Chapter

# 11

# Rigid Board Insulation

Rigid insulation is made from fibrous materials or cellular plastic foams and is pressed, extruded, or molded into boardlike forms. Board products can provide both thermal and acoustical insulation, possess modest strength properties with low weight, and provide adequate coverage with few heat-loss paths when installed properly. Rigid insulation boards also may be manufactured with various facers to enhance or protect certain physical properties.

Even though rigid board products are typically more expensive than other types of insulating materials, they are used commonly in buildings where there are space limitations, where rigidity is critical to the application, or where higher R-values are necessary. Rigid board insulation R-values can range from 4 to 8 per inch of thickness depending on the composition and the method of aging.

Board insulation products can be applied in a variety of locations. Exterior sheathings applied over wall framing members (especially with steel stud framing systems), within wall cavities, in masonry veneer wall cavities, or behind an interior finish material are but a few examples.

A number of board insulation products are also used with low-slope roofing systems. Although predominantly found in commercial construction, the most common types include cellular glass, glass fiber, mineral fiber, perlite, polyisocyanurate, polystyrene (expanded and extruded), wood fiberboard, and composites. (Polyisocyanurate is the most common roof insulation according to 1999 statistics.)

Rigid insulation is also being used in innovative ways in new construction to create more energy-efficient homes. Stressed-skin walls can replace traditional stick framing with engineered panels consisting of a foam core with structural sheathing adhered to both sides. Known as *structural insulated panels* (SIPs), they usually incorporate expanded polystyrene (EPS) or polyisocyanurate foam as the core material. Insulating concrete formwork is another foam-based product that is used in lieu of traditional construction (see Chap. 15 for SIPs and ICF).

Many variables affect the installed thermal performance of rigid board insulation. These include the density of the foam, the blowing agent used to create the foam, the method of aging, the cellular structure, the durability of the material, the presence of dents and chips, the thickness and type of facer (if any) that is used, the thickness of the board, and the conditions in which the foam is installed. Owing to the quantity and variety of products, interested readers will require more information than what can be presented within the scope of this book. The long-term thermal performance of any insulation product always should be evaluated prior to its selection or application. Manufacturer's literature is a place to start, but any information should be complemented with independently sponsored research.

Rigid insulation can be used as an air infiltration retarder when installed properly. With respect to moisture movement, special attention must be paid to the use of rigid board products on the exterior of a wall when a vapor retarder is already in place on the interior of the wall. Permeance ratings must be verified to ensure that moisture vapor will not become trapped within the wall assembly.

Chlorofluorocarbons (CFCs) are no longer used as a blowing agent for plastic foams. Hydrochlorofluorocarbons (HCFCs), originally a U.S. Environmental Protection Agency (EPA)–approved blowing substitute for (the discontinued) CFCs, are currently found in extruded polystyrene foam boards and polyisocyanurate foam boards. As discussed in detail in Chap. 10, the scheduled phase-out of HCFCs also has played a role in the research, development, and modification of various rigid board insulation products.

Burrowing insects can reduce the thermal performance and structural integrity of the insulation. Although rigid board insulation offers no food value to insects, it provides the potential for insects to easily tunnel from the ground to more desirable materials. The foam is also an attractive nesting environment. For these reasons, some manufacturers treat their foam products with an insecticide, usually a borate compound. Additional precautions such as treating the earth around the building with insecticides, using bait station treatment methods, keeping an inspection area bare of insulation board, removing all wood debris, maintaining specific above-grade clearances, or installing the foam board over the interior of the basement walls rather than the exterior also will help minimize the risk of insect infestation.

All organic cellular plastics, whether or not they contain fire retardants, should be considered combustible and handled accordingly. Terms such as *fire-retardant* and *flame-resistant* are sometimes used to describe the combustibility characteristics of foams. While they are valid measures of the performance of these materials under small fire exposure, they are not intended to reflect hazards under exposure to large-scale fire conditions.[1] The combustion characteristics of foam insulation products vary with the combustion temperatures, chemical formulation (which will determine thermoplastic or thermoset behavior), and available air. Plastic foam insulation may appear relatively difficult to burn, but when ignited, it burns readily and emits a dense black smoke containing toxic gases (as do all organic combustibles commonly used in construction). Foam insulation used in construction requires a fire-protective covering such as $^{1}/_{2}$"-thick gypsum wallboard or similar 15-minute code-approved thermal barrier. Building codes contain many exceptions regarding the use of thermal barriers, so always verify requirements with the local building code or fire officials and insurers.

*Geofoam* is another popular buzzword of late. Even though the term has been used since 1992, there is still some confusion as to its definition. Quite simply, *geofoam* is the generic name for any foam material, usually expanded polystyrene, used in a geotechnical (above-grade or in-ground) application. Ground stabilization, embankment, or other ground-fill applications where a lightweight fill material is required can use geofoam to reduce stresses on underlying soils. Geofoam is now recognized worldwide as a geosynthetic product category in the same sense as geotextiles, geomembranes, geogrids, etc.[2] (Fig. 11.1).

## Expanded Polystyrene (EPS)

Polystyrene, a thermoplastic polymer, is manufactured for building insulation by extrusion or molding. Extruded polystyrene (XPS) was formerly called *extruded expanded polystyrene* (XEPS) foam

**Figure 11.1** Geofoam. (*R-Control Building Systems*)

board. It is created by the process of extrusion, which results in fine, closed cells that contain a mixture of air and refrigerant gas. Extruded polystyrene is discussed in the next section.

The other manufacturing process is molding, which produces coarse, closed cells containing air. Molded expanded polystyrene (MEPS) foam board, now called *expanded polystyrene* (EPS), can be molded into many everyday items such as coffee cups, coolers, protective cushioning for shipping materials, or insulation boards for construction applications. This closed-cell material, often referred to as *beadboard* in construction jargon, is less expensive than extruded polystyrene and generally is white in color.

EPS is used for a variety of building applications. These include cavity wall insulation, exterior insulation and finish systems (EIFS), exterior sheathing, perimeter insulation, and underslab insulation. Low-slope roof applications include flat or tapered roof insulation for built-up roof systems and ballasted, mechanically attached, or fully adhered single-ply membrane roof systems. Specialty products also include cores for structural insulated panels and concrete masonry unit core inserts (Fig. 11.2).

### Product description

EPS is a molded, closed-cell plastic made from petrochemicals derived from crude oil and natural gas. EPS starts out as unexpanded polystyrene beads containing the blowing agent pentane and flame-retardant additives. In a vessel, the beads are exposed

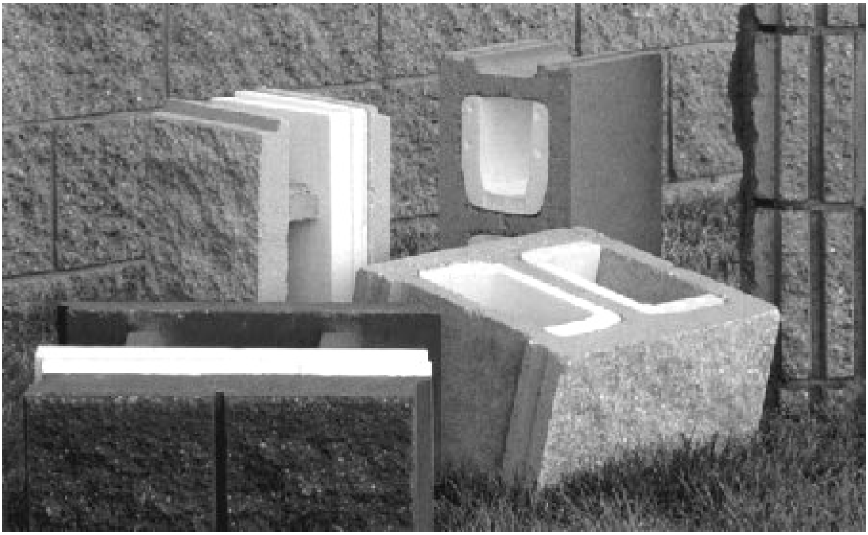

**Figure 11.2** CMU core inserts. (*Korfil*)

to heat (steam) and are expanded from 30 to 50 times their original size. Following a stabilization period, the beads are injected into a mold and, under more heat and pressure, are further expanded and fused into blocks. After curing, the blocks are cut into the required sizes with hot-wire cutting equipment. The wires are electrically heated to over 400°F. The wires are drawn down through the block to achieve the desired length and width. The blocks are then pushed through additional hot wires via a conveyer to achieve the desired thickness.

