ENCLOSURE SOLUTIONS

Technical Bulletin ES-PRMA-01

FOAMULAR® Extruded Polystyrene

Insulation in Protected Membrane Roof Assemblies & Vegetative Roof Assemblies

PRMA

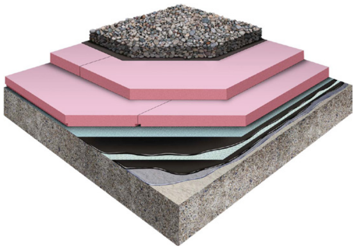
Protected Roof Membrane Assemblies (PRMA) place the waterproofing membrane below other components known as overburden which may include insulation, drainage components, growing media, pavers, aggregate ballast, and/or vegetation. Vegetative Roof Assemblies (VRAs) are part of a unique roof design category. Benefits of PRMAs Include:

- Protection of the waterproofing membrane from mechanical damage
- Protection of the waterproofing membrane assembly from UV exposure and temperature extremes
- Prolonged life of the membrane
- Aesthetically pleasing roof surfaces
- Occupiable space on the roof
- Ability to retain storm water runoff on the roof

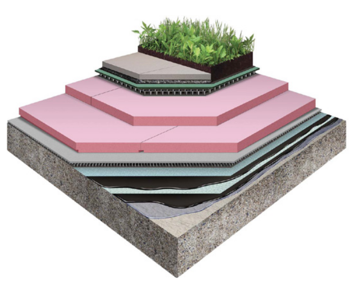
Vegetative Roof Assemblies (VRAs) include components to serve many functions on the roof which are:

- Watertightness
- Root resistance
- Thermal insulation
- Drainage and/or water retention
- Growing media to support vegetation
- Vegetation-free zones for maintenance and access
- Alternate surfacing such as concrete slab, pavers, or loose stone
- Vegetation

This bulletin discusses selected best design practices for PRMA and VRA roof insulation as well as performance standards required by the International Building Code (IBC) and the National Roofing Contractors Association (NRCA).



PRMA: Protected Roof Membrane Assembly



VRA: Vegetative Roof Assembly

Best Design Practices

Selecting a Type of Insulation

FOAMULAR® Extruded Polystyrene Insulation (XPS) is uniquely suited for use in high moisture and vapor exposure PRMA applications. In fact, XPS is the only type of insulation that is recommended by National Roofing Contractors Association (NRCA) for use in Vegetative Roof Assemblies.[1] There are two primary reasons that XPS is highly water resistant. First, XPS insulation has a continuous closed cell structure, unlike expanded polystyrene (EPS) that has an open board structure with open spaces between the individual beads that comprise EPS, or polyisocyanurate that has larger and interconnected cells. See Figures 1,2, and 3. Second, the XPS polystyrene molecule is hydrophobic, meaning that the polystyrene molecule is not attracted to the water molecule. These two characteristics cause FOAMULAR® XPS to reject water instead of absorbing it, making it almost the exclusive choice for use in PRMA and VRA roofing systems.

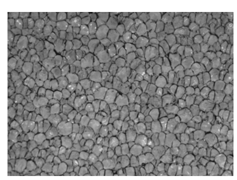


Figure 1: Magnified Section of XPS Insulation Showing No Gaps between Cellular Structure

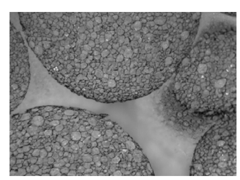


Figure 2: Magnified Section of EPS Insulation Showing Gaps between Cellular Structure

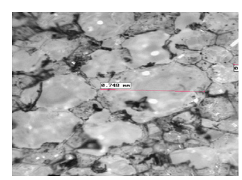


Figure 3: Magnified Section of Polyisocyanurate Insulation Showing Irregular Cellular Structure

Providing Drainage & Water Retention

Many components are employed to address drainage and water retention including molded plastic, dimensional mesh, integrated tray system, gravel, or XPS such as FOAMULAR® 404/604 or 404/604 RB. See the descriptions provided regarding the intended use of these products. The selection of the particular component should be based upon the intended performance of the overall assembly including factors such as height, required warranty, anticipated weight, required drainage rate, and required water retention rate. Materials used for drainage and water retention layers and their placement must be confirmed with the manufacturer that is providing the system waterproofing warranty.

