VEGETATIVE ROOF SYSTEMS, OCCUPIED ROOF AREAS AND DECKS

Table of Contents

Page

List of Figures

List of Tables

1.0 SCOPE

This data sheet provides guidance for selecting and installing vegetative roof systems, occupied roof areas and decks. These structures may also be known as landscaped roofs, roof-top gardens, roof-top parks, roof terraces, plazas and lounge areas. They are installed on or above the roof or waterproofing membrane assembly.

This data sheet does not address structures such as penthouses or roof mounted solar photovoltaic panels. Follow applicable FM Data sheets for guidance on roof-top structures and penthouses and FM Property Loss Prevention Data Sheet 1-15, *Roof Mounted Solar Photovoltaic Panels*.

Vegetated roofs, combustible decks and other combustibles should only be installed in areas not susceptible to wildland fire per Data Sheet 9-19, *Wildland Fire*.

1.1 Hazards

1.1.1 Collapse

Additional loads from vegetative roofing, roof-top decks and other roof-top installations to convert a roof to an occupied space can be significant and must be considered to determine possible reinforcement needs for existing roofs and proper design for new roofs. Failure to do so could result in collapse due to overload or excessive deflection that could also result in excessive ponding.

In addition to strength, structural stiffness is also critical. Stiffness governs the amount of deflection the roof structure will experience when loaded. A roof structure that has sufficient strength may not necessarily possess sufficient stiffness. If stiffness is insufficient, a progressive deflection scenario can develop from ponding water (from rain, melting snow, or un-checked irrigation) resulting in collapse. Ponding water is a concern with all roof systems, but of particular concern with vegetative roof systems because of the large amount of water that can be retained in the system.

Existing steel-framed buildings with steel roof decks will likely need structural strengthening and stiffening to properly support a new vegetative roof system.

Proper drainage is also critical to ensure overloading does not occur, especially considering the large amount of water that can be retained in the system.

1.1.2 Wind Uplift

Although the dead weight of growth media in vegetative roof systems can help resist wind uplift pressures, the relatively small particle size and lightweight nature of the growth media make it susceptible to erosion and scour from both wind and water. Therefore, a fully adhered or mechanically fastened waterproofing membrane should be provided to protect the building from the weather.

In roof zones 2 and 3, where the wind uplift pressures are substantially greater than in zones 1 and 1’, non-vegetated border zones should be established to reduce erosion and scour of growth media.

Elevated pavers and tiles on decks also need to be secured against wind uplift.

1.1.3 Windborne Debris

Vegetative roof systems and rooftop installations associated with making a roof an occupiable space provide ample material that can become damaging windborne debris. Examples are landscaping materials, trees, plants, furniture, unsecured trash receptacles, pergolas, fabric canopies, temporary installations, etc.

1.1.4 Fire

A wide range of fire hazards can be associated with vegetative roofs, roof decks and occupied roof spaces. For instance, a vegetative roof introduces large continuous plant cover that could spread fire. In addition, these systems can utilize layers of combustible materials within the assembly, such as plastic mats, barriers, insulation, protective boards and pre-cultivated vegetative mats that use synthetic or natural fiber fabrics.

Roofs that are designed or converted to an occupiable space may include elevated decks and contouring (landscaping) that create large, continuous, combustible concealed spaces where fire could spread. Detection and control of such a fire could be very difficult given the concealed and inaccessible nature of the space as well as the concerns for the safety of emergency responders.

Additional fire hazards could be present from amenity installations including furniture, rooftop bars and restaurants, pergolas and temporary installations for special events.

1.1.5 Earthquake

Vegetative roof systems and other rooftop installations associated with making a roof an occupiable space can add significant mass to the roof of a structure. For existing construction, the original structural design would not have accounted for this increased mass, nor the associated increased lateral loads induced during a seismic event.

1.1.6 Hail

The growth media layer normally provides substantial protection to waterproofing membranes from hail impact. However, areas of membrane without growth media or hardscape surfacing (e.g., vertical surfaces at curbs or parapets) as well as other rooftop installations will be exposed to hail impact just as with a conventional roofing system.

In addition, hail can be expected to damage some of the roof vegetation, wood decks and furniture.

1.2 Changes

October 2025. Interim revision. Minor editorial changes were made. Updated figures in Appendix F, *Using RoofNav to Select Vegetative Roof*.

2.0 LOSS PREVENTION RECOMMENDATIONS

The following sections provide recommendations for reducing exposures to natural hazards, fire, and excessive loads.

2.1 Introduction

2.1.1 Use FM Approved equipment, materials, and services whenever they are applicable and available. For a list of products and services that are FM Approved, see the *Approval Guide* and Roof*Nav*, online resources of FM Approvals.

2.1.2 Install the roof deck, above-deck waterproofing components, and stone or concrete paver ballast in accordance with Data Sheet 1-29.