EPS is a lightweight, strong, resilient, noncorrosive, dimensionally stable material that does not cause skin irritation. Typically, expanded polystyrene has a lower R-value than extruded polystyrene because of its lower density and because it does not contain refrigerant gas. The main advantage of this board over extruded polystyrene is that it typically costs 40 percent less.[3]

EPS is manufactured in varying densities, from less than 1.0 lb/ft$^3$ to over 2.0 lb/ft$^3$ depending on the application. The high-density board is more moisture-resistant and can be used on the exterior of a foundation, provided the surrounding soil is dry and sandy. EPS foam used for roofing materials must be of sufficient density to resist damage from foot traffic (Fig. 11.3).

EPS is water-resistant, although the spaces between the foam beads can absorb water. When used as a sheathing, it is not

**Figure 11.3** EPS below grade. (*R-Control Building Systems*)

considered a vapor barrier. Typical water vapor permeance for 1" of material ranges from 5.0 for the low-density foams to 2.0 for the high-density materials. Although EPS provides a high level of moisture resistance and breathability, recommended design practices for walls and foundations should be followed in the selection of vapor and moisture barriers for severe exposures. A vapor diffusion retarder is necessary if water transmission through the insulation might present a problem for the user.

Although EPS is affected by and possibly can deteriorate from contact with organic solvents, their vapors, and solvent-based adhesives, it can be used for specific low-slope roofing systems. Compatibility always should be confirmed. For example, only low temperature bitumens can be applied to the boards. Cover boards are necessary in asphalt or adhered systems to protect the insulation.[4]

## R-value

EPS thermal insulation meeting American Society for Testing and Materials (ASTM) C578 type I (0.9 lb/ft$^3$ minimum density) has a typical R-value of 3.8 per inch, whereas the higher-density type IX (1.80 lb/ft$^3$) boards are approximately 4.35 per inch. Board thickness ranges from $^1/_2$ to 36", and lengths up to 24 ft are available depending on the supplier and end use (Fig. 11.4).

*Stable* or *stabilized R-value* refers to the quantitative ability of a foam insulation material to retain its as-manufactured R-value. Over time, some foam insulations lose their blowing agent and with it up to 25 percent of their R-value. This process is called *thermal drift*. As long as the EPS foam is kept dry, the R-value is permanent because its cellular structure contains only stabilized air.[5] Even if allowed to absorb some moisture, it appears that EPS retains its R-value.

# R-Value* at 40° and 75° F

Insulation Only

| Thickness | Standard Board Size | **AFM Type I EPS (Nom. 1.00 pcf) 40° | 75° | AFM Type VIII EPS (Nom. 1.25 pcf) 40° | 75° | AFM Type II EPS (Nom. 1.50 pcf) 40° | 75° | AFM Type IX EPS (Nom. 2.00 pcf) 40° | 75° |
|---|---|---|---|---|---|---|---|---|---|
| 1/2" | 4' x 8' or 4' x 9' | 2.08 | 1.93 | 2.13 | 1.96 | 2.28 | 2.09 | 2.38 | 2.18 |
| 3/4" | 4' x 8' or 4' x 9' | 3.13 | 2.89 | 3.19 | 2.94 | 3.41 | 3.13 | 3.57 | 3.26 |
| 1" | 4' x 8' or 4' x 9' | 4.17 | 3.85 | 4.25 | 3.92 | 4.55 | 4.17 | 4.76 | 4.35 |
| 1 1/2" | 4' x 8' or 4' x 9' | 6.26 | 5.78 | 6.38 | 5.88 | 6.83 | 6.23 | 7.14 | 6.53 |
| 2" | 4' x 8' or 4' x 9' | 8.34 | 7.70 | 8.50 | 7.84 | 9.10 | 8.34 | 9.52 | 8.70 |
| 2 1/2" | 4' x 8' or 4' x 9' | 10.43 | 9.63 | 10.63 | 9.80 | 11.38 | 10.43 | | |
| 3" | 4' x 8' or 4' x 9' | 12.51 | 11.55 | 12.75 | 11.76 | | | | |
| 3 1/2" | 4' x 8' or 4' x 9' | 14.60 | 13.48 | | | | | | |
| 4" | 4' x 8' or 4' x 9' | 16.68 | 15.40 | | | | | | |

**Design Consideration:** System R-Values can be increased approximately 2.5 with the use of a bright foil laminate. A minimum 1/2" air space on the reflective foil surface of the sheathing is required to achieve this additional R-Value. (Reference: ASHRAE Handbook Fundamentals)

* R-Value means resistance to heat flow. The higher the R-Value, the greater the insulating power.

** Types designated by ASTM C 578 Specifcation Standard.

AFM EPS size and number of pieces per package vary. Check label on package. Manufacturer has fact data sheet on file and is available on request.

Board sizes supplied normally range from 4' x 8' to 4' x 9', up to 4" thick. Other sizes can be provided for special conditions as required.

**Figure 11.4** EPS R-values. (*R-Control Building Systems*)

Published data on EPS indicate that even at 7.0 percent moisture by volume, EPS retained 90 percent of its R-value. (Most listings for absorption by volume list about 3 percent as the normal limit.[6])

### Limitations

EPS can degrade when exposed to sunlight or temperatures over 180°F. It also must be protected from solvents, and only compatible adhesives and sealants should be used. If the insulation is to be used in the interior of a house, it needs to be covered with a fire-resistant material such as gypsum wallboard. EPS, although containing a flame-retardant additive, should be considered combustible and should not be exposed to an open flame or any source of ignition. Thin beadboard also can warp or chip easily, so it should not be used in high-use applications, such as movable window insulation.

### Environmental considerations

Most EPS products are actually 90 percent or more air, because it is the only rigid foam of insulation that has never been made with CFCs, HCFCs, or hydrofluorocarbons (HFCs) (verify with the specific manufacturer). During manufacture, polystyrene beads are expanded with pentane, a hydrocarbon that contributes to smog but is not implicated in ozone depletion or global warming. The pentane quickly diffuses out of the insulation and is replaced by air during the manufacturing process. To meet federal and state clean air requirements, several EPS manufacturers have redesigned their plants to collect and control up to 95 percent of the pentane used in production. BASF Corporation also has developed a low-pentane EPS bead formulation.[7]

EPS products also can be made from recycled EPS. This is accomplished by crumbling the old EPS foam into small particles, mixing it with virgin prepuff, and remolding the material into usable products. Most clean EPS waste can be recycled into cushion packaging, but because of building code requirements, waste EPS construction products can only be recycled into noninsulation building applications.

EPS is inert and nontoxic. The styrene used in polystyrene insulation is identified by the EPA as a possible carcinogen, mutagen, chronic toxin, and environmental toxin. Furthermore, styrene is produced from benzene, another chemical with both environmental and health concerns.[7]

## Extruded Polystyrene (XPS)

Another board insulation is made of extruded polystyrene (XPS) and often referred to as foamboard. XPS is a homogeneous product consisting of fine, closed cells containing a mixture of air and an insulating gas also used in other industries as a refrigerant. Available brands of extruded polystyrene are easily recognized by their colors: blue, pink, green, or yellow.

XPS is often referred to by one of its proprietary names, *Styrofoam*. Styrofoam extruded polystyrene insulation was developed originally by the Dow Chemical Company in the early 1940s as a flotation material in liferafts and lifeboats.

XPS is manufactured by pushing freshly expanded foam through an extrusion die. A number of edge configurations are available, some straight and some with a profile designed to interlock to ensure a continuous thermal break and help to seal the joints between the panels.

