FOAMULAR® & FOAMULAR® NGX™ ES-PRMA-01 DESIGN GUIDE

EXTRUDED POLYSTYRENE INSULATION IN PROTECTED ROOF MEMBRANE ASSEMBLIES & VEGETATIVE ROOF ASSEMBLIES

Protected Roof Membrane Assemblies (PRMAs)

PRMA roofs place the waterproofing membrane underneath other components. These components are known as overburden, which may include insulation, drainage composites, growing media, pavers, aggregate ballast, and/or vegetation.

Benefits of PRMAs include:

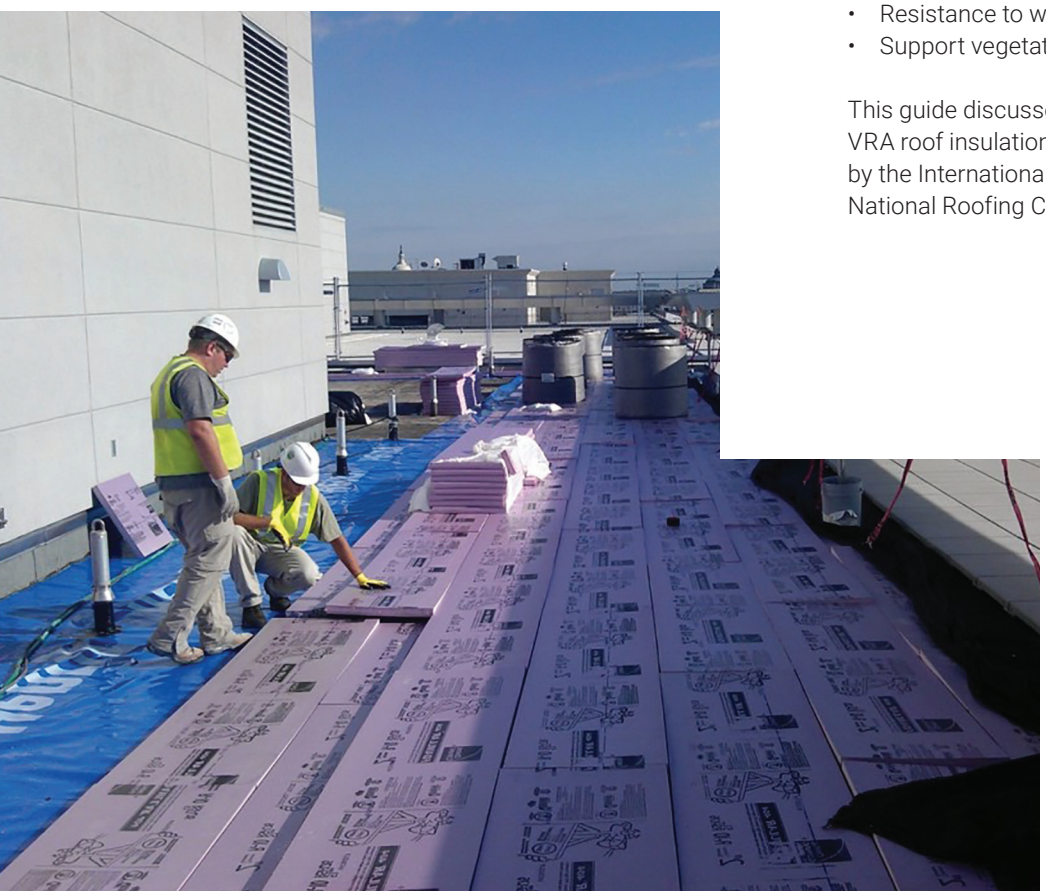
- Protecting waterproofing membrane from mechanical damage, UV exposure, and temperature extremes
- Prolonging the life of the membrane
- Retaining the storm water runoff on the roof when required
- Allowing for design of aesthetic roof surfaces
- Increasing occupiable space on the roof

Vegetative Roof Assemblies (VRAs)

A subcategory of PRMAs, Vegetative Roof Assemblies are designed as a system. The components of this system collectively must perform several functions, including:

- Watertightness
- Root-resistance
- Resistance to thermal loss
- Drainage and/or water retention
- Access for maintenance
- Resistance to wind uplift forces
- Support vegetation growth

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



Selecting a Type of Insulation

FOAMULAR® & FOAMULAR® NGX™ Extruded Polystyrene (XPS) insulation are 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 open spaces between the individual beads that comprise EPS, or polyisocyanurate, which has larger and interconnected cells. See Figures 1,2, and 3. Second, the XPS molecule is hydrophobic, meaning that the polystyrene molecule is not attracted to the water molecule. These two characteristics cause FOAMULAR® & FOAMULAR® NGX™ XPS to reject water instead of absorbing it, making it almost the exclusive choice for use in both PRMA and VRA roofing systems.

