Acceptance, below).

INITIAL COST

XPS insulating sheathing is comparable in cost to other insulation material options for foundations, especially when compared on an equivalent R-value (thermal-resistance) basis. XPS also offers excellent durability and moisture-resistant performance, especially for foundation or below-ground applications. If used for a frost-protected shallow foundation (FPSF) in colder climates, overall foundation construction costs can be significantly reduced, and energy efficiency can be improved.

OPERATIONAL COST

XPS insulation can outperform other insulation products in moist foundation applications. For example, other insulation materials may lose R-value when subject to a moist environment. With this consideration, long-term operational costs of XPS foundation insulation may be considered superior to many other insulation choices.

CODE ACCEPTANCE

XPS insulation is accepted by all national model building codes in the United States. Section R314 of the 2006 International Residential Code (IRC) covers foam plastic insulation. For many interior applications, exposed foam plastic insulation must be covered with an approved thermal barrier such as gypsum board. In some cases, XPS may not require thermal or ignition barriers (it is important to consult the ICC-Evaluation Service report for a specific product to see if that product is exempt from requiring such barriers). Please see each manufacturer's current evaluation reports, which may be found at **www.icc-es.org**.

RESULTS FROM THE FIELD

Field studies have shown that XPS insulation used in FPSF can save a significant amount over the installed cost of a conventional foundation. Little additional training is required to implement XPS for use in FPSF construction. Delays are sometimes encountered during installation when code officials are unfamiliar with FPSF and XPS design. Check with local code officials to expedite the review process.

WARRANTY

Check the warranty provided by the manufacturer.

THE BASICS

Extruded polystyrene (XPS) foam insulation is a closed-cell extrusion, which differentiates it from other insulation materials that contain open cells or voids (see

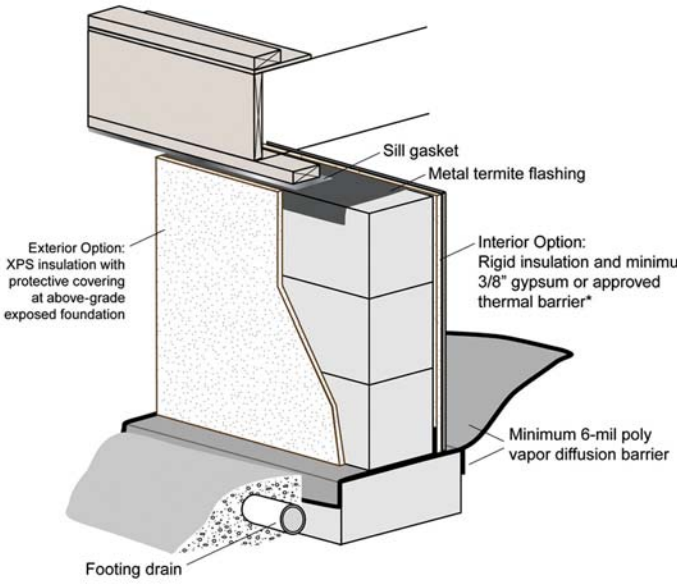

Figure 1 – Insulated crawlspace.

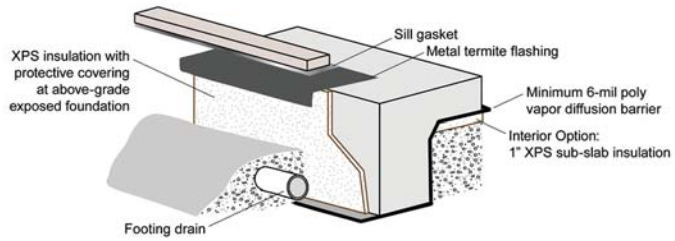

Figure 2 – Insulated slab.

Definitions sidebar, page 23). XPS comes in a variety of sizes, with typical panel sizes ranging from ½ in to 2 in thick, with face dimensions of 2 to 4 ft wide by 8 to 10 ft long. Panels may be square-edged, tongue-and-grooved, or shiplapped.