XPS is used for insulating foundations and concrete slabs, for residing underlayments, and for exterior wall sheathing, for protected membrane roof applications, and as the insulation for structural insulating panels (SIPs) and insulating concrete forms (ICFs) (see Chap. 15). It is also installed either on the interior or exterior where space is limited such as cathedral ceilings, flat roofs, etc. (Fig. 11.5).

### Product description

The creation of XPS foam begins when solid polystyrene crystals, along with special additives and a blowing agent that forms gas bubbles, are fed into an extruder. Within the extruder, the mixture is combined and melted under controlled conditions of high temperature and pressure into a viscous plastic fluid. The hot, thick molten mass is then forced in a continuous process through a shaping die. As it emerges from the die, it expands to a foam and is shaped, cooled, and cut as required.

XPS products can range in thickness from $^1/_2$ to 3" (or thicker for SIPs applications) and in board sizes of 2' × 8', 4' × 8', and 4' × 9' for a variety of sidewall, below-grade, and roofing applications. Total R-values per board can range from 2.8 to 20 depending on board thickness. The R-value of XPS is R-5, regardless of density. A number of edge treatments such as square edge, ship lap, and tongue and groove are available. Polyethylene facers are also available for additional board durability.


**Figure 11.5** Extruded polystyrene. (*Tenneco*)

Thin $^1/_4$ to $^3/_8$" XPS insulation products are also produced in a fanfold bundle design. Typically, 4' $\times$ 50', the fanfolded bundle unfolds to cover large areas quickly, resulting in reduced overall installation time. These also can be sandwiched between two perforated plastic capsheets or with a laminated inner layer for use as exterior sheathing in residing applications (Figs. 11.6 and 11.7).

Not only is XPS naturally hydrophobic (no chemical affinity for water), but its fine, closed-cell structure and smooth, continuous skin also help the foam resist moisture. This property also results in resis-


**Figure 11.6** Fanfolded bundle. (*Pactive*)

tance to cell damage that would be induced by freezing/thawing temperature fluctuations if water were present in the cells.

Although XPS is more expensive than EPS, it has a higher R-value, lower water absorption levels, and a higher compressive strength than EPS. The high-density board product can handle relatively high pressures such as applications under concrete slabs.

**Figure 11.7** Residing underlayment. (*Pactive*)

The foamboard does not cause skin irritation, and when board joints are properly sealed, XPS can act as an air barrier.

XPS is also used for low-slope roofing systems. XPS will deteriorate from contact with organic solvents and adhesives, and only low-temperature bitumens can be applied to the boards. Cover boards are necessary in asphalt or adhered systems to protect the insulation.[4]

### R-value

Unlike EPS, the R-value of XPS does not depend on the density of the material. The R-value is consistently 5.0 per inch.

### Limitations

XPS can be attacked by many petroleum-based solvents in adhesives, paints, stains, water-repellent or preservative coatings, and bituminous waterproofing. Solvents should be allowed to evaporate before touching the foam.

XPS must be protected from sunlight because, over time, ultraviolet (UV) light degrades it. When installed on the job and left exposed to the sun, the surface of XPS becomes yellow and dusty. (The dust can be brushed off before installation.)

### Environmental considerations

The styrene used in polystyrene insulation is the same material used in many household products such as disposable foam dinner plates. Identified by the EPA as a possible carcinogen, mutagen, chronic toxin, and environmental toxin, the relatively small quantities associated with building occupant exposure should not be a cause for concern. It is produced from benzene, another chemical with both environmental and health concerns.[7]

### Fire resistance

XPS softens at 165°F and melts at around 200°F. It is flammable and gives off noxious fumes when burned. XPS must be covered with a fire-rated sheathing when used in interior applications.

### Installation and applications

The issue of thermal bridging in steel-framed walls has been attributed to the reduction of whole-wall R-values in these applications. In a study performed by National Association of Home Builders (NAHB) Research Center, R-values measured for steel-framed wall assemblies (including gypsum wallboard and plywood sheathing) were lower than values typical for similar wood-framed walls. For example, a 6" steel stud wall with R-19 batt insulation measured only R-10.1, demonstrating a 47 percent loss in insulation value at the center of the cavity. The wood-framed walls only lost 10 percent of the nominal insulating value.[8]

Tests show that foam sheathing helps block the rapid heat loss that would otherwise cut in half the value of cavity insulation. In fact, the application of foam sheathing increased the insulating value of the steel stud wall by more than its rated R-value. For example, the test wall has an R-value of 10.1. Adding 1" of XPS with an R-value of R-5.0 increased the wall's R-value to R-16.2. The efficiency of the 1" XPS board was 122 percent. By blocking the thermal bridge, foam sheathing restores some of the insulating value of cavity insulation that had been bypassed by the steel studs.[8]

In comparison, foil-faced polyisocyanurate insulation had a notably lower thermal efficiency. Another test wall increased from R-10.1 to R-17.1, whereas the nominal value of the polyisocyanurate board itself was listed at R-6.8. The foil facer may be the reason the board's efficiency rating was a slightly lower 102 percent efficiency rating.[8] (Fig. 11.8).

Placing foam tape on the face of the studs also was studied. The tape increased the insulating value by only R-0.5. It started out at $^5/_{16}$" and was compressed directly under the screw to only $^1/_8$". There appears to be little to gain by increasing the thickness of the wall cavity. The best-performing wall measured in this study was $3^5/_8$" thick with an R-11 batt and 2" of XPS insulation. It surpassed a wood-framed R-19 wall by a value of R-0.5.[8]

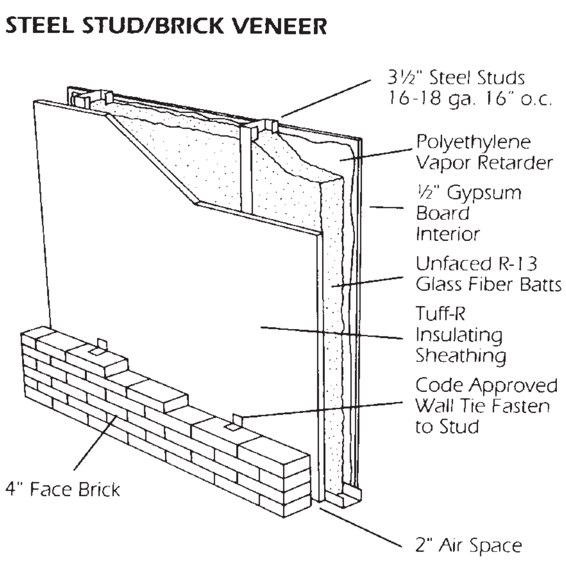


**Figure 11.8** Wall assembly. (*Celotex*)

### Cold spots and streaking

Tests show that foam sheathing reduces the potential for dust streaking on the inside surface of walls in northern climates. On the test wall with only plywood sheathing, the gypsum wallboard temperature remained constant over the insulated cavity. However, it began dropping rapidly about 2" from the edge of the stud. Directly over the stud the gypsum wallboard temperature was 10°F lower than the temperature over the cavity. The wall with 2" of XPS sheathing showed only a 2.5°F temperature drop from cavity to stud. These cold spots sometimes promote condensation on the inside wall surface. Dust attracted to the water causes streaks, sometimes called *ghosting*.[8]

The temperature of the interior wall surface plays a major role in this process. The report cited previous research indicating that slight ghosting can be expected when the wall temperature over the stud is 3.3°F lower than the temperature over the cavity, and that severe streaking occurs when the temperature is 8°F lower. In this test, walls with plywood sheathing showed 8 to 10°F lower temperatures over the studs, making them likely to develop streaks. The report states that no ghosting problems would be expected in any of the walls with insulated sheathing. However, walls with 1" of XPS showed a temperature drop of about 4 to 5°F. If a 3.3°F temperature difference is the magic number, then these walls may face some risk for streaking.[8]

## Polyurethane

### Product description

Polyurethane (PUR) plastics were developed originally in the 1930s and were used primarily in military and aerospace applications until the 1950s. Their application in consumer and industrial products became popular in the late 1950s, when they were used mostly for cushioning (flexible foam), coatings (polyurethane modified oil-based), and thermal insulation applications (rigid foam). In the 1970s, there was a growth in the use of rigid PUR foam thermal insulation in refrigerators, as panel products, and in spray-applied insulating foam. Development of new chemical recipes and catalysts in Europe and the United States resulted in a next-generation product called *polyisocyanurate foam* (PIR). Also called *polyiso foam,* it first appeared on the U.S. market in the mid-1970s.