[1] National Roofing Contractors Association. The Vegetative Roof Systems Manual. 2nd Ed. 2009.

What FOAMULAR® XPS Product Should be Specified

Owens Corning FOAMULAR® XPS Insulation comes in a variety of configurations to assist in providing drainage and managing water vapor in PRMA and VRA roofing. All of the PRMA/VRA FOAMULAR® XPS insulation products are available with channels around all four bottom edges that are in contact with the protected membrane to assist with drainage on top of the membrane.

The products differ in compressive strength, and, the "RB" products have drainage ribs cut into the top surface as well as bottom side channels. The integration of channeled and ribbed products is thoroughly discussed later. See the "Typical Physical Properties" chart.

FOAMULAR® XPS Roofing Insulation Products: Typical Physical Properties[1]

Product	Thickness (inches)	Thermal Resistance[2,3] @ 75°F (R-Value)	Thermal Resistance @ 40°F[2,4] (R-Value)	Long Term Thermal Resistance[2] (R-Value)	Compressive Strength[5] (PSI)	Water Absorption[6] (Max. % by Volume)	Ribbed	Channeled
404	2"	10	10.8	10.6	40	0.05		X
	2½"	12.5	13.5	13.4	40	0.05		X
	3"	15	16.2	16.2	40	0.05		X
	4"	20	21.6	22	40	0.05		X
404RB	2"	9.5			40	0.05	X	X
	3"	14.5			40	0.05	X	X
604	1½"				60	0.05		X
	2"	10	10.8	10.6	60	0.05		X
	3"	15	16.2	16.2	60	0.05		X
604RB	1½"				60	0.05	X	X
	2"	9.5			60	0.05	X	X
	3"	14.5			60	0.05	X	X

[1]Properties shown are representative values for core 1" thick material, unless otherwise specified.
[2]R means resistance to heat flow; the higher the value, the greater the insulation power. This insulation must be installed properly to get the marked R-Value. Follow the manufacturer's instructions carefully. If a manufacturer's fact sheet is not provided with the material shipment, request this and review it carefully. R-Values vary depending on many factors including the mean temperature at which the test is conducted, and the age of the sample at the time of testing. Because rigid foam plastic insulation products are not all aged in accordance with the same standards, it is useful to publish comparison R-Value data. The R-Value for FOAMULAR® XPS Insulation is provided from testing at two mean temperatures, 40°F and 75°F, and from two aging (conditioning) techniques, 180 day real-time aged (as mandated by ASTM C578) and a method of accelerated aging sometimes called "Long Term Thermal Resistance" (LTTR) per CAN/ULC S770-03. The R-Value at 180 day real-time age and at 75°F mean temperature is commonly used to compare products and is the value printed on the product.
[3]R-Value (180 day) minimum, hr•ft²•F/Btu @75°F mean temperature.
[4]R-Value (180 day) minimum, hr•ft²•F/Btu @40°F mean temperature.
[5]Values at yield or 10% deflection, whichever occurs first. [6]Data ranges from 0.00 to value shown due to the level of precision of the test method.

Compressive Strength

FOAMULAR® XPS Insulation comes in three compressive strengths.

- 40 psi for low loads and light traffic
- 60 psi for higher loads and heavier traffic
- Specialty 100 psi for high loads and heavy vehicular traffic

When selecting products, designers must consider the anticipated traffic and occupancy of the roof space including the combined live and dead loads (including saturated overburden). Generally, the IBC requires a uniform live load of 100 psf for "occupiable roof gardens" (VRA) and "assembly areas" (Table 1607.1) and 20 psf uniform design live load for unoccupied landscaped areas on roofs (1607.12.3.1). Snow loads, drifting, and other special conditions must also be taken into account. See the IBC for complete details.