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

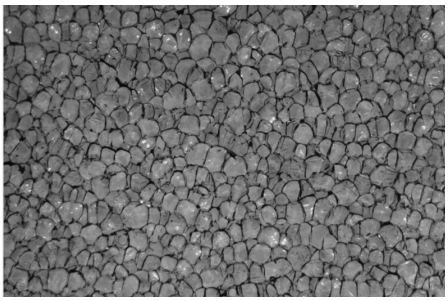


Figure 1:
Magnified section of XPS insulation showing no gaps between cellular structure.

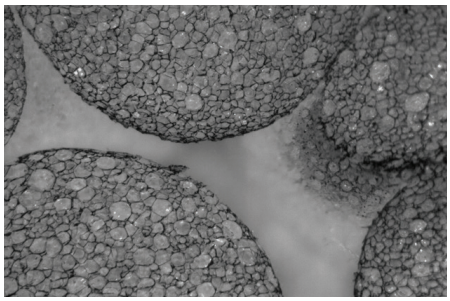


Figure 2:
Magnified section of EPS insulation showing gaps between cellular structure.

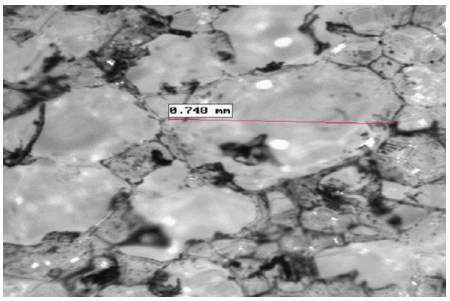


Figure 3:
Magnified section of Polyisocyanurate insulation showing irregular cellular structure.

Providing Drainage and Water Retention

When designing roof systems, it's important to select the right component in order to achieve the required drainage and water retention. Component options include molded plastic, dimensional mesh, integrated tray systems, gravel, or XPS products, such as FOAMULAR® & FOAMULAR® NGX™ 404/604 or 404/604B, which are designed specifically for drainage.

Factors such as required warranty, anticipated height and weight, required drainage rate, and water retention rates should be considered when selecting the components for the assembly. Materials used for drainage and water retention layers and their placement must be confirmed with the manufacturer that is providing the system waterproofing warranty.

FOAMULAR® & FOAMULAR® NGX™ XPS Product Specifications

Owens Corning FOAMULAR® & FOAMULAR® NGX™ 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 FOAMULAR® & FOAMULAR® NGX™ XPS insulation products for PRMA and VRA applications 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® & FOAMULAR® NGX™ XPS Roofing Insulation Products: Typical Physical Properties[2]

PRODUCT	THICKNESS (INCHES)	THERMAL RESISTANCE[3, 4] @ 75°F (R-VALUE)	THERMAL RESISTANCE @ 40°F[3,5] (R-VALUE)	LONG-TERM THERMAL RESISTANCE[3] (R-VALUE)	COMPRESSIVE STRENGTH[6] (PSI)	WATER ABSORPTION[7] (MAX. % BY VOLUME)	RIBBED	CHANNELED
404	2"	10	10.8	10.6	40	0.30		X
	2½"	12.5	13.5	13.4	40	0.30		X
	3"	15	16.2	16.2	40	0.30		X
	4"	20	21.6	22	40	0.30		X
404RB	2"	9.5	10.3		40	0.30	X	X
604	1½"	7.5			60	0.30		X
	2"	10	10.8	10.6	60	0.30		X
	3"	15	16.2	16.2	60	0.30		X
604RB	1½"	7			60	0.30	X	X
	2"	9.5			60	0.30	X	X
	3"	14.5			60	0.30	X	X

2 Properties shown are representative values for core 1-inch-thick material, unless otherwise specified.

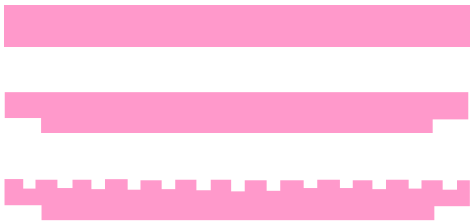
3 R means resistance to heat flow; the higher the value, the greater the insulation power. This insulation must be installed properly to get the marked R-value. Follow the manufacturer's instructions carefully. If a manufacturer's fact sheet is not provided with the material shipment, request this and 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® & FOAMULAR® NGX™ 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.