2.1.3 Use FM Approved flashing or coping selected and installed in accordance with Data Sheet 1-49, *Perimeter Flashing*.

2.1.4 For best performance from wind in all geographic areas, select non-vegetative surfaced FM Approved roofs using Roof*Nav* and following Data Sheets 1-28, 1-29 or 1-31. Vegetative roof systems approved to FM Approval Standard 4477 have not had the portion of the roof above the waterproofing membrane tested for wind uplift or wind scouring. All vegetative surfacing, bushes and trees will experience wind scouring.

2.2 Construction and Location

2.2.1 Geographic Restrictions

2.2.1.1 Use vegetative roof systems and rooftop gardens only in geographic locations that are not susceptible to wildland fires per Data Sheet 9-19, *Wildland Fire*. Decks and plazas with noncombustible pavers can be used in all areas.

2.1.1.2 When the design wind speed (3 sec. gust) as determined from Data Sheet 1-28, *Wind Design*, is greater than or equal to 100 mph (63 m/s), use growing medium that meet the following conditions:

A. 1/2 in. (12.5 mm) diameter growing medium (100% passing ½-inch (12.5 mm) sieve), with a saturated particle density ≤ 1.4 g/ml (0.051 lb./in.^{3})

B. 3/8 in. (9.5 mm) growing medium 100% passing 3/8-inch (10 mm) sieve) with a saturated particle density > 1.4 g/ml and ≤ 1.7 g/ml.

Density thresholds noted here are for the saturated aggregate particle - not bulk density or unit weight that account for the voids and degree of compaction for a layer of aggregate.

Do not use pea gravel.

2.2.2 Selecting Vegetative Roofs and Roof Waterproofing Assemblies

2.2.2.1 Use only FM Approved vegetative roofs with a Class A fire rating for exterior fire exposure where the roof abuts an MFL fire wall. Install the assembly directly on the roof deck with no concealed air spaces. See Data Sheet 1-42, *MFL Limiting Factors*.

2.2.2.2 Extensive (shallow) Vegetative Roofs without Concealed Air Spaces

2.2.2.2.1 Use Roof*Nav* to select an FM Approved assembly (vegetation surfacing and waterproofing assembly) with a class A rating for exterior fire exposure. See Appendix F, Using Roof*Nav* to select Vegetated Roof Assemblies.

2.2.2.3 Extensive (shallow) Vegetative Roof Assemblies with Concealed Air Space(s)

2.2.2.3.1 Use only non-combustible materials in the concealed air space. This includes the support system such that there are no exposed combustible materials within the air space including pedestals, framing, structural decking, trays or drainage mats etc.

2.2.2.3.2 Use Roof*Nav* to select an FM Approved assembly with vegetation surfacing with a class A rating for exterior fire exposure. See Appendix F Using Roof*Nav* to Select Vegetative Roof Assemblies.

The vegetation surfacing (FM Approved vegetation and drainage mats, etc.) will be supported, typically by grates and pedestals, creating a concealed air space.

2.2.2.3.3 Use Roof*Nav* to select one of the following roof assemblies for installation on the roof deck:

(The support structure for the vegetative assembly, commonly grates and pedestals, will be on this roof assembly creating a concealed air space between this assembly and the underside of the vegetative assembly.)

1. An FM Approved assembly with concrete paver surfacing. See Appendix F, Using Roof*Nav* to Select Vegetative Roof Assemblies.

These protected membrane roof assemblies have extruded polystyrene (XPS) insulation boards adhered with hot asphalt to the built-up roofing plies and topped with loose laid concrete pavers. All have a 1-90 roof rating but can be used for any recommended wind rating when the XPS boards and multi-ply roofs are fully adhered to concrete decks.

Concrete pavers and the polystyrene boards in the FM Approved assembly can be replaced with extruded polystyrene (XPS) insulation boards with a factory laminated, latex modified cement topping having a minimum thickness of 15/16 in. (24 mm). These boards are still adhered to the built-up roofing plies with hot asphalt.

2. An FM Approved roof assembly for low slope roofs topped with loose laid concrete pavers with a slip sheet between the concrete pavers and the roof cover. The combination of slip sheet and paver should be acceptable to the roof manufacturer.

Use minimum 2 in. (51 mm) thick concrete pavers meeting ASTM International, ASTM C1491-18, *Standard Specification for Concrete Roof Pavers*, 2018.

2.2.2.4 Intensive or Semi-Intensive Vegetative Roofs without Concealed Air Spaces

2.2.2.4.1 Use roof-top vegetation and hardscaped areas from a designer experienced in this construction, and following guidance in section 2.2.15 Vegetation Roof Components and section 3.0 Support for Recommendations.