Refer to the "Maximum Design Load Recommendations" for dead and live load recommendations based on the compressive strength of each product and load reduction factors based on rib configuration and to minimize long term compressive creep.

FOAMULAR® XPS Roof Insulation Products: Maximum Design Load Recommendations

Product	Dead Load (PSF)	Live Load (PSF)
404	1,910	1,150
404RB	1,110	660
604	2,880	1,720
604RB	1,660	1,000

Channels

In addition to compressive strength options, FOAMULAR® 404 and 604 XPS is available with the bottom edges channeled on all four sides to allow excess moisture to drain across the top of the roof membrane to aid in drainage and enhance the performance of the entire system. See Figure 4.

Ribs

In addition to being channeled on the bottom edges, FOAMULAR® 404RB and 604RB are ribbed on the top surface to create a drainage plane at the face of the insulation and pavers. The drainage layer prevents pavers from sitting in a water film during long term freeze/thaw cycling which may cause deterioration. The ribs also enable ventilation to create a "vapor diffusion open" interface that is required between the XPS and a vapor impermeable component such as pavers. See Figure 4. See the "Typical Physical Properties" chart regarding availability of products in both ribbed and channeled configurations.

Tapered & Flat

In addition to flat thicknesses up to 4", FOAMULAR® THERMAPINK® XPS is also available in a variety of tapered configurations. Tapered THERMAPINK® XPS is used to create slope under waterproofing membranes and on Vegetative Roof Assemblies. Required slope should be selected by the designer based upon performance requirements such a drainage and insulation value as well as aesthetics. See Figure 5. See the FOAMULAR® Tapered Roofing Products data sheet for more information.