4 R-value (180-day) minimum, hr•ft²•F/Btu @75°F mean temperature.

5 R-value (180-day) minimum, hr•ft²•F/Btu @40°F mean temperature.

6 Values at yield or 10% deflection, whichever occurs first.

7 Data ranges from 0.00 to value shown due to the level of precision of the test method.



400/600 SQUARE EDGE

404/604 CHANNELED BOTTOM

404RB/604RB RIBBED TOP & CHANNELED BOTTOM

Compressive Strength

FOAMULAR® & FOAMULAR® NGX™ 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® & FOAMULAR® NGX™ 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

Both FOAMULAR® & FOAMULAR® NGX™ 404/604 XPS are available with the bottom edges channeled on all four sides. These channeled edges allow excess moisture to drain across the top of the roof membrane and improve the overall performance of the entire system.

Ribs

In addition to being channeled on the bottom edges, FOAMULAR® & FOAMULAR® NGX™ 404RB/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

FOAMULAR® & FOAMULAR® NGX™ are available in a variety of standard tapered configurations as well as standard flat thicknesses up to 4 inches. Tapered XPS is used to create a slope under waterproofing membranes and on Vegetative Roof Assemblies. The required slope should be selected by the designer based upon performance requirements such as drainage and insulation value as well as aesthetics. See Figure 5. For more information, see Owens Corning publication number 10015849, FOAMULAR® & FOAMULAR® NGX™ Tapered Roofing Design Guide.

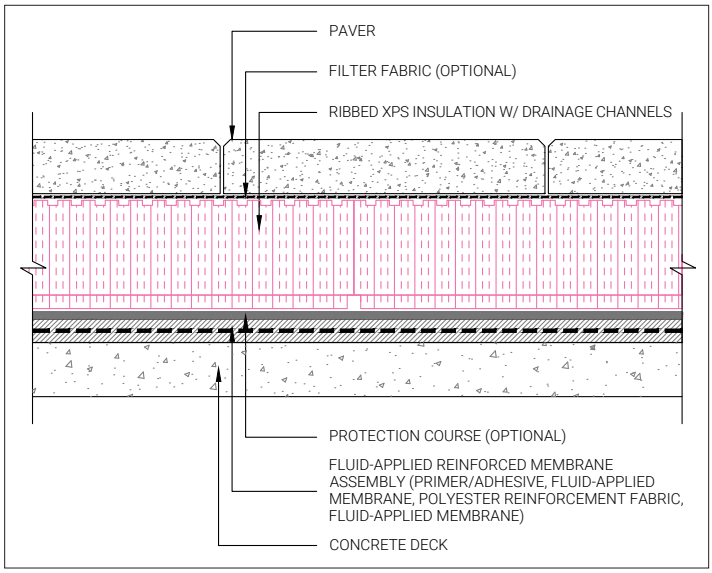


Figure 4: Ribbed top and channeled bottom surfaces of FOAMULAR®/FOAMULAR® NGX™ XPS.