2.2.2.4.2 Use Roof*Nav* to select an FM Approved roof assembly compatible with the vegetative surfacing.

2.2.2.5 Intensive or Semi-Intensive Roofs, Including Hardscapes and Decks with Concealed Air Spaces

2.2.2.5.1 For intensive or semi-intensive roofs, follow the recommendations in Sections 2.2.2.3.1 and 2.2.2.3.3.

2.2.2.5.2 For hardscapes or decks, follow the recommendations in Sections 2.2.2.3.1 and 2.2.2.3.3, OR

Follow the recommendations in Section 2.2.2.3.1 and install the following on the roof deck:

1. An FM Approved roof assembly with a Class A exterior fire rating. The roof assembly must include a noncombustible cover board or noncombustible insulation immediately below the roof cover.

2.2.2.5.3 Use roof-top vegetation and hardscaped areas from a designer experienced in this construction, and follow guidance in Section 2.2.15 Vegetative Roof Components and Section 3.0, Support for Recommendations.

2.2.3 Wind Securement

2.2.3.1 Secure the vegetative roof modules and components such as drainage mats and protection boards that are loose-laid for the wind uplift design pressures determined from Data Sheet 1-28. Use a safety factor of 1.7 with an effective wind area of 10 ft^2 (0.9 m^2).

2.2.3.2 Where pre-cultivated vegetative mats are installed (rather than direct planting of plugs or cuttings) do the following:

2.2.3.2.1. When possible, install pre-cultivated vegetative mats when they have the longest time to grow prior to the onset of the season with the highest winds. This is critical in tropical cyclone areas.

2.2.3.2.2 Anchor pre-cultivated vegetative mats until the mat's root growth has achieved sufficient attachment into the growth media to adequately resist wind action (at least one full growing season). Ensure vegetated mats are properly anchored or ballasted against wind uplift design pressures determined from Data Sheet 1-28 using a safety factor of 1.7.

2.2.3.3 When propagating from cuttings or dry seed, use non-combustible photo-degradable mesh "wind blankets" to protect against erosion until the plants are sufficiently established as ground cover. Typically, this takes from two to three growing seasons.

2.2.3.4 When stone ballast is used in areas not covered with vegetation, use a minimum depth of 3 in. (76 mm) of stone ballast unless greater depths are recommended either in Data Sheet 1-29, *Deck Securement and Above-Deck Roof Components*, or by the vegetative roof designer. Use clean, smooth, well-rounded stone ballast that conforms to the graduation requirements of Standard Size No. 3 Course Aggregate per ASTM D 448 (nominal 1 to 2 in. [25 to 50 mm] in diameter). Adhere to the recommendations in Data Sheet 1-29, including wind speed, area, and height restrictions.

2.2.3.5 Secure raised decks, tiles and pavers for the wind uplift pressures developed using Data Sheet 1-28.

2.2.3.5.1 Secure pedestals for raised decks as follows:

1. Use FM Approved fasteners for concrete deck with a minimum 1 in. (25 mm) penetration or expansion anchors that engage the full thickness of the latex-modified cement layer of composite XPS insulation boards.
2. In zone 1': secure alternating (every other) pedestals with a minimum of two fasteners per pedestal to either the latex-modified cement layer of composite XPS insulation boards, concrete paver blocks or the underlying structural deck.
3. In zones 1, 2 and 3: secure every pedestal with a minimum of two fasteners per pedestal to either the latex-modified cement layer of composite XPS insulation boards, concrete paver blocks or the underlying structural deck.

Exception: Raised decking may be ballasted or loose laid provided wind resistance test reports of the actual deck assembly are provided to verify that the assembly can resist design wind loads as determined from DS 1-28 or wind tunnel tests.

2.2.3.6 Securely fasten roof-top objects including benches, trash receptacles and light poles to the building structure. This usually means installing fasteners in all securement holes with many objects having four holes. At times holes may need to be drilled or straps installed.

2.2.3.7 Secure roof-top trees. Securing the tree's root ball and /or the tree's trunk with guywires to concrete dead-man weights can be used. See Figure C.2.2-4.

2.2.4 MFL Fire Walls

2.2.4.1 Provide an area totally clear of vegetation, growth media, trees, decks, lounges, etc. on both sides of MFL fire walls in accordance with Data Sheet 1-42, *Maximum Foreseeable Loss Limiting Factors*. Only waterproofing assemblies covered with large stone ballast, concrete paver blocks or gravel is allowed. Roof surfacing depends on the roof cover type. See 2.2.3.4 for ballast requirements and Data Sheet 1-29 for restrictions on where stone ballast and concreter pavers can be used.

See recommendation 2.2.2.1 for the type of vegetative roof that can be used.

2.2.5 Non-Vegetated Border Zones and Fire Breaks

See Recommendation 2.2.14.2 for the vegetation and growth media free border zones for vegetative roofs at grade.

2.2.5.1 Zone 2 and 3 Roof Areas

2.2.5.1.1 Ensure that zone 2 and 3 roof areas (these have higher wind uplift pressures than zones 1 and 1') identified in Data Sheet 1-28, *Wind Design*, are free of vegetation and growth media. When stone or concrete pavers are provided, see 2.2.3.4 and Data Sheet 1-29.