PUR and PIR insulations are manufactured by chemical reactions between polyalcohols and isocyanates. Both are a closed-cell board product in which the cells contain refrigerant gases instead of air. The boards are usually double-faced with foil or sometimes come bonded with an interior or exterior finishing material. The boards must be protected from prolonged exposure to water and sunlight, and if used in an interior application, they must be covered with a fire-resistant thermal barrier material such as gypsum wallboard.

Thermal drift is an issue with each of these foams. Over the first few years after installation, the R-value of the foam drops as the gas slowly escapes from the cells and is replaced by ambient air. Experimental data on polyurethane foams indicate that most thermal drift occurs within the first 2 years after manufacture. Foil and polymer sheet facers on foam boards can inhibit the escape of gas from the cell structure. Laboratory and field testing data suggest that the stabilized R-value of rigid foam with metal foil facers remains unchanged after 10 years, usually 7.1 to 8.7 per inch.[9]

Rigid PUR and PIR foams will, when ignited, burn rapidly and produce intense heat and dense smoke and gases that are irritating, flammable, and/or toxic. As with other organic materials, the most significant gas is usually carbon monoxide. Thermal decomposition products from PUR foam consist mainly of carbon monoxide, benzene, toluene, oxides of nitrogen, hydrogen cyanide, acetaldehyde, acetone, propene, carbon dioxide, alkenes, and water vapor.[1]

## Polyisocyanurate

Polyisocyanurate (PIR) rigid insulation is actually a mixture of rigid PUR and PIR. By incorporating the chemical benefits of both products, PIR is sometimes referred to as PUR/PIR foam. Other monikers include *iso board* and *polyiso*. Most commonly sold with a shiny foil facer on one or both sides, PIR foam board rigid insulation has the highest R-value of any common insulation material. Although somewhat water resistant, PIR is not recommended for below-grade applications. PIR products must meet the requirements of ASTM C1289, “Standard Specification for Faced Rigid Cellular Polyisocyanurate Thermal Insulation Board.”

### Product description

PIR is a thermoset, closed-cell, rigid foam plastic insulation that is manufactured through a controlled chemical reaction. Liquid raw materials expand and are molded into boards, and facers are applied to the top and bottom surfaces. Facers provide strength, improve rigidity, enhance thermal performance, and help limit thermal drift. These facers are usually asphalt-saturated organic and inorganic felts, inorganic glass fiber mats, or aluminum foil and are selected to enhance the end use of the foam (Figs. 11.9 and 11.10).

For example, foil-faced PIR is used most commonly as wall sheathing in residential construction or in masonry cavity wall construction. The facers protect the foam core from UV degradation. Roof applications rely on glass fiber facers or glass fiber–reinforced organic felt facers. Most commonly supplied as 4' × 8' or 4' × 9' sheets in a range of thickness from 1/2 to 4", PIR board insulation is

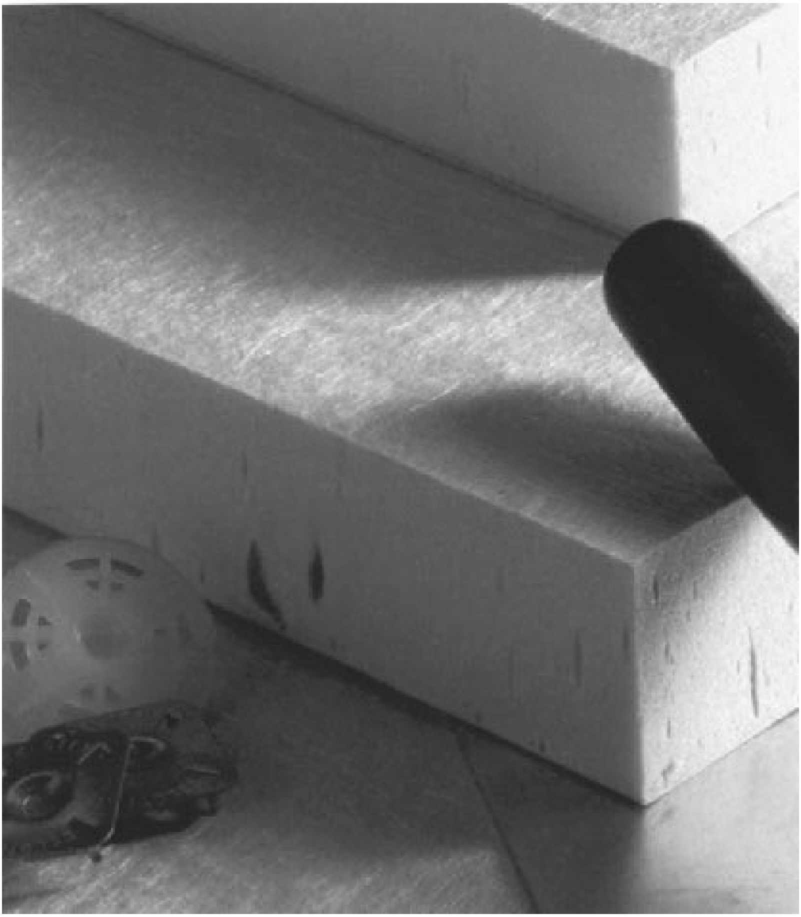

**Figure 11.9** Polyisocyanurate core with fiberglass mat. (*Celotex*)


**Figure 11.10** Foil-faced polyisocyanurate sheathing. (*Celotex*)

moisture-resistant, is classified as a water-repellent panel sheathing, and is resistant to the solvents often found in construction adhesives.

It is also a cost-effective roof insulation product because it is approved for installation directly to the steel roof deck without the need for a thermal barrier. Although not as critical to residential applications, PIR is stable over a large temperature range (−100 to +250°F). It can be used as a component in roof systems that use hot bitumen, but the insulation material will blister if the hot asphalt product is applied directly to it. As mentioned earlier, PIR with glass fiber or organic felt facers will lose thermal resistance over time, which must be taken into account when designing the roofing system.[4]

### R-value

PIR is a closed-cell foam that contains a low-conductivity gas (HCFC) in the cells. Over time, the R-value of the foam drops as some of the gas escapes and air replaces it. As mentioned earlier, *stabilized R-value* is a term used by some manufacturers to accurately represent the long-term R-value of the installed board product. The thicker the product, the longer it takes to stabilize. Impermeable facers such as aluminum foils or patented coated-paper facers used on PIR products are essential in maintaining a relatively high, aged R-value. For example, foil-faced PIR boards have R-values that range from 7.2 to 8.0 per inch. Glass-fiber-faced PIR sheathing, such as that used as an EIFS or roofing substrate, has an R-value of 5.6 per inch.[5]

#### Limitations

More expensive than most other types of insulation, PIR boards must be protected from prolonged exposure to sunlight or water (unless facers are used), and when they are used in an interior application, a fire-resistant covering generally is required.

#### Environmental considerations

Recycled material is used in many PIR products. The Polyisocyanurate Insulation Manufacturers Association (PIMA) says that almost all products today meet the EPA procurement guidelines for federally funded buildings, which call for a minimum 9 percent recycled content. Rather than using recycled foam, however, manufacturers buy polyol chemical components with recycled content. The foil facers used on PIR products are typically 70 to 80 percent recycled aluminum. The industry reportedly used 20 to 30 million pounds of recycled postconsumer chemicals in 1993.[7]

#### Limitations

In 1992, most PIR insulation manufacturers changed their products' blowing-agent components from a chlorofluorocarbon (CFC-11) to a hydrochlorofluorocarbon (HCFC-141b). PIR insulation manufacturers will again need to find a suitable blowing-agent replacement because the EPA will restrict the production of HCFCs, including HCFC-141b, as of January 1, 2003. It is unclear as to what specific blowing agent(s) PIR insulation manufacturers will use, or when products using new blowing agent(s) will enter the marketplace. Some manufacturers are test marketing products manufactured with hydrocarbon blowing agents. The physical properties and field performance of PIR insulation using the next generation of blowing agents(s) are also largely unknown at this time, although preliminary data show comparable performance with current products.