As a code-compliant insulation material, XPS is manufactured to comply with ASTM C-578 and has a standard thermal resistance (R-value) of 5 per inch of thickness. Various standardized types of XPS are available that provide a range of foam densities and properties suitable for different applications. For example, below-ground XPS foundation insulation may require Type IV (minimum 1.6 lbs/cu ft density) when used for an FPSF (addressed below), while above-grade XPS wall sheathing is typically Type IV or X (1.3 lbs/cu ft density).

The higher the density of the foam, the greater its compressive or load-bearing strength. For thinner wall-sheathing products (e.g., ½ in thick), a clear polymeric (plastic) film facer may be applied to the surface of the product to provide added rigidity or toughness for handling and installation purposes. However, such facers are typically not necessary for foundation or below-ground applications.

XPS products are especially noted for their durability in maintaining R-value under moist conditions, such as below-ground applications.

Conventional applications of XPS sheathing on foundations include

- Crawlspace foundation insulation (interior or exterior wall surface). (See *Figure 1.*)
- Slab-on-grade foundation insulation (perimeter or below slab). (See *Figure 2.*)
- Basement foundation insulation (interior or exterior wall surface). (See *Figure 3.*)

FROST-PROTECTED SHALLOW FOUNDATIONS

XPS insulation is a favored material for FPSF construction, due to its superior moisture resistance when compared to other foam insulating sheathing products.

FPSF is a code-recognized foundation construction method that combines the energy-efficient benefits of polystyrene foam insulation with its ability to retard heat flow from the soil under a building foundation. As such, foundations in cold climates can be constructed at a lesser depth — and at a

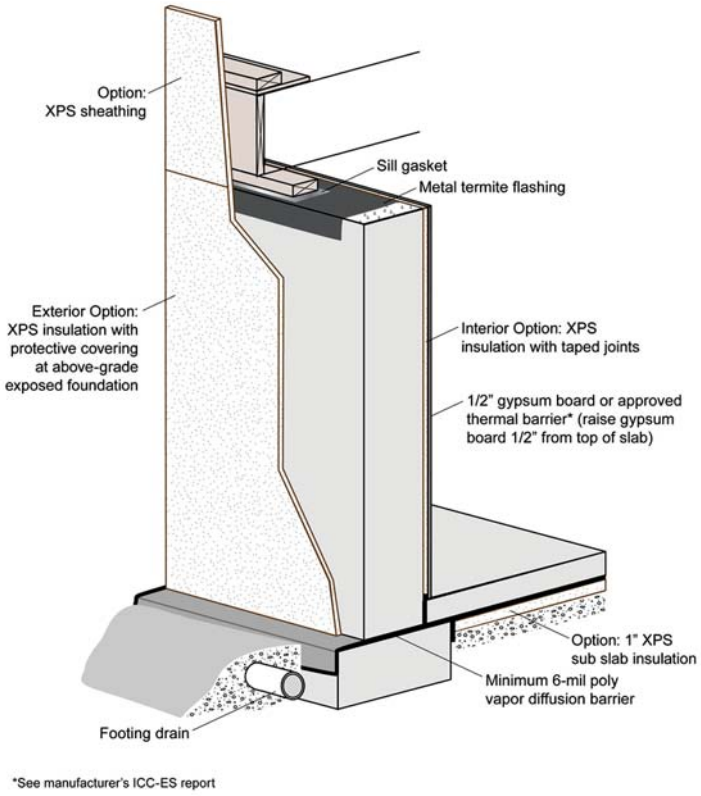

Figure 3 – Insulated basement.

BENEFITS (+) / DRAWBACKS (x)

+ CODE COMPLIANCE: Extruded polystyrene (XPS) insulation is recognized and accepted for use in U.S. model building codes.

+ ENERGY EFFICIENCY: XPS insulating sheathing has an R-value of 5 per inch thickness. It is not adversely affected by moisture and retains its R-value over time.

+ MOISTURE RESISTANCE: XPS insulation is one of the most moisture-resistant insulation products on the market.