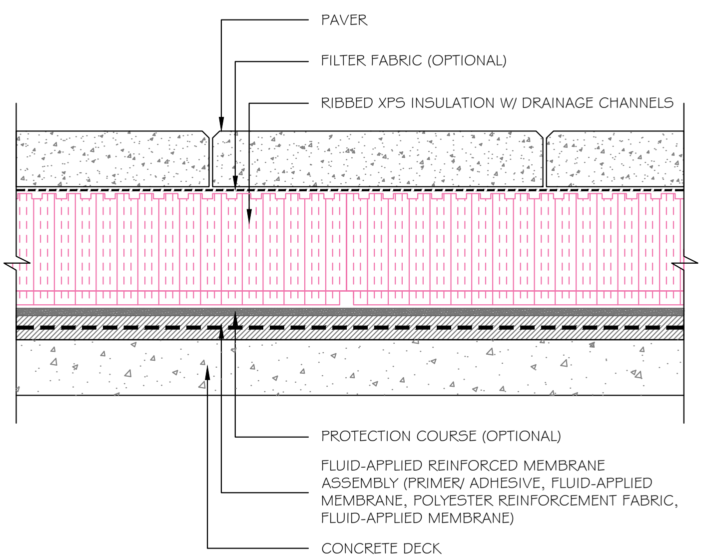


Figure 4: Ribbed top and channeled bottom surfaces of FOAMULAR® XPS

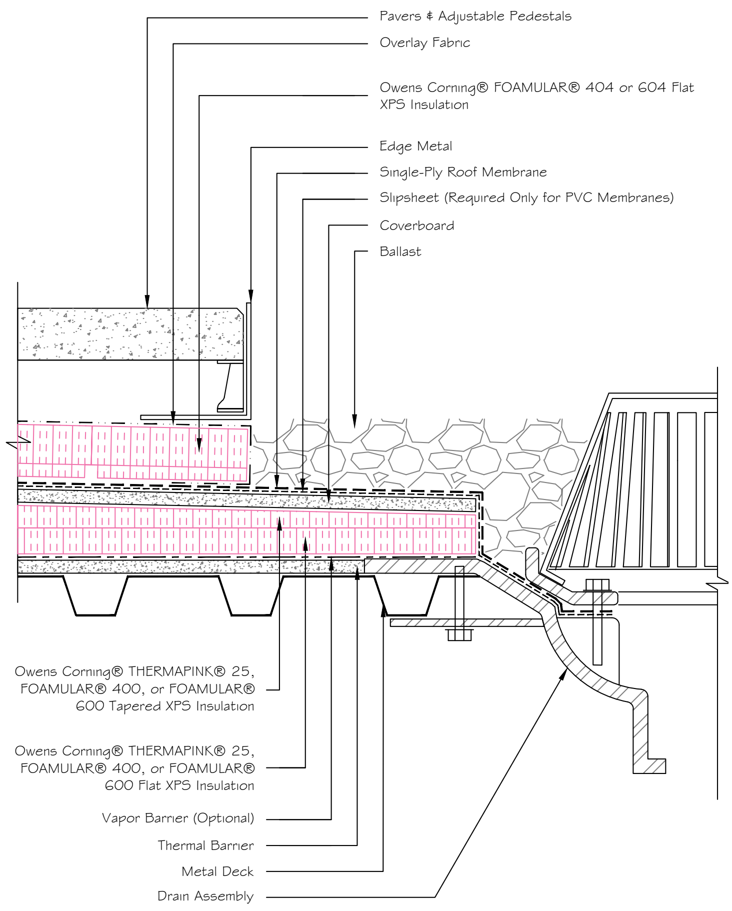


Figure 5: Flat FOAMULAR® and Tapered THERMAPINK® XPS

Creating a Diffusion Open Drainage Layer

In PRMA and VRA insulation applications that are topped with a vapor impermeable overburden layer, a drainage layer should always be located under the overburden, and above the FOAMULAR® XPS Insulation layer to enable water drainage and to relieve vapor pressure that may drive water vapor into the XPS. If not provided, with a water vapor impermeable membrane under the XPS, and with a diffusion closed layer above the XPS, water vapor may be driven into the XPS. Growing media, concrete topping slabs, and pavers with no drainage area below are all considered vapor impermeable overburden and require a drainage layer above the XPS to create a vapor diffusion open system. See figure 6.

Optional Additional Drainage

In addition to the required drainage layer above the XPS insulation, some waterproofing membrane manufacturers may require a drainage layer directly above the waterproofing membrane to relieve hydrostatic pressure as well as vapor drive. See Figure 7. Installation of a drainage layer under the insulation, on top of the waterproofing membrane may cause a reduction in thermal performance due to air convection through the drainage layer below the insulation. It is recommended that the waterproofing membrane manufacturer be consulted with regard to placement of additional drainage planes during the design process. If used, a loss of 10-20% R-Value performance may occur. Therefore, to achieve the minimum R-Value performance required it is recommended that 10-20% additional XPS insulation be added to the design.