The provision for the 8.5 ft (2.6 m) increased minimum dimension for zone 2 and 3 areas in Data Sheet 1-29 for ballasted roofs need not apply if the roofing membrane does not rely on ballast to resist wind uplift forces.

2.2.5.1.2 When the parapet wall height is at least 30 in. (760 mm), roof zones 2 and 3 can be permitted to have vegetation with a setback distance of 36 in. (900 mm) from the edge of the roof.

2.2.5.1.3 Cover the protection fabric, root barrier, or other components above the waterproofing membrane with stone ballast (meeting 2.2.3.2) or concrete paver blocks. See Figure 2.2.5.1-1. The FM Approved waterproofing assembly can be exposed.

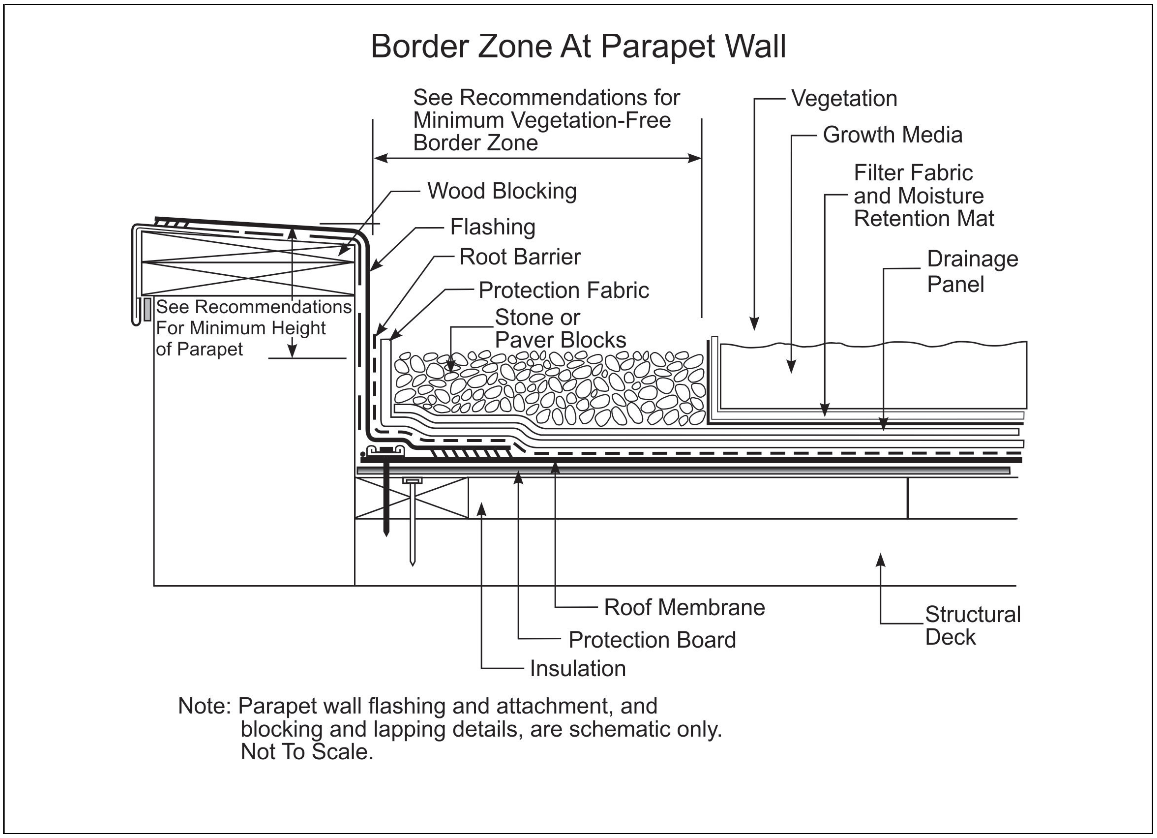

Fig. 2.2.5.1-1. Example of non-vegetated border zone detail at parapet wall

2.2.5.2 Subdividing Surface Areas

2.2.5.2.1 Provide minimum 13 ft (4.0 m) wide roof areas free of vegetation, growth media and combustibles to partition the roof into sections not exceeding 15,625 ft^2 (1,450 m^2), with each section having no dimension greater than 125 ft (39 m). Incorporate subdivisions into expansion joints or roof area dividers wherever possible.

2.2.5.3 Rooftop Structures, Penetrations, and Joints

2.2.5.3.1 Provide a minimum 3.0 ft (0.9 m) wide continuous border zone free of vegetation and growth media surrounding all non-combustible rooftop structures (including mechanical and machine roofs, penthouses), adjacent non-combustible walls and equipment, penetrations (e.g., ducts, drains, pipe, conduit), skylights, solar panels, antenna supports, expansion joints, roof area dividers, and interior parapet walls (unless part of an MFL fire wall; refer to Section 2.2.4).