+ FOUNDATION COST SAVINGS: When used to provide a frost-protected shallow foundation (FPSF), substantial construction cost savings are possible in addition to long-term energy savings.

x INITIAL COST FOR CONVENTIONAL FOUNDATIONS: Using XPS insulation on conventional foundations does cost a little more than some minimally code-compliant options, such as using a fiberglass blanket on unfinished basement walls.

x PROTECTIVE COVERING: XPS placed on the exterior side of foundation walls must be protected against physical damage and UV degradation where it is exposed above grade. XPS installed on the interior of a basement wall or crawl space wall will typically require a thermal barrier such as half-inch gypsum board to provide code-compliant fire protection. These precautions are similar for other insulation products. However, there are exceptions in some cases to thermal-barrier requirements.

significantly reduced cost — than comparable conventional foundations built to extend below a locally prescribed ground frost line. By storing heat in the ground and preventing heat loss from the building foundation perimeter, XPS insulation used for an FPSF prevents ground frost (or frost heave) from occurring in soils under the building. For more information on this type of construction, refer to the Resources sidebar on page 26.

BASEMENTS, CRAWLSPACES, AND SLABS

Whether used as part of an FPSF to protect against frost heave or as a means of insulating a conventional foundation for energy efficiency, XPS insulation also provides moisture-resistant protection to finishes on basement walls and floors. This practice also reduces moisture vapor loads on above-grade portions of the structure that migrate from the basement or foundation.

For example, XPS insulation used on the interior of a foundation wall can help prevent condensation and mold on basement wall finishes. Similarly, when used as a substrate for concrete slab floors (either in a basement or above-grade living areas), XPS rigid foam insulation can provide a moisture barrier to protect floor finishes and to help provide a warm, comfortable floor surface.

For more information regarding these applications, refer to manufacturer recommendations and the Resources sidebar. (HUD, 2006, *Moisture Resistant Homes. . .* ; Sections 2.4.3, 2.4.4, and 2.4.5).

When using XPS insulation on the interior side of a basement or crawlspace foundation wall, an additional consideration related to fire resistance is necessary. According to current building code, these applications require that the XPS foam sheathing be protected by a suitable thermal barrier or ignition barrier in accordance with section R314 of the 2006 IRC. As an example, a suitable thermal barrier includes typical ½-in gypsum wallboard as an interior finish.

Similarly, when XPS insulation is used on an exterior foundation surface, any exposed, above-ground portions must be protected against UV degradation (sunlight) and sources of physical damage, such as from lawn maintenance activities, etc. To protect XPS from sunlight exposure and physical damage, various compatible coverings are typically used. (NAHB Research Center, 2004, Appendix I in the *Revised Builder's Guide to Frost-Protected Shallow Foundations*.)

DEFINITIONS

Closed-Cell and Open-Cell Foam

Foam plastics are composed of millions of tiny cells or bubbles. When the cells are completely intact with no holes or spaces between the cells, it is called closed-cell foam. When the cells have holes connecting one cell to another, it is called open-cell foam.

Open-cell foam is usually made of many smaller foam beads that are expanded by temperature within the confines of a mold to shape the material. This process leaves open pathways or channels between the expanded beads that permit moisture and air migration through the material as a function of its density.

Closed-cell foam is made by including a "blowing agent" in melted foam plastic that causes tiny air bubbles (cells) to form within the plastic material as it is extruded into a desired shape. Thus, there are no open pathways through the material, and it is resistant to moisture and air migration regardless of its density. All other factors equal, closed-cell foam also tends to be stronger (in bending and compressive strength) than open-cell foam.

Frost Heave

Frost heave is the expansion and contraction of soil as it freezes and thaws with yearly conditions.

FOOD FOR THOUGHT

Before using XPS insulation technology, make sure it's the right choice for the project.