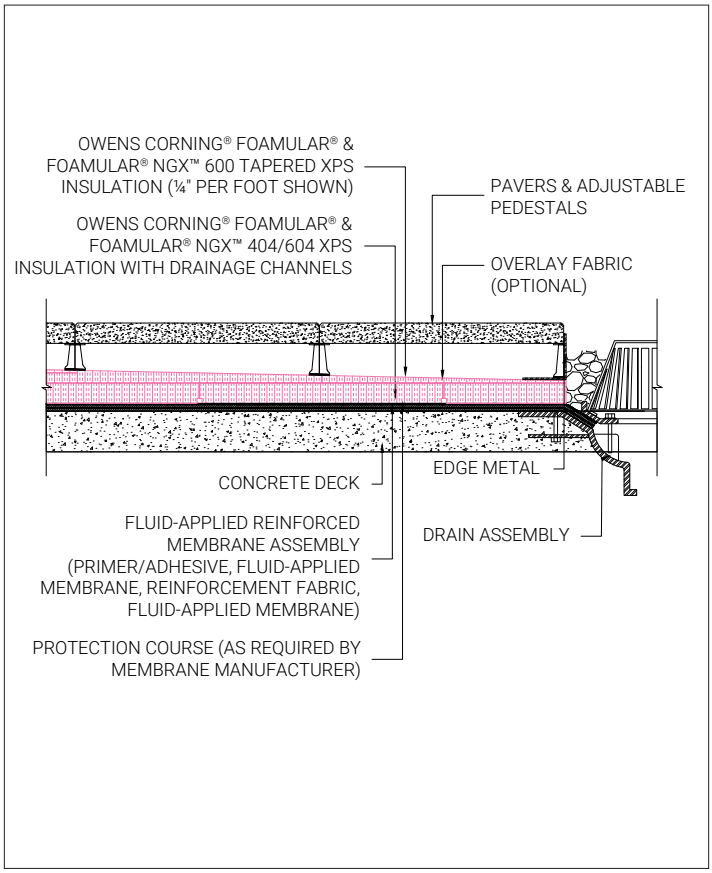


Figure 5: Flat and Tapered FOAMULAR®/FOAMULAR® NGX™ XPS.

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® & FOAMULAR® NGX™ XPS insulation layer. This enables water drainage and relieves vapor pressure that may drive water vapor into the XPS. When a water vapor impermeable layer such as the roof membrane is located below the XPS and a vapor diffusion closed layer is placed above the XPS, water vapor may be forced into the XPS due to no path for escape. 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.

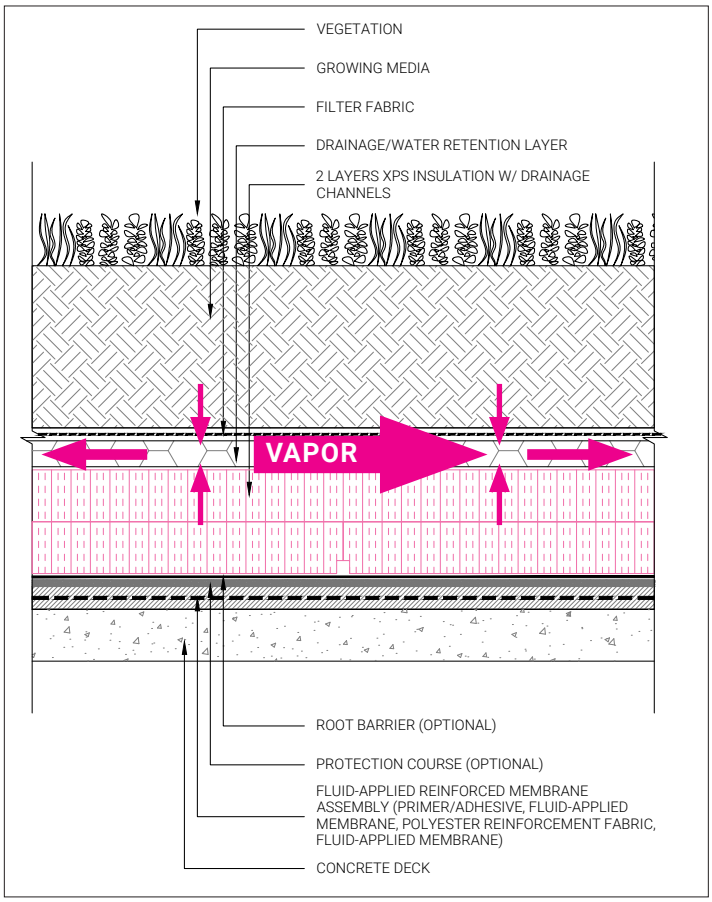


Figure 6: Typical Vegetative Roof Assembly allowing vapor to diffuse through the drainage layer located above XPS insulation.

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 a 10–20% additional XPS insulation be added to the design.