Consider wider vegetation-free zones in cases where HVAC intake or exhaust could be expected to affect or be affected by plant growth; for instance, where taller plant growth might restrict intake, or high-velocity exhaust emissions could cause plant damage.

2.2.5.3.2 Provide a minimum 13 ft (4 m) wide continuous area free of vegetation and growth media surrounding all combustible rooftop structures, equipment, and features.

2.2.5.3.3 Provide a minimum 6 ft (1.8 m) wide continuous fire break free of vegetation and growth media, with the waterproofing assembly covered with concrete pavers or stone ballast, at abutting combustible vertical surfaces or at fire barriers. Use of stone ballast is subject to Recommendation 2.2.3.4.

2.2.6 Parapet Walls

2.2.6.1 Provide perimeter parapet walls for all vegetative roof systems as follows:

A. For roof heights up to 150 ft (46 m), at least 6 in. (150 mm) in elevation above the top of the growth media

B. For roof heights greater than 150 ft (46 m), at least 30 in. (760 mm) in elevation above the top of the growth media

2.2.7 Supporting Structure

2.2.7.1 Provide a galvanized finish for all exposed steel elements, steel anchors, and steel deck. Provide minimum G90 galvanizing (0.90 oz/ft^2 [275 g/m^2] zinc coating, per ASTM standard A653 or equivalent) for steel deck. Provide concrete cover for top reinforcing based on permanent exposure to weather, according to ACI standard 318 or equivalent.

2.2.8 Gravity Loads

2.2.8.1 Design the structure and roof deck to properly support the loads associated with the vegetative roof system in a fully-saturated condition, as well as any additional supported environmental loads (e.g., snow, rainwater, ice), suspended or supported dead loads (e.g., rooftop equipment, suspended interior finishes, piping, ductwork, roofing assembly), and superimposed roof live loads. In addition, ensure the roof structure can adequately support the hardscape roof features such as stone ballast, pavers, trees and curbing. See Section 2.2.12, Roof Drainage, for minimum standing water load requirements based on drainage configuration. Refer to section 2.2.13, Roofs at Grade, for additional load requirements and include the following:

1. Dead Loads

Design the dead load of the vegetative roof system in conformance with ASTM E2397 and ASTM E2399 or equivalent test standard. If conformance with these test standards cannot be verified, then base the design dead load of growth media on a saturated density of not less than 100 lb/ft^3 (134 kg/m^3) for maximum gravity load combinations. In addition to the typical components comprising the dead load, consider captured and retained water to be part of the dead load.

2. Live Loads

Determine minimum design roof live load requirements in accordance with Data Sheet 1-54, *Roof Loads for New Construction*, with the following restrictions:

A. For extensive vegetative roofs (see Appendix A for definition), use a minimum roof live load of no less than 12 psf. (0.58 kPa), even when considering live load reduction.

B. For intensive and simple intensive vegetative roofs (see Appendix A for definitions), use a minimum roof live load of no less than 20 psf. (0.96 kPa), even when considering live load reduction.

C. For systems where people are expected or encouraged to congregate, such as in such assembly areas (similar to balconies, terraces, etc.), design the supporting roof structure to support a minimum roof live load of 100 psf. (4.8 kPa).

3. Environmental Loads

Design snow and rain loads in accordance with Data Sheet 1-54, *Roof Loads for New Construction*. Consider transient water to be part of the total rain load.

2.2.9 Future Load Allowances

2.2.9.1 Increase the specified depth of saturated growth media by not less than 15% for the purpose of structural load calculations to account for future additions of growth media and inconsistencies in grading. Do not use future load allowances in calculations if these loads counteract any uplift or overturning forces.

2.2.10 Design Surface Loads of Vegetation

2.2.10.1 Use the vegetation surface loads provided by the vegetative roof supplier or installer. See Table 2.2.10-1 for reasonable minimum design loads.

Table 2.2.10-1. Reasonable Minimum Design Loads by Type of Vegetation

Type of Vegetation	*Reasonable Minimum Design Loads, psf (kg/m^2)*
Succulents (Sedums), herbs, grasses	2 (10)
Grasses and bushes up to 6 in. (150 mm)	3 (15)
Shrubs and bushes up to 3 ft (1 m)	4 (20)

2.2.11 Seismic Loads

2.2.11.1 When calculating maximum seismic base shear and maximum seismic overturning and uplift, evaluate the following conditions when determining the dead loads used in the most stringent design load combinations:

A. Include the full weight of the entire vegetative roof assembly (including fully-saturated growth media with retained and captured water). Consider the effects of localized removal of the vegetative roof assembly or hardscape components where the result would constitute a more stringent design condition for the structural support system.

B. Exclude the full weight of the above-membrane vegetative roof components (assume a conventional roof cover).

Refer to Data Sheet 1-2, *Earthquakes*, for additional seismic load guidance.