- For finished basement foundation walls, placing a 1-in-thick layer of XPS against the foundation wall and using furring strips or studs with unfaced fiberglass batt insulation to the inside of the foam sheathing will prevent excessive moisture migration and potential mold formation on interior finishes. Interior finishes, such as gypsum wallboard, should be finished with a breathable coating such as latex paint. Nonbreathable finishes such as wallpaper should be avoided on basement walls.
- For FPSF construction, using XPS in the most stringent locations around the foundation perimeter is a requirement of ASCE 32-01.
- Placing XPS on the exterior surface of a foundation wall provides the most energy-efficient configuration for foundation insulation, but XPS requires protection from UV radiation (sunlight) and physical damage where it projects above the ground surface.
- Using XPS together with furring strips and subfloor sheathing for finished flooring in a basement or slab-on-grade foundation can prevent moisture damage to flooring and creates a warm, comfortable floor surface.

RESULTS FROM THE FIELD

This technology has been evaluated by other builders in real-world building projects. For more information on technologies in practice, visit **www.toolbase.org**.

FROST-PROTECTED SHALLOW FOUNDATIONS

Housing and Urban Development's Partnership for Advanced Technology in Housing, or HUD/PATH

Several demonstrations have been completed using XPS foundation insulation in stringent below-ground applications such as found in FPSF. These demonstrations confirmed the performance of XPS insulation in protecting foundations against heat loss and frost heave in moist/cold climates ranging from Vermont to Alaska. These studies demonstrated typical construction cost savings of as much as $4,000 or more in comparison to typical foundation prac-

Table 1 – Cost of XPS and Other Common Foundation Insulation Materials

Foundation Insulation Product	Insulation Material Costs Per Sq Ft for R-10*	Finished Wall Added Costs Per Sq Ft**
Extruded Polystyrene (XPS) [2 in]	$0.54 - $1.12	½-in gypsum board secured to ¾-in nailing strips and taped: **$1.40**
Expanded Polystyrene (EPS) [2½ in]	$0.40 - $1.12	
Polyisocyanurate (Polyiso) – foil-faced [1½ in]	$0.70 - $1.01	
Fiberglass Batts – foil- or vinyl-faced [2½ in] (with integral approved thermal barrier, draped)	$0.30 - $0.35	Cost of studs and drywall to present a finished wall surface: **$2.50 - $2.80**

*Prices for foam obtained from Home Depot and Lowe's in South, East, and Midwest regions as of November 2008. Fiberglass foil-faced prices obtained from Cabot Components Corporation in June 2008. Installation not included.

**Added costs for approved thermal barriers and finished walls compiled by NAHB Research Center in December 2008 from average costs reported by builders in three climate zones.

tices. In addition, studies of long-term performance of XPS and other foundation insulation materials resulted in making effective R-value recommendations in the ASCE 32-01, "Design and Construction of Frost-Protected Shallow Foundations (FPSF)." These recommendations demonstrate the ability of XPS insulation to maintain R-value in below-ground foundation applications. (See Resources sidebar, page 26, for additional information.)

Freedom Township, NJ, K. Hovnanian Inc. (2002 HUD/PATH field evaluation)

- The builder reported a $750 savings on installation compared to conventional design.
- Synthetic stucco provided the most appealing finish for both aesthetics and in protecting the XPS foam of the foundation.
- Initially, building officials were not familiar with the FPSF system, resulting in a delayed start.

Denver, CO, Oakwood Homes (2002 HUD/PATH field evaluation)

- The builder reported installed cost savings of 15% over conventional foundation installation.
- No special tools were required, and little training was needed for crews to install the FPSF.
- Building officials were not familiar with the FPSF system initially but approved the design after some discussion.

DOLLARS AND SENSE

XPS insulation is competitive with other rigid foam insulation material options for foundation applications. When all factors are considered (i.e., durability, moisture resistance, and thermal resistance or R-value), XPS is often considered a superior choice for foundation insulation applications. Material costs for XPS in comparison to other common insulation options permitted for the interior of basement or crawlspace walls are shown in *Table 1*. For comparison purposes, the International Residential Code's (2006) minimum prescriptive R-value for Zone 4 basements, R-10, is used. Because rigid foam sheets have different R-values per inch, the thickness will vary among types of foam and manufacturer. This means a higher level of thickness may be required, even if it achieves a greater R-value than required by code.