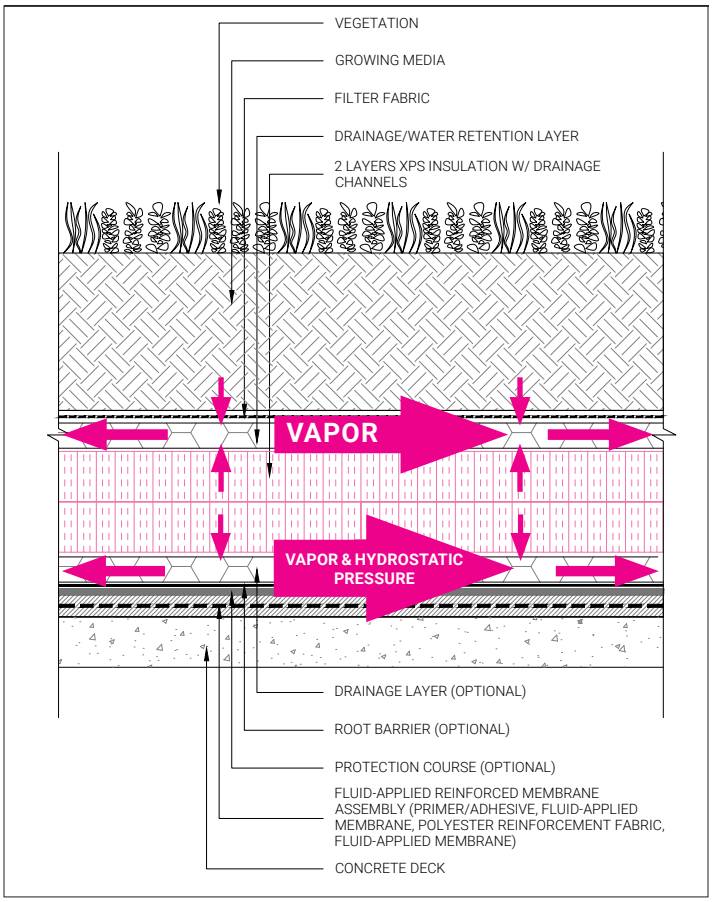


Figure 7: Typical Vegetative Roof Assembly showing additional drainage layer located below insulation if required by membrane manufacturer. Note: This design reduces performance of the insulation.

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 a staggered fashion. When installing multiple layers of insulation, the bottom layer of insulation should be a minimum of 1½-inch 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® & FOAMULAR® NGX™ XPS as dark surfaces may collect energy, resulting in excessively high temperatures that may damage the foam insulation. When possible, FOAMULAR® & FOAMULAR® NGX™ XPS insulation should be installed print-side down and covered as soon as possible to reduce potential heat exposure.

For more information on installation, please refer to publication number 10024461, "Owens Corning® FOAMULAR® & FOAMULAR® NGX™ XPS Insulation Commercial Roof Installation Instructions."

Compatibility

Solvent-based adhesives and mastics are not compatible with polystyrene insulations, including FOAMULAR® & FOAMULAR® NGX™ XPS. Where incompatible materials are present, a slip sheet 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 2018 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 but not limited to the basic wind speed associated within 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 PRMA Roofs, §1504.4 ballasted low-slope roofing systems of 2018, 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."[7] ANSI/SPRI RP-4 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 feet in height. Buildings greater than 150 feet 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."[8]

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], Section 1607.13 and the International Fire Code."[9] 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.

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 on the following page 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.

7 International Code Council. 2018 International Building Code. "Section 1504.4, Ballasted Low-Slope Roofing Systems." July 2018.
8 International Code Council. 2018 International Building Code. "Section 1504.8." July 2018.
9 International Code Council. 2018 International Building Code. "Section 1507.16, Vegetative Roofs, Roof Gardens, and Landscaped Roofs." July 2018.

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 an 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 contoured-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 an 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 contoured-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 2018 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 2018 IBC §1505.10, "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]."[10] 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 ft² with no dimension greater than 125 feet. Greater areas must be divided by fire stops 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.

10 International Code Council. 2018 International Building Code. "Section 1505.10, Roof Gardens and Landscaped Roofs." July 2018.

Warranty

Insulation Properties Limited Warranty

FOAMULAR® & FOAMULAR® NGX™ XPS insulation limited lifetime warranty maintains 90% of its R-value for the lifetime of the building and covers all ASTM C578 properties. See "FOAMULAR® Extruded Polystyrene Insulation Lifetime Limited Warranty" for complete details, limitations, and requirements."

Thermal Overlay Limited Warranty

A FOAMULAR® & FOAMULAR® NGX™ 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® & FOAMULAR® NGX™ 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
- Certified by SCS Global Services to contain pre-consumer recycled content
- The use of products with zero ozone depletion formulas (FOAMULAR® & FOAMULAR® NGX™ XPS insulation is made with a zero ozone depletion formula)
- Blowing agent with a 90% reduction in global warming potential (FOAMULAR® NGX™)
- 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

RECYCLED CONTENT MATTERS

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