2.2.12 Roof Drainage

2.2.12.1 Provide a primary roof drainage system capable of removing rainwater from the roof at a rate equal to or greater than that resulting from the 60-minute duration, 100-year mean recurrence interval (MRI) rainfall event. Use rainfall maps in Data Sheet 1-54, *Roof Loads for New Construction*.

2.2.12.2 Provide a secondary drainage system completely independent of the primary drainage system. Ensure the secondary drainage system is capable of removing rainwater from the roof at a rate equal to or greater than that resulting from the 15-minute duration, 100-year MRI rainfall event.

Ensure the base (invert) of the secondary drainage inlets are at least 2 in. (50 mm), but no more than 6 in. (150 mm), in elevation above the base of the primary drainage inlets.

2.2.12.3 Include the weight of rainwater (based on the depth required to achieve the secondary drainage design capacity) in the roof design load. Consider potential ponding resulting from roof deflections.

2.2.12.4 Provide drainage systems designed to conform to the more stringent of the following conditions:

A. The vegetative roof system as proposed

B. The roof with a traditional roof cover (i.e., without the above-membrane vegetative roof assembly)

2.2.12.5 Provide drains and outlets that have inspection chambers with removable covers, allowing for easily accessible inspections to ensure plants, growth media, and gravel do not restrict or reduce flow.

2.2.12.6 Ensure the drainage design accounts for vertical sheet flow from large facades due to wind-driven rains in addition to that from horizontal roof surfaces.

2.2.12.7 Use steel roof drains with steel drain lines on the top floor when expanded or extruded polystyrene is not isolated with a fire barrier or part of an FM Approved assembly.

2.2.12.8 Refer to Data Sheet 1-54, *Roof Loads for New Construction*, for additional information regarding design rainfall intensity and duration.

2.2.13 Roof Slope

2.2.13.1 Provide a minimum roof slope of 2% (1/4 in./ft or 1.1°) for all vegetative roofs supported by structural concrete decks. For vegetative roofs supported by other structural systems (e.g., metal roof deck), provide a minimum roof slope of 3% (3/8 in./ft or 1.8°).

2.2.13.2 Provide additional anti-shear stability layers or anchorage, and erosion control for roof slopes greater than 20% (11°) but less than 40% (22°). Do not use roof slopes greater than 40% (22°) as they will pose a significant challenge regarding stability and erosion.

2.2.13.3 Ensure shear loads induced by the roof slope do not damage any underlying layers (e.g., the drainage panel, protection fabric, root barrier, or membrane). Ensure growth media is placed and cultivated in such a way as to protect against sliding in both dry and saturated conditions.

This may be achieved by the use of crushed aggregate (e.g., brick, expanded shale, pumice) in the mineral soil, which will provide good shear resistance due to the rough angular nature of the particles. Limiting fine aggregate content in the growth media, combined with good root penetration, will also promote stability and limit wash-out.

2.2.13.4 Ensure the supporting structure has been designed and checked by a registered structural engineer to properly support all dead, live, and environmental loads (e.g., snow, rain, ice, flood, wind, seismic) associated with vegetative roof systems, including the effects of ponding.

2.2.14 Vegetative Roofs at Grade

2.2.14.1 Use a minimum 100 psf (4.8 kPa) roof live load for roofs located at or below grade, or transitioned into a sloping grade (e.g., partially built into a hillside). For roofs where vehicle access is feasible (commercial trucks, fire service tankers, or similar), use appropriate vehicle loads, with maximum axle loads of not less than 32,000 lb (14,500 kg) or equivalent uniform surcharge loads of not less than 250 psf (12 kPa). Where roofs are not designed to support vehicle loads, provide permanent physical barriers (e.g., bollards, guard rails) along with appropriate signage to restrict vehicular access.

2.2.14.2 Provide a continuous vegetation-free border zone at least 3 ft (0.9 m) wide to separate the vegetative roof system from adjacent at-grade vegetation or materials. If the surrounding grade materials are deemed to pose a fire hazard (e.g., forest, grass, or brush fires) refer to Data Sheet 9-19, *Wildland Fire*. Evaluate other potential fire exposure hazards on a site-specific basis.

2.2.14.3 For roofs built into a sloping grade, ensure the structural engineer and geotechnical engineer have evaluated the roof structure and site conditions for potential mudslide or landslide hazards. The building official should be consulted regarding local historical occurrences relating to soil stability.

2.2.14.4 Evaluate roofs at or below grade (e.g., below-grade parking facility with landscaped vegetative roof) for flood loads. Use the 500-year flood elevation as a basis for the evaluation.

2.2.15 Vegetative Roof Components

When installing an FM Approved vegetative roof assembly, follow the manufacturer's instructions using the vegetation and components in the FM Approval.