#### Fire resistance

PIR insulation, a thermoset material, stays intact during fire exposure by forming a protective char layer and remaining in place during the tunnel test (the tunnel test is the ASTM E84, "Standard Test Method for Surface Burning Characteristics of Building Materials," which assesses the spread of flame on the surface of a material). Nevertheless, most PIR sheathing products cannot be left exposed and must be covered with an interior finish of a minimum 1/2" gypsum board or equivalent thermal barrier. Some manufacturers produce PIR panels with a 1.25-mil (up to 16.5 mil) embossed acrylic-coated aluminum sheet laminated to 1.0-mil aluminum sheets on each side of the PIR core that are rated for interior exposure. These panel types are used primarily in industrial and agricultural buildings but are also commonly installed on the interior of basement walls and may be left exposed.

## Perlite Board

### Product description

As discussed in Chap. 7, perlite is a granular-type insulation made from a naturally occurring silicous rock quarried mainly in the western United States. Perlite is different from other volcanic glasses because when the crushed ore is heated to a suitable point in its softening range, it expands from 4 to 20 times its original volume.

Used for low-slope roofing systems, perlite insulation is manufactured as a rigid board that is composed of these expanded volcanic minerals combined with organic fibers and binders. An asphalt emulsion is used to treat the top surface to inhibit the absorption of bitumens. Perlite is compatible with bitumens and other adhesives, fire-resistant, dimensionally stable, and compatible with other roofing materials. The board will withstand impact, but care must be taken when handling the boards because they can break easily. The thermal resistance of the insulation is stable, but it has a relatively low R-value. Typically, perlite is not used with ballasted, loose-laid membranes because the board will readily absorb moisture.[4]

## Wood Fiber

### Product description

Fiberboard, historically called *structural insulating board,* is made primarily from wood, cane, or other organic fibers combined with a variety of binders.[10] Fiberboard was popular during the two decades after World War II. During manufacture, the raw material is reduced to a pulp, and then the fibers are chemically treated with waterproofing materials. Some boards are impregnated with asphalt either during or after the manufacturing process for moisture resistance. Sheet size is typically $^1/_2$, $^{25}/_{32}$, or 1", with standard lengths of 8 ft. Historically, this board type was used for interior finishes, sheathing, roof insulation, and roof deck planks.[10]

When used for low-slope roofing systems, the surfaces of the boards can be left plain, coated with asphalt, or impregnated with asphalt. Wood fiberboard is compatible with bitumens and adhesives, is impact-resistant, and is dimensionally stable. The material is flammable and must be protected from an ignition source. This insulation will hold water and must be protected from moisture. The thermal resistance of wood fiberboard is stable, but the R-value is relatively low.[4]

## Mineral Fiber

### Product description

Although the term *mineral fiber* historically refers to rock wool and slag wool, fiberglass products are also included in this category. These are also called *man-made vitreous fibers* (MMVFs), referring to the glassy, noncrystalline nature of these materials. A binding agent helps form the fibers into a rigid insulation board to be used for low-slope roofing systems. A glass-mat facer is applied to the top surface of the board. Mineral fiber insulation is compatible with bitumens and other adhesives, fire-resistant, dimensionally stable, and compatible with other roofing materials. Mineral fiber insulation is not as sensitive to moisture as fiberglass insulation because the separate mineral fibers absorb (but retain) only minimal moisture.

Fiberglass insulation board is a slightly modified product. After bonding fiberglass into a board shape, asphalt is used to bond a kraft paper facer to the top surface of the board. The paper facer will deteriorate if wetted, and the fiberglass board will retain water, reducing the thermal value.

The thermal resistance of mineral fiber is stable and has a relatively high R-value compared with other insulation materials. Mineral fiber board has a low compressive strength and is not recommended for loose-laid, ballasted roofing systems or mechanically fastened roofing membranes.[4]

## Phenolic Foam

### Product description

Based on research conducted for this book, the phenolic foam insulation board industry in both Canada and the United States declined rapidly and essentially disappeared in 1993–1994. Incidents of deck corrosion have been reported in cases where the insulation is in direct contact with steel roof decks and moisture is present.[11]

Phenolic foam board products were manufactured from phenol formaldehyde resin as an open- or closed-cell product. For several years, a high-R-value phenolic rigid insulation board was on the market. This closed-cell insulation had a typical R-value of 8.3 per inch. Because the foam boards often shrank, warped, or decomposed, manufacturers stopped making them.[12]

## Cellular Glass

### Product description

Cellular glass insulation is a rigid roof insulation board composed of heat-fused, closed glass cells blown with hydrogen sulfide. Available for low-slope roofing systems, the boards typically have kraft paper facers applied to the surfaces after the material is formed. Cellular glass is compatible with bitumen and other adhesives and is fire-resistant. The board itself is moisture-resistant, but the paper facers, to which other materials are adhered, will deteriorate if wetted. The boards are rigid and require care in handling so that they do not crack or spall. The thermal resistance of cellular glass is stable but not as high as it is for other insulation materials.[4]

## Composite

### Product description

Composite board insulation is usually is made of two different insulation materials that are laminated together. Mainly used for low-slope roofing, a typical example of a composite board is PIR or EPS combined with perlite or wood fiberboard. Composites also can incorporate insulation with other roofing materials, such as PIR laminated to a nailable substrate such as oriented strandboard.

The advantage of using a composite board is that it combines the benefits of two different materials in one board. Composites generally are compatible with bitumens and are impact-resistant. The fire, moisture, and thermal resistance can vary depending on the materials used.[4]

## Contoured Foam Underlayment

### Product description

Contoured foam underlayment (CFU) is a drop-in rigid foam insulation product that is custom made to fit snugly behind different styles of vinyl siding. This new product is intended to improve the rigidity of vinyl siding as well as its resistance to denting and warping. CFU typically is made from XPS foam that provides an R-value of 2.8 to 3.3 per inch and has a permeance rating of 5 (it is not a vapor barrier). Installation is relatively simple because the CFU is placed behind the siding and cut to size as necessary. The siding is snapped into its final position and nailed to the structure in accordance with the siding manufacturer's recommendations.

CFU is also available from some manufacturers as an integrated, fused vinyl siding and foam product. The installation is similar to conventional siding except that two courses go up at once and special accessories are used for corner and trim details.

## Compressed-Straw Panels

### Product description

Compressed-straw panels are not new. The process for producing compressed agricultural fiber (CAF) panels was invented in Sweden in 1935 by Theodor Dieden and later developed into a commercial product in Britain under the name *Stramit* by Torsten Mossesson in the late 1940s. Although the original patents have expired on the technology for producing compressed straw panels, numerous companies using the Stramit process are popular in Europe and Australia.

As revealed during the short-lived U.S. manufacture of Stramit panels, straw is compressed under a high temperature of approximately 390°F. The straw fibers become limp and form around each other, essentially "bonding" together without any adhesives. The panels ranged in thickness from 2 to 4" and were faced with heavy-weight kraft paper. Most of the products were prerouted for electrical wiring, and clips were sold to join panels securely together.

Several companies that have produced compressed straw panels and straw core stressed-skin panels have had difficulty continuing operations due to exaggerated R-values, inflated shipping costs, and poor marketing strategies. Nevertheless, cabinet carcasses, carpet underlayment, and interior sheathing products have started to achieve a small market share in the United States. It remains to be seen if a viable straw-based insulation board product will become a mainstay in residential construction.