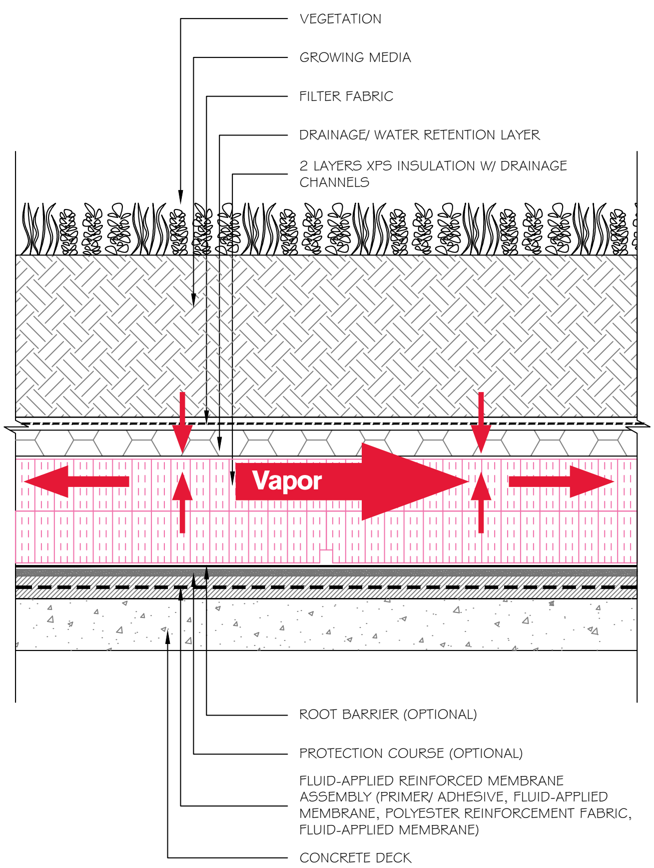


Figure 6: Typical Vegetative Roof Assembly allowing vapor to diffuse through the drainage layer located above XPS Insulation

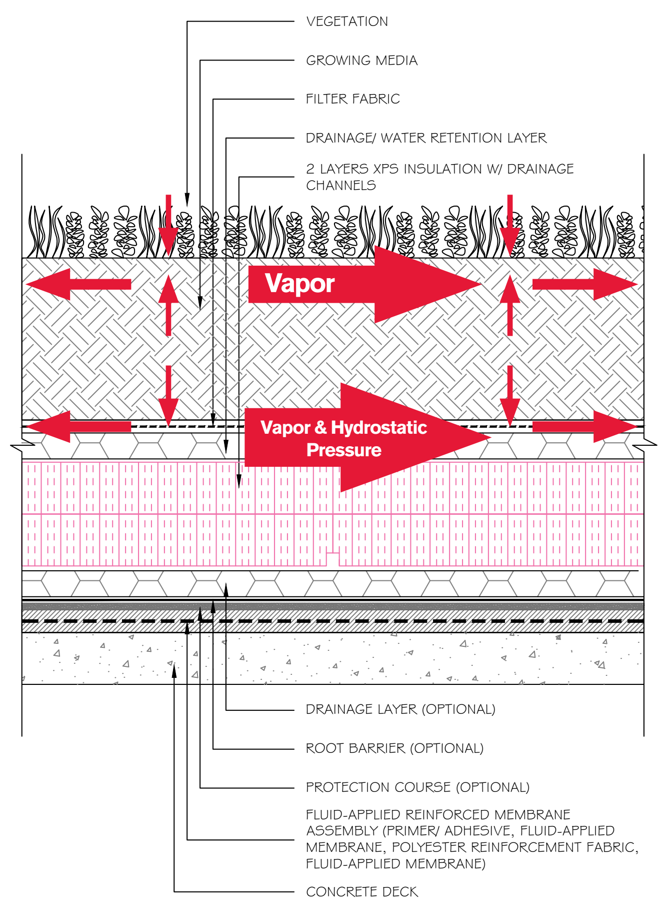


Figure 7: Typical Vegetative Roof Assembly showing additional drainage layer located below insulation if required by membrane manufacturer. Note: This design reduces performance of the insulation.

Insulation Installation

PRMA and VRA roof insulation is loose laid and held in place by the dead weight of overburden designed in accordance with prescribed standards. It is best to install insulation in multiple layers so that joints in multiple layers can be staggered. When installing multiple layers of insulation, the bottom layer of insulation should be a minimum of 1½" thick and equal to the thickness of the top layer of insulation if possible. Installation should be sequenced to be covered as soon as possible to limit exposure to mechanical damage and to solar heat that may result in distortion. Dark colored drainage boards, membranes, or fabrics should not be left exposed to the daily sun when placed over FOAMULAR® XPS due to the dark surfaces potentially collecting energy and resulting in excessively high temperatures that may damage the foam insulation. When possible, FOAMULAR® XPS insulation should be installed print-side down and covered as soon as possible to reduce potential heat exposure.

Compatibility

Solvent-based adhesives and mastics are not compatible with polystyrene insulations including FOAMLULAR® XPS. Where incompatible materials are present, a slipsheet or coverboard must be used to separate materials. Verify compatibility with other chemicals such as fertilizers, insecticides, and herbicides prior to application.