This section provides additional information when details are not provided. See Appendix C Supplementary Information and NRCA's Vegetative Roof Systems Manual for additional guidance.

2.2.15.1 Vegetation

2.2.15.1.1 Use plants generally accepted as appropriate for vegetative roof applications, the local climate, and the rooftop microclimate. Vegetation on high-rise buildings dry out faster than those on lower roofs due to the more consistent air flow and winds.

2.2.15.1.2 Avoid the use of grass and moss, which can dry out and create a potential fire hazard.

2.2.15.1.3 For extensive roofs, growth media should be fully covered with vegetation with at least 60% of vegetation from the Sedum family for groundcover plantings where they are appropriate. (Sedums may not be appropriate in warmer climates such as in Florida, USA.) Use at least three different species of Sedums, in more or less equal quantities.

2.2.15.1.4 For groundcover plantings, sow seeds at a rate of not less than 3,000 seeds per 100 ft^2 (325 per 1 m^2), distribute cuttings at not less than 2.5 lb per 100 ft^2 (12 kg per 100 m^2), or install pre-grown plugs at the rate of not less than 100 plugs per 100 ft^2 (11 plugs per 1 m^2).

2.2.15.1.5 For intensive and semi-intensive roofs, select shrubs and trees that will not readily ignite and burn fiercely, such as those with a high water or salt content, or low amounts of volatile oils. Deciduous trees are preferred over evergreen trees as they require lower maintenance with all the leaves dropping together in autumn instead of continuously throughout the year.

2.2.15.2 Growth Media (Engineered Soil)

2.2.15.2.1 Provide no less than 3 in. (80 mm) of uniform depth growth media in its installed (compacted) condition in conformance with the manufacturer's or landscape horticultural professional's specifications. See Section 3.10.1 for typical requirements regarding air and salt content, pH, and water content and permeability.

2.2.15.2.2 Do not substitute standard landscaping soil or loam for growth media. Growth media contains porous aggregate materials, such as crushed clay brick, expanded shale, and crushed pumice, that are specifically designed to retain water, provide aeration, and allow for proper drainage.

2.2.15.3 Moisture Retention Mat

2.2.15.3.1 Provide a moisture retention mat that conforms to the requirements of the vegetative roof system. Typically, a water retention capacity of not less than 0.2 in./ft^2 (0.12 gal/ft^2 [5.0 l m^2) will be necessary.

2.2.15.4 Drainage Panel and Filter Fabric

2.2.15.4.1 Provide drainage panels with a compressive strength sufficient to properly support the required loads (saturated overburden of growth media and vegetation, roof gravel, and pavers in hardscape areas, roof live loads, and any required environmental loads) according to the manufacturer's specifications.

2.2.15.4.2 Ensure the filter fabric will allow for unimpeded root penetration and provide a minimum vertical capillary rise of 4 in. (100 mm) in five minutes. Take particular care to ensure properly detailed filter fabric terminations are used around drainage fixtures to prevent erosion of growth media and clogging of drains.

2.2.15.5 Protection Fabric

2.2.15.5.1 Provide a durable water-permeable protection fabric of no less than 0.75 lb/yd^2 (285 grams/m^2).

2.2.15.6 Root Barrier

2.2.15.6.1 For systems with asphalt-based or bituminous waterproofing membranes and materials, provide a root barrier not less than 0.03 in. (0.8 mm) thick, and continuously seal (heat weld or solvent weld) all root barrier seams.

2.2.15.6.2 When the seams of waterproofing membranes are not designed to be heat-welded (e.g., EPDM membranes), provide continuous heat-welded root barrier seams.

2.2.15.6.3 Lap all root barrier seams to be sealed at least 6 in. (150 mm). Use welded seams not less than 1.5 in. (38 mm) wide in order to create a watertight seal. Test welded seams for integrity by either air lance or hand scribe techniques.

2.2.15.7 Protection Board

2.2.15.7.1 Provide protection board of sufficient strength and durability to adequately protect the waterproofing membrane during construction and in the permanent fully assembled condition. Avoid materials that will lose effectiveness with prolonged exposure to moisture.

2.2.15.8 Insulation Board

2.2.15.8.1 Use insulation board with adequate compressive strength and durability to support the weight of the saturated vegetative roof hardscape materials, such as roof gravel and pavers, roof live loads, and environmental loads, according to the manufacturer's specifications.

2.2.15.8.2 If also using above-membrane insulation board, provide boards with integral drainage channels to facilitate drainage.

2.2.15.9 Mulch

2.2.15.9.1 Use non-combustible mulch. When non-combustible mulch is not available, use mulches that are less combustible, with lower flame height and spread such as wood or bark chips. Do not use shredded, rubber, pine needle or straw mulches.

Combustible mulches vary in their flame height, rate of fire spread and combustion temperature; and are also affected by the rooftop temperature and humidity.

See The Combustibility of Landscape Mulches https://naes.agnt.unr.edu/PMS/Pubs/1510_2011_95.pdf for additional information.