## Exterior Insulation and Finish Systems

Exterior insulation and finish systems (EIFS) are multilayered exterior wall systems that are used in both commercial and residential construction. Sometimes referred to as *synthetic stucco,* the basic five primary components include a rigid insulation board, an adhesive to attach the insulation board to a suitable substrate, a reinforcing mesh that is embedded in a base coat over the insulation board, and a textured finish. EIFS (pronounced "eefs" or "eefus") were developed in Europe in the early 1950s and were introduced to the United States around 1969. They were first used on commercial buildings and later on homes. EIFS currently account for about 17 percent of the U.S. commercial exterior wall market and about 3.5 percent of the residential wall market (Fig. 11.11).

### Product description

Direct applied systems do not incorporate the use of rigid board insulation and are not within the scope of this book. Also polymer-based, the synthetic stucco is applied to a variety of water-durable substrates such as concrete masonry units and concrete.

There are two fundamental wall construction concepts of EIFS that will be discussed here. These are known as the *barrier-type method* and the *drainable type.* Although variations exist between proprietary barrier-type and drainable-type systems, an EIFS typically consists of the following three components:

1. A rigid insulation board, which is secured to the exterior wall surface with a specially formulated adhesive and/or mechanical attachment
2. A durable, water-resistant base coat, which is troweled on top of the insulation and reinforced with fiberglass mesh (or scrim) that is embedded in the wet base coat for added strength
3. A durable finish coat material, an acrylic polymer that usually contains an integral pigment and sand or marble aggregate and

**Figure 11.11** EIFS. (*Dryvit*)

is troweled over the base coat, providing the finished exterior surface, which can be applied in a wide variety of colors and textures

For a barrier-type EIFS, the base coat, finish coat, and any related building sealants (e.g., sealants around windows) are intended to create a surface that serves as a barrier against all water penetration. Any water that penetrates this barrier and infiltrates the wall assembly effectively has leaked into a building's interior. This design is the original EIFS concept that was brought to the United States and is the most common method used on existing EIFS-clad buildings. As discussed later in this chapter, recent construction flaws have exposed a number of weaknesses in the barrier-type system. Even the United States Gypsum Company recently released a report that stated "'barrier' EIFS construction is not practical or reliable for residential or commercial construction."[13]

The drainable-type EIFS installation, also known as a *water-managed* or *rain-screen system,* is similar in concept to masonry cavity wall drainage construction. This method is growing quickly in popularity and is even required by some building codes. Some proprietary systems use an insulation board manufactured with drainage channels that is installed against an exterior wall substrate or weather-resistive barrier. Other EIFS may use some other type of material over the weather-resistive barrier and behind the insulation board to provide a drainage plain. These materials could include a drainage fabric, a metal or plastic lath, or a series of vertical spacers, similar to small furring strips, to remove any water that penetrates the exterior skin (Figs. 11.12 and 11.13).

Drainable-type EIFS are designed so that any incidental water that penetrates the exterior barrier surface drains down the drainage channels, fabric, or membrane and escapes from the base of the wall (or any horizontal obstruction) before it can leak into a building's interior. A drainable-type EIFS is flashed and weeped and features special construction details such as drainage tracks, drip edges, etc. to prevent moisture from entering in or around window openings (Figs. 11.14 and 11.15).

The insulation board used in EIFS can be EPS, XPS, or PIR. Attachment of the insulation board, whether by mechanical fastening or by adhesives, will be per manufacturer's installation instructions. Proprietary systems will outline acceptable substrates to be used. These include cement board, exterior-grade gypsum sheathing, glass-mat-faced gypsum sheathing, exterior-grade plywood, or exterior-grade oriented strandboard (OSB).

Most EIFS are formulated with an integral pigmented (colored) acrylic-based finish coat that provides resistance to fading, chalking, and yellowing. Although surfaces can be painted, the integral colors are designed to maintain their original appearance over time. An EIFS is very flexible in order to avoid the unsightly cracking problems that are common with stucco, concrete, and brick exteriors. An EIFS is usually about $4 to $6 per square foot.

### Legal history

The barrier-type EIFS was plagued by large-scale moisture intrusion problems in the 1990s in various locations around the country. Few locales received more attention than those in Hanover County and Wilmington, North Carolina, the sites of the initial discovery of moisture damage problems in 1995. Although damage was reported across the United States, experts believe the accelerated number of housing starts in the Wilmington area may have overwhelmed homebuilders' ability to maintain quality control, thereby leading to the use of substandard building components and unqualified applicators using non-code-approved EIFS.