Designing Ballast to Resist Wind Uplift

The 2015 International Building Code references an ANSI/SPRI prescriptive standard for ballast design, while placing additional restrictions in certain situations. Wind uplift pressure exerted on a roof is influenced by many characteristics including the basic wind speed associated with a geographic location, surrounding terrain, building height, and parapet height. Based on these characteristics, prescriptive charts are provided to enable the selection of a ballast system that varies depending on where it is located on the roof (field, perimeter or corner), the type of ballast used (stone or paver), and the weight per unit of area of the stone or paver. The Designer of Record must select an appropriate ballasting system according to the required wind design standard specified in the IBC, or in accordance with accepted wind engineering practice.

Single-Ply Protected Roof Membrane Assemblies

For Single-Ply PMRA Roofs, § 1504.4 Ballasted low-slope roofing systems of 2015 International Building Code requires that "Ballasted low-slope (roof slope <2:12) single-ply roof system coverings installed in accordance with Sections 1507.12 and 1507.13 shall be designed in accordance with Section 1504.8 and ANSI/SPRI RP-4."[4] ANSI/SPRI RP-4 2013 Wind Design Standard for Ballasted Single-Ply Roofing Systems sets forth required ballast for roofs used on corner, perimeter, and field zones based on wind speed, building height, parapet height, and exposure. This standard lists ballasting system options for buildings up to 150' in height. Buildings greater than 150' in height are not covered by the scope of the prescriptive standard and must be designed by a registered design professional approved by the authority having jurisdiction.

In addition to meeting various other requirements regarding edge securement (§1504.5), weathering (§1504.6), and impact resistance (§1504.7), the IBC places additional restrictions on any aggregate used as ballast to resist wind uplift stating that it must meet Section 1504.8 Aggregate which states that:

"Aggregate used as surfacing for roof coverings and aggregate, gravel or stone used as ballast shall not be used on the roof of a building located in a hurricane-prone region as defined in Section 202, or on any other building with a mean roof height exceeding that permitted by Table 1504.8 based on exposure category and basic wind speed at the site."[3]

Vegetative Roof Assemblies

ANSI/SPRI RP-14 Wind Design Standard for Vegetative Roofing Systems is similar to ANSI/SPRI RP-4 and sets forth required ballast for roofs used on corner, perimeter, and field zones based on wind speed, building height, parapet height, and exposure. For Vegetative Roof Assemblies, IBC §1507.16 requires that "Vegetative roofs, roof gardens and landscaped roofs shall comply with the requirements of this chapter [15], Sections 1607.12.3 and 1607.12.3.1 and the International Fire Code."[4] Although RP-14 is not specifically referenced in the IBC, it is later referenced in VF-1 §3.7 Wind Design requiring roofs to be designed according to "SPRI RP-14 'Wind Design Standard for Vegetative Roof Systems' or other design standards as approved by the authority having jurisdiction." This standard is also referenced in existing building standards inspections as the maintenance of the Vegetative Roof Assembly affects uplift and fire protection.

[2]International Code Council. 2015 International Building Code. "Section 1504.4 Ballasted low-slope roofing systems." July, 2015.

[3]International Code Council. 2015 International Building Code. "Section 1504.8." July, 2015.

[4]International Code Council. 2015 International Building Code. "Section 1507.16 Vegetative roofs, roof gardens and landscaped roofs." July, 2015.

Ballast Selection

Protected Roof Membrane Assemblies (PRMA) require the weight of the overburden to resist wind uplift and/or occasional floatation of the XPS Insulation. Ballast is categorized per ANSI/ASCE-7 as #4 or #2. These are referenced in both ANSI/SPRI RP-4 and ANSI/SPRI RP-14 in Wind Uplift. See the ANSI/SPRI RP-4 and RP-14 "Ballast Categories" charts for examples of the recommended ballasting/overburden options depending on the system design that is specified after completing a full project review in accordance with the standards. In the case of VRA, and ANSI/SPRI RP-14 where growing media is involved, unsaturated weight is considered in selecting enough overburden to keep the XPS insulation in place. Additional ballast may be required at corners and at the roof perimeter per ANSI/SPRI RP-4 for Single-Ply Ballasted Protected Membrane Roofs or ANSI/SPRI RP-14 for Vegetative Roof Assemblies.