2.2.16 Roof Expansion Joints

2.2.16.1 Provide noncombustible, compressible insulation (such as mineral wool) within the roof expansion joints or around other roof penetrations when thermoplastic insulation (expanded or extruded polystyrene) is exposed in concealed spaces or exposed to the underside of elevated decks.

For more information see FM Property Loss Prevention Data Sheet 1-15, *Roof-Mounted Solar Photovoltaic Panels*.

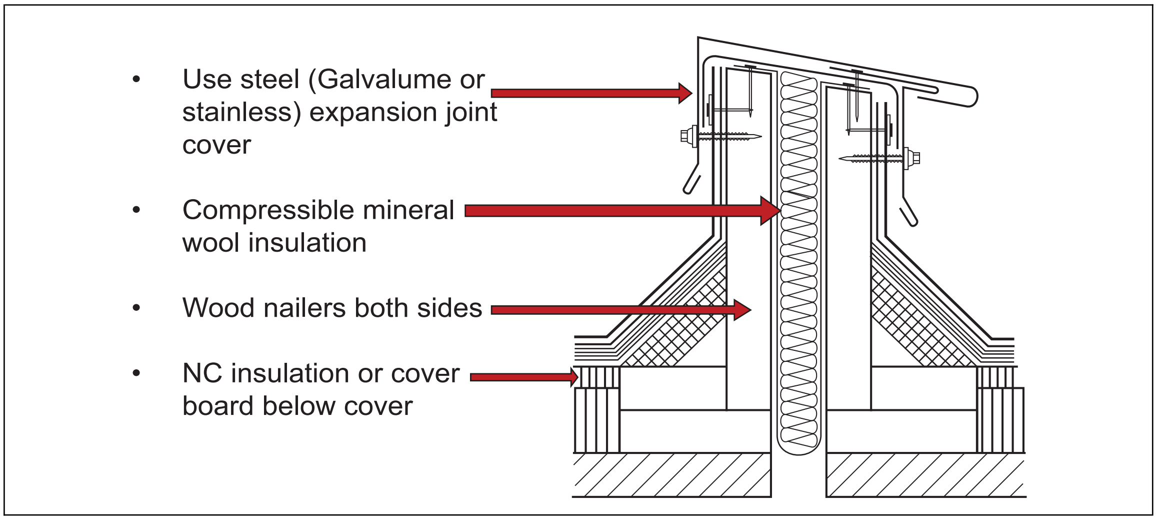

Fig. 2.2.16-1. Recommended roof expansion joint detail

2.3 Protection

2.3.1 Provide automatic sprinklers with a 0.20 gpm/ft^2 over 2000 ft^2 (8.1 mm/min over 190 m^2) density in the following areas (A and B):

Note: Sprinkler systems must be accessible for maintenance, including dry-pipe systems that must be accessible to be properly drained. Where lack of accessibility prevents proper sprinkler system maintenance, refer to Section 2.3.3 for recommendations in lieu of sprinkler installation.

A. Under wood or plastic decks, regardless of their fire rating.

B. In concealed areas with any of the following:

1. Exposed combustibles including the support structure, fiberglass grates, plastic pedestals or plastic trays.

2. Combustible foam plastic boards (e.g., extruded or expanded polystyrene) where the surface that is exposed to the concealed space is not covered by minimum 2 in. (51 mm) thick concrete pavers or minimum 15/16 in. (24 mm) latex modified concrete.

When no other combustibles such as plastic grates or pedestals are present, the latex modified concrete covering can be reduced to a minimum thickness of 3/8 in. (10 mm).

3. Roof covers without a topping of minimum 2 in. (51 mm) thick concrete pavers, unless the recommendations in Section 2.2.2.5.2 for rooftop hardscapes or decks are met.

2.3.2 Exceptions to the sprinkler installation recommendations in Section 2.3.1:

A. Sprinklers are not needed in the following situations:

1. When the only combustible component is either a landscaping fabric or an FM Approved roof assembly installed as recommended in Section 2.2.2.5.2.

2. When concrete pavers are elevated less than or equal to 2 in. (51 mm) above the roof assembly. The 2 in. (51 mm) maximum elevation applies throughout the entire area since the elevation varies with roof slope. Concrete pavers must not be on plastic trays. See Figure C.2.2.-6 for this construction.

2.3.3 Install both A and B where sprinklers are recommended in Section 2.3.1 but cannot be installed due to space or maintenance limitations:

A. FM Approved linear heat detection. Install in accordance with Data Sheet 5-48, *Automatic Fire Detection*.

Linear heat detection need not be installed when concrete pavers are elevated less than or equal to 2 in. (51 mm) above the roof assembly. The 2 in. (51 mm) maximum elevation applies throughout the entire area since the elevation varies with roof slope. Concrete pavers must not be on plastic trays. See Figure C.2