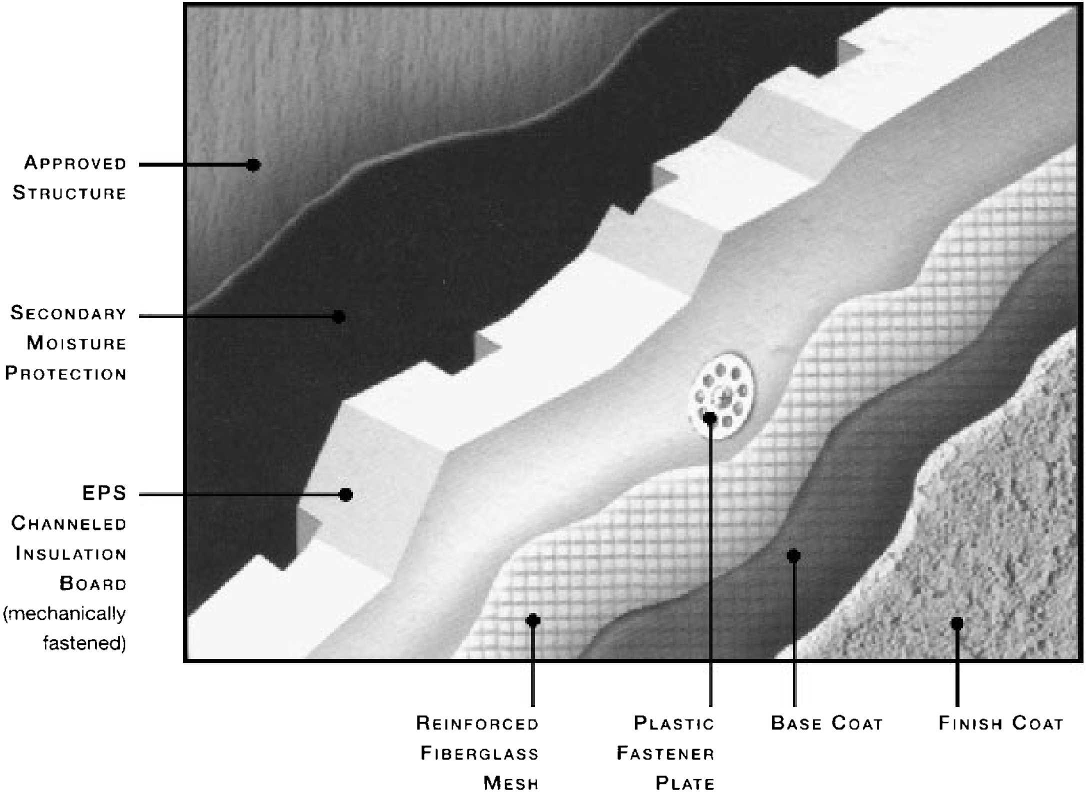


**Figure 11.12** Drainable type—grooved EPS. (*TEC Specialty Products*)

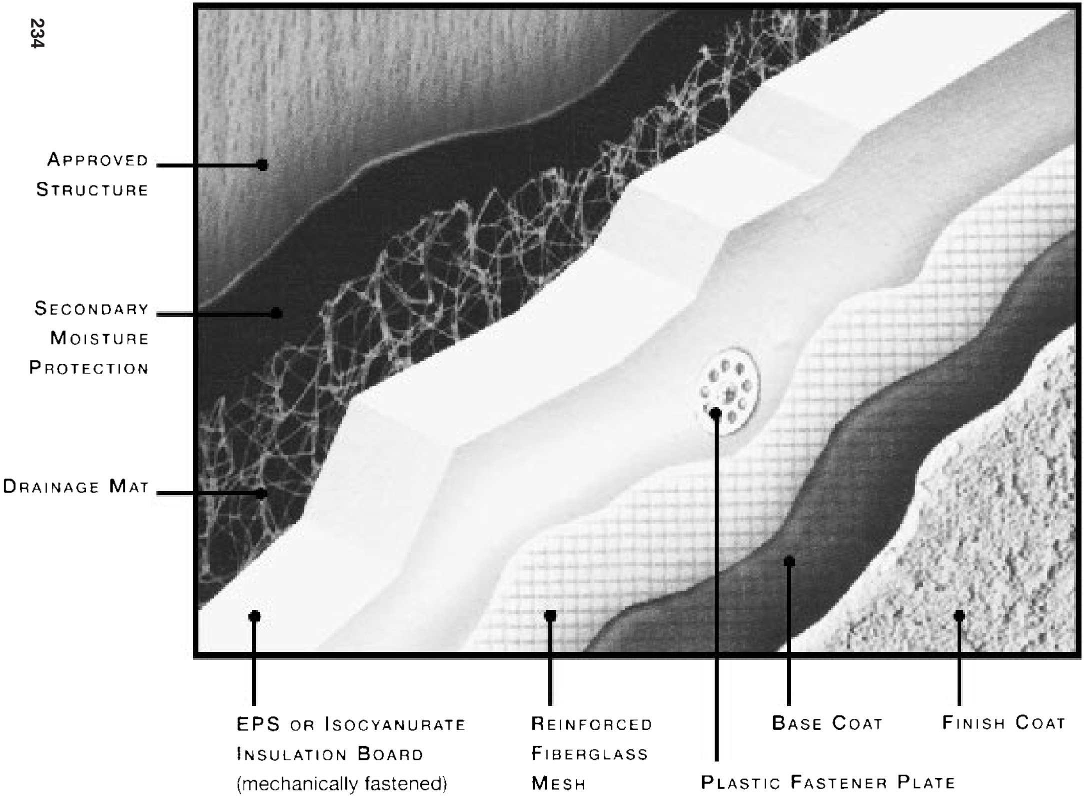


**Figure 11.13** Drainable type—drainage fabric. (*TEC Specialty Products*)

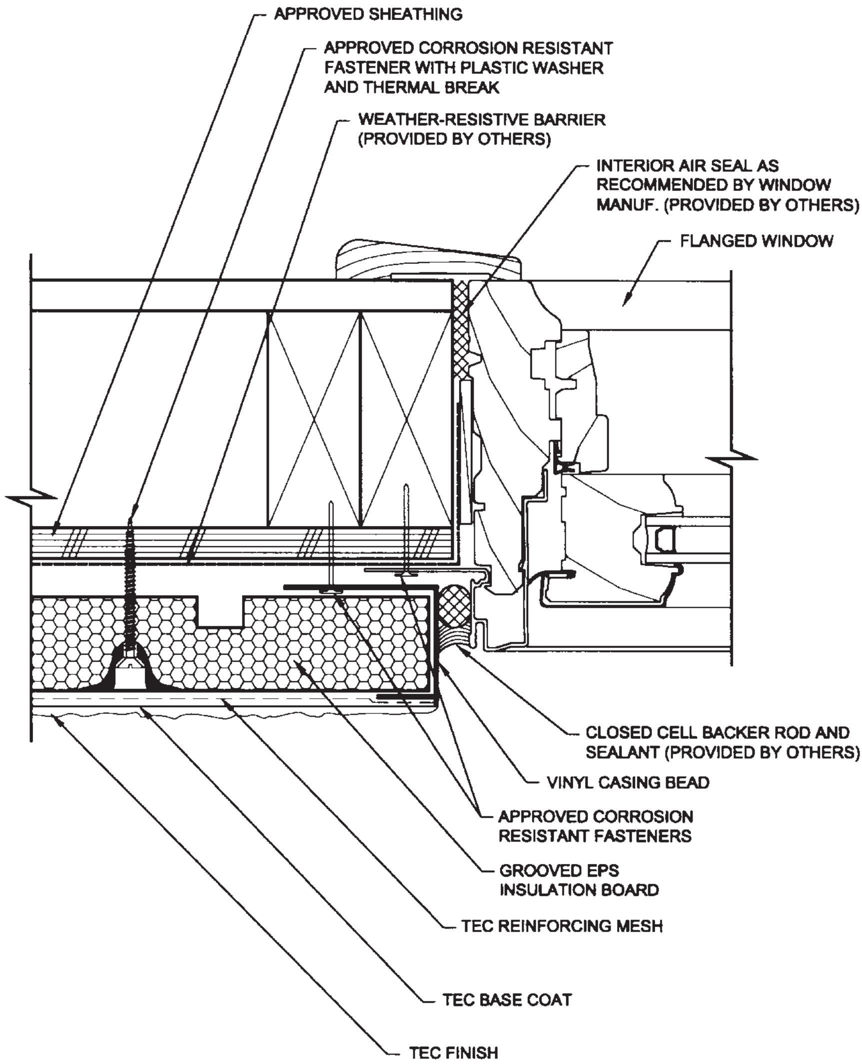


**Figure 11.14** Plan detail of grooved EPS at window jamb. (*TEC Specialty Products*)

The specific cause of the EIFS problem has been studied extensively by the National Research Council of Canada (NRCC). According to NRCC reports, wind-driven rain most commonly enters the waterproof barrier EIFS surface in and around windows and other penetrations and at wall-roof intersections. Because a barrier-type EIFS provides no means for allowing water to escape the wall cavity, escape occurs only through evaporation into the structure or through the breathable EIFS. If it is not allowed to

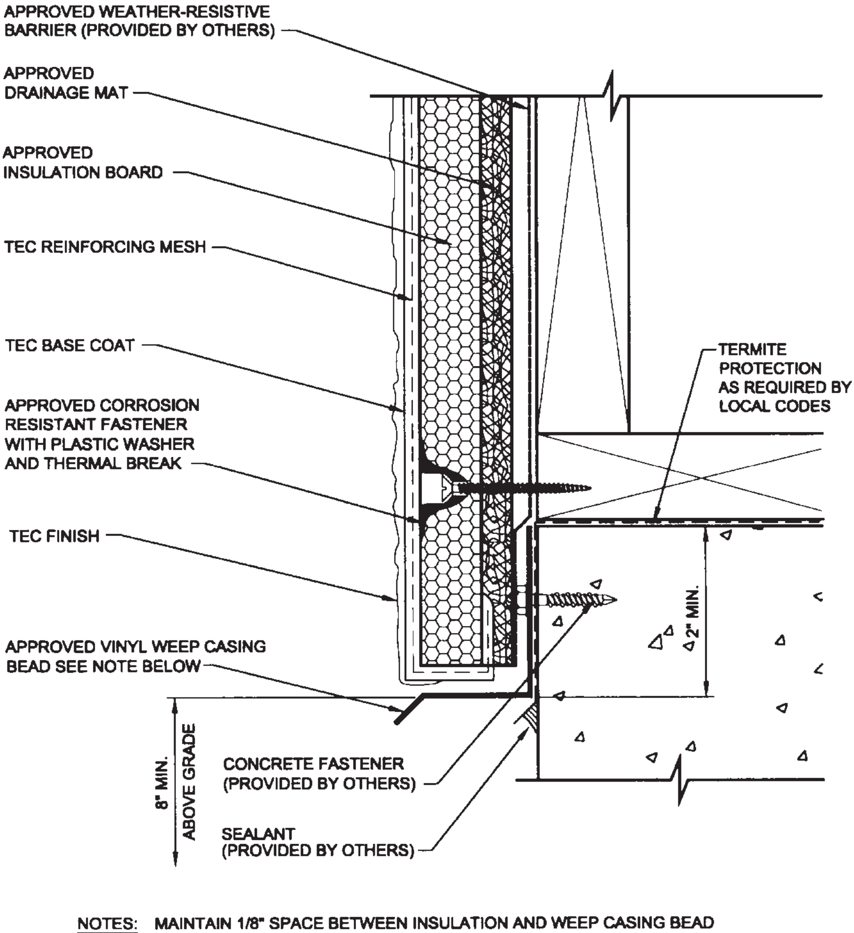


**Figure 11.15** Section detail of drainage fabric at foundation. (*TEC Specialty Products*)

evaporate, as was the case in Wilmington because of the unusual climatic conditions coupled with the state building codes, it can remain in the wall for extended periods of time and eventually damage and even rot wood framing, sheathing, and other moisture-sensitive building components.