ANSI/SPRI RP-4: Ballast Categories		
Stone Ballast Minimum Requirements	#4 Ballast: Nominal 1½" smooth river bottom stone of ballast gradation size #4, or alternatively, #3, #2, or #1 as specified in ASTM D448 or ASTM D7655/D7655M spread at a minimum rate of 1,000 psf	Vegetation coverage or erosion protection required
	#2 Ballast: Nominal 2½" smooth river bottom stone of ballast gradation size #2, or alternatively, #1 as specified in ASTM D448 or ASTM D7655/D7655M spread at a minimum rate of 1,300 psf	
	Crushed Stone: When the gradation requirements for #4 Ballast and #2 Ballast above are met a protection layer meeting the membrane manufacturer's specifications shall be installed between the membrane and the crushed stone.	
Paver Ballast Minimum Requirements	#4 Ballast: Standard concrete pavers (minimum 18 psf), or interlocking, beveled, doweled, or contoured fit lightweight pavers (minimum 10 psf)	Vegetation coverage or erosion protection required
	#2 Ballast: Concrete pavers (minimum 22 psf), or approved interlocking, beveled, doweled, or contoured fit lightweight concrete pavers (minimum 10 psf) when documented as equivalent	
	Protected Membrane Ballasted Systems Using wan Attached Cementitious Coating attached to Insulation: The panels shall be interlocking and weight a minimum of 4 psf	

ANSI/SPRI RP-4 Wind Design Standard for Vegetative Roofing Systems, 3.12 & 3.13
Ballast Requirements. See ANSI/SPRI RP-4 for additional requirements.

ANSI/SPRI RP-14: Ballast Categories		
#4 Ballast	Growth media spread at a minimum dry weight of 10 psf of inorganic material plus organic material	Vegetation coverage or erosion protection required
	Interlocking contoured fit or strapped together trays containing growth media spread at minimum dry weight of 10 psf of inorganic material plus organic material	
	Independently set modular pre-planted or pre-grown vegetative roof trays containing 18 psf dry weight inorganic material plus organic material.	
	River bottom or course stone nominal 1½" of ballast gradation size #4, or alternatively, #3, #24, #2, or #1 as specified in ASTM D448, "Standard Sizes of Course Aggregate" spread at a minimum weight of 10 psf	Vegetation coverage or erosion protection not required
	Concrete pavers independently sent (minimum 18 psf)	
	Interlocking, beveled, doweled, or contour-fit lightweight concrete pavers (minimum 10 psf)	
#2 Ballast	#4 Ballast: Standard concrete pavers (minimum 18 psf), or interlocking, beveled, doweled, or contoured fit lightweight pavers (minimum 10 psf)	Vegetation coverage or erosion protection required
	#2 Ballast: Concrete pavers (minimum 22 psf), or approved interlocking, beveled, doweled, or contoured fit lightweight concrete pavers (minimum 10 psf) when documented as equivalent	
	Protected Membrane Ballasted Systems Using wan Attached Cementitious Coating attached to Insulation: The panels shall be interlocking and weight a minimum of 4 psf	
	River bottom or course stone nominal 2½" of ballast gradation size #2, or alternatively, #1 as specified in ASTM D448, "Standard Sizes of Course Aggregate" spread at a minimum weight of 13 psf	Vegetation coverage or erosion protection not required
	Concrete pavers independently sent (minimum 22 psf)	
	Interlocking, beveled, doweled, or contour-fit lightweight concrete pavers (minimum 10 psf)	

ANSI/SPRI RP-14 Wind Design Standard for Vegetative Roofing Systems, 3.13
Ballast Requirements. See ANSI/SPRI RP-14 for additional requirements

Fire Resistance

Single-Ply Protected Membrane Roof Assemblies

Per 2015 IBC Section 1505.1, roof assemblies shall be classified as Class A, B, or C and shall be tested in accordance with either ASTM E108 Test Methods for Fire Test of Roof Coverings (used with Single-Ply PRMA) or UL790 (used with Building Integrated Photovoltaics). The ASTM E108 test classifies exterior roof surfaces for resistance to external surface spread of fire from an external fire source. Class A roof coverings, the rating that is commonly achieved when stone or paver ballast is used in PRMA systems, are the most effective against severe fire exposure. Class B systems are effective against moderate fire exposure. Class C systems are effective against light fire exposure.

Vegetative Roof Assemblies

Per 2015 IBC §15051.10, "Roof gardens and landscaped roofs shall comply with §1507.16 and shall be installed in accordance with ANSI/SPRI VF-1 [External Fire Design Standard for Vegetative Roofs]."[5] ANSI/ SPRI VF-1 generally requires non-vegetated areas to be classified as ASTM E108 Class A and requires vegetation that is categorized as either succulent or grass. It also limits areas to 15,625 ft^2 with no dimension greater than 125 ft. Greater areas must be divided by firestops described in the standard. As the overburden plays a critical role in the fire resistance of the roof, this standard references the previously discussed ANSI/SPRI RP-14.

[5]International Code Council. 2015 International Building Code. "Section 1505.10 Roof gardens and landscaped roofs." July, 2015.

Warranty

Insulation Properties Limited Warranty

Owens Corning® FOAMULAR® XPS is warranted to maintain 90% of its R-Value and to retain all other physical properties defined in ASTM C578 for the lifetime of the building. Refer to the actual warranty document for complete details.

Thermal Overlay Limited Warranty

A FOAMULAR® XPS Thermal Overlay Warranty (TOW) may be offered as part of the VRA or PRMA package. This warranty includes the physical properties warranty and covers the PRMA or VRA roof covering staying in place against wind speeds up to 73 mph when designed in accordance with the referenced standards. The TOW requires minimum slope, no ponding water over 48 hours, and a vapor diffusion open design. The roof must be designed to IBC §1504.4, §1504.8, and ANSI/SPRI RP-4 to attain this warranty. Refer to the actual warranty documents for complete details.

Overburden and Single-Source Assembly Warranty

Some waterproofing membrane manufacturers provide a single-source warranty, sometimes called an "overburden warranty," to include all components of the VRA under one warranty. Owens Corning® FOAMULAR® XPS is included in many of these assemblies as a recognized leader in the industry. Please note that the waterproofing manufacturer may require purchase and installation through a single provider and always verify with the manufacturer to ensure eligibility for the warranty.

Sustainability & Evidence-Based Design

XPS and VRAs may contribute to IgCC, LEED, Green Globes, and other voluntary sustainability or evidence-based design initiatives. For example, those practicing evidence-based design may cite studies regarding patients with a view of nature having better outcomes. Such studies have been used to support the integration of vegetative roofs and planters throughout medical facilities. Additional sustainable practice contributions may include:

- Protecting and restoring habitats by providing environments for native vegetation and wildlife
- Maximizing open space by increasing occupiable and/or aesthetically pleasing spaces
- Stormwater control by retaining water and minimizing runoff
- Reducing heat island effect
- Increasing energy performance by creating roofs with higher thermal resistance
- Less trips to the landfill because materials can be reused. Please see the DFW Airport Case Study, http://www.owenscorning.com/NetworkShare/EIS/59400-A-FOAMULAR-DFW-Airport-Case-Study.pdf
- The use of products with high recycled content (FOAMULAR® XPS Insulation has 20% recycled content certified by SCS Global Services)
- The use of products with zero ozone depletion formulas (FOAMULAR® XPS Insulation is made with a zero ozone depletion formula)
- Reducing emissions by using locally available materials thereby reducing shipping
- Increasing occupant comfort with better thermal performance
- The presence of a green roof is recognized alone as a credit in several rating systems.

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