If placing insulation on the exterior face of a foundation is specified or desired, then

RESOURCES

Extruded Polystyrene Foam Association (XPSA)
4223 Dale Boulevard
Woodbridge, VA 22193
1-800-978-9772
www.xpsa.com/res/found.html

Revised Builder's Guide to Frost-Protected Shallow Foundations
NAHB Research Center, Inc.
400 Prince George's Boulevard
Upper Marlboro, MD 20774
September 2004
www.toolbase.org

Design and Construction of Frost-Protected Shallow Foundations
SEI/ASCE 32-01.
American Society of Civil Engineers
Reston, VA 20191
ASCE 2001
www.asce.org

International Residential Code
International Code Council, Inc.
Washington, DC 20001
ICC 2006
www.iccsafe.org

Frost-Protected Shallow Foundations, Phase II – Final Report
U.S. Department of Housing and Urban Development (HUD)
Washington, DC 20026
1994
www.huduser.org

Moisture-Resistant Homes: A Best Practice Guide and Plan Review Tool for Builders and Designers, With a Supplemental Guide for Homeowners
U.S. Department of Housing and Urban Development (HUD)
Washington, DC 20026
2006
www.huduser.org

some additional costs are required, such as protection of insulation from damage or UV radiation (sunlight) at the above-grade area of the foundation. In addition, some insulation products listed in *Table 1* do not perform well in moist, ground-contact exposures. In moist applications or when a high compressive strength is required of the insulation material, XPS may be the only viable option – as is often the case with FPSF construction.

On the other hand, if a basement is intended to be unfinished but must be insulated to meet energy code, using XPS insulation may require that the basement walls be finished with a suitable thermal barrier, which could add to the initial cost of a new basement foundation, as detailed in column three of *Table 1*. However, the value-added appeal of a finished or semifinished basement can be very marketable. Furthermore, experts recommend that a minimum 1-in-thick layer of XPS sheathing (R-5) installed on the interior of a basement foundation wall can be considered a best practice for controlling moisture migration and moisture condensation through a foundation wall, while still allowing the foundation wall to remain dry. (HUD, 2006, Section 2.4.3).

SWITCHING TO XPS

Making the switch to XPS foundation insulation is easy. Specific changes may depend on a builder's current practice for insulating foundations. If the current practice involves use of another type of insulation, the change can involve nothing more than a simple substitution; however, differences in R-value may require a slight increase or decrease in insulation thickness. Also, if the insulation is exposed to the interior of a basement or crawl space, some types of insulation may require a fire-protective layer (see XPS manufacturers' ICC evaluation service reports). Thus, the use of XPS on basement walls is most economical if a basement is being finished immediately. Attaching XPS insulation to foundation walls can be done with appropriate construction adhesives and/or power-actuated fasteners with suitable washers. If furring strips are used over the XPS insulation board to allow attachment of finishes, these can be used to help secure the insulation boards to the foundation wall. For superior moisture performance, joints in XPS insulation on the interior side of basement walls should be taped.

TECH CHECK

- Be sure to verify that the correct type of XPS sheathing is specified in accordance with ASTM C-578. This is particularly important for FPSF applications.
- When using adhesives to attach foam sheathing to foundation walls, be sure the adhesive is designed for this purpose, and plan on using some mechanical fasteners or furring strips to help press the foam insulation into lines of adhesive on the foundation wall and to hold it in place as the adhesive sets.
- Refer to manufacturer installation recommendations and follow them carefully. Some manufacturers may produce specialty products for basement or foundation insulation projects.
- Make sure to specify a suitable thermal or ignition barrier over XPS insulation when used on the interior of a basement or crawl space foundation. If used on the exterior face of a foundation, be sure to specify a suitable protective covering.
- When specifying or purchasing XPS insulation, be sure to check local availability with the supplier and product manufacturer.