The class-action lawsuits stemming from these problems typically involved the barrier-type EIFS that used insulation board over plywood, oriented strandboard, exterior-grade gypsum, or other nonmasonry substrate on an exterior wall assembly. Drainable systems that included a secondary weather barrier did not suffer the same problems incurred by the barrier-type EIFS.

**Limitations**

Problems associated with an EIFS include cracking, surface degradation, impact damage, inadequate closure (e.g., sealants at windows), and system delamination. Each of these problems can result in water leaking into a building's interior. The culprit does not appear to be the synthetic stucco finish, but the barrier-type EIFS. It is inevitable in building construction that water will always find a way into a wall assembly. It is when the water or moisture *cannot get out* that problems seem to occur.

There are a number of areas that are more prone to water intrusion in residential applications of EIFS. These include

1. Interfaces between an EIFS and dissimilar materials.
2. Window joints around the perimeter of a window.
3. Seams and joints in the construction of the window unit, such as jambs and the sill interface.
4. Ganged window units that are not factory mulled.
5. Roof terminations against the lower edge of a wall.
6. Chimneys, decks, and any other penetration of the EIFS. This includes the installation of cap flashing, cricket flashing at trapped valleys, and effective kick-out flashing for roof-to-rake wall intersections.
7. Missing, damaged, or deteriorated sealant between the EIFS cladding and windows and doors, and around electrical fixtures, electric meter bases, hose bibs, refrigerant lines, etc. (Annual inspections of all seals by the homeowner is a good idea.)
8. Using sealants that are not polyurethane- or silicone-based (ASTM C920, "Standard Specification for Elastomeric Joint Sealants.")
9. Using a high-pressure power washer. (Low-pressure washing, such as with a garden hose, may be used.)
10. Kick-out flashing (cants) at roof-to-wall intersections.
11. Diverter flashing or crickets around trapped valleys.
12. Inadequate flashing (flashing should "terminate to daylight").
13. Inability or lack of access for visual inspection and treatment of the foundation for pest control. (The termination of EIFS should always be above finished grade.)

Periodic maintenance should include a thorough check of the flashing and sealing to ensure that the building envelope remains watertight. Damaged or missing flashing should be repaired or replaced immediately; likewise, cracked or deteriorated sealants should be repaired immediately or removed and replaced. Periodic use of a moisture meter will test for moisture content.

### Installation standards and practices

To ensure long-term performance of an EIFS, the EIFS Industry Members Association (EIMA) recommends that the following steps be taken prior to and during construction:

1. Selection of an EIMA member manufacturer who can provide technical support, documented product and system test results, and building code compliance information.
2. Verification that all components are supplied and/or approved by one manufacturer.
3. Selection of a knowledgeable, experienced applicator who has current approval of the manufacturer or other manufacturer-certified education requirements.
4. A thorough review by the EIFS manufacturer of any unusual project details or conditions before the work commences.
5. Verification that the proper materials (with identification and labels intact) were shipped and stored in accordance with the manufacturer's requirements.
6. Checking to make sure the applicator is using all components from the same company.

## Appendix

EIFS Industry Members Association (EIMA)
3000 Corporate Center Drive, Suite 270
Morrow, GA 30260
800-294-3462
770-968-7945
Fax: 770-968-5818
*http://www.eifsfacts.com*

Energy Efficiency and Renewable Energy Clearinghouse (EREC)
P.O. Box 3048 Merrifield, VA 22116
800-DOE-EREC (363-3732)
Email: *doe.erec@nciinc.com*

EPS Molders Association
2128 Espey Court
Suite 4
Crofton, MD 21114
800-607-3772
410-451-8341
Fax: 410-451-8343
E-mail: *bdecampo@aol.com*
*http://www.epsmolders.org/*

Polyisocyanurate Insulation Manufacturers Association (PIMA)
1331 F Street, NW, Suite 975
Washington, DC 20004
202-628-6558
Fax: 202-628-3856
E-mail: *pima@pima.org*
*http://www.pima.org/contactus.html*

AFM Corporation/R-Control
P.O. Box 246
24000 W. Highway 7
Excelsior, MN 55331
800-255-0176
952-474-0809
Fax: 952-474-2074

BASF Corporation
3000 Continental Drive North
Mt. Olive, NJ 07828
973-426-3908
Fax: 973-426-3904
*http:// www.basf.com*

Celotex Corporation
4010 Boy Scout Blvd.
Tampa, FL 33607
800-CELOTEX
813-873-4000
E-mail: *international@celotex.com*
*http://www.celotex.com/*

Dryvit Systems, Inc.
One Energy Way
West Warwick, RI 02893
401-822-4100
800-556-7752
Fax: 401-823-8820
*www.dryvit.com*

Owens Corning
One Owens Corning Parkway
Toledo, OH 43659
800-438-7465
*http://www.owenscorning.com*

Parex, Inc.
P.O. Box 189
Redan, GA 30074
770-482-7872
800-537-2739
Fax: 770-482-6878
*www.parex.com*

Tec Specialty Products Inc.
315 South Hicks Road
Palatine, IL 60067
800-323-7407
847-358-9500
Fax: 800-952-2368

Pactive Building Products
Amocor, Amofoam, Tenneco
2100 Riveredge Parkway
Suite 175
Atlanta, GA 30328
800-227-7339
678-589-7337
*http://www.tennecobuildingprod.com/index.html*

USG Corporation
125 S. Franklin St.
Chicago, IL 60606
800 USG-4YOU
800-874-4968
312-606-4000
E-mail: *usg4you@usg.com*
*http://www.usg.com/*

## Reference

1. "The Fire Hazard of Polyurethane and Other Organic Foam Insulation Aboard Ships and in Construction," *Hazard Information Bulletin,* OSHA. Available at *http://www.oshaslc.gov/dts/hib/hib_data/hib19890510.html*.
2. John S. Horvath, *Geofoam Geosynthetic: Past, Present, and Future.* (Bronx, NY: Manhattan College.
3. J. D. Nisson and Gautam Dutt, *The Superinsulated Home Book* (New York: John Wiley & Sons, 1985), p. 87.
4. Mark Robert Morden, "Selecting Roof Insulation," *Building Operating Management Magazine*. Available at *http://www.facilitiesnet.com/fn/NS/NS2b7bb.html|ticket*=12345678901234567891127538 35.
5. EPS Molders Association Web site: *http://www.epsmolders.org/techinfo/9502.htm*.
6. EcoPan Panel Building System product literature. Available at *http://www.ecopan.ca/Eco-Pan.htm*.
7. Alex Wilson, *Environmental Building News,* 4(1), 1995.

8. "Foam Sheathing Essential for Steel-Framed Walls," *Energy Source Builder* 38, 1995. Available at *http://oikos.com/esb/38/steelstudy.html.*
9. "Foam and Foam Board Insulation," *EREC Reference Briefs,* Energy Efficiency and Renewable Energy Clearinghouse, U.S. Department of Energy, Washington.
10. Tyler Stewart Rogers, *Thermal Design of Buildings,* (New York: John Wiley and Sons, 1964), p. 33.
11. Roofhelp Web site, E. J. Sandquist: *http://www.roofhelp.com/Rvalue.htm.*
12. "New Types of Insulation," *EREC Reference Briefs.* Available at *http://www.eren.doe.gov/consumerinfo/refbriefs/eb9.html.*
13. Jim Reicherts, "Water-Management: The Future of EIFS," United States Gypsum Company literature, p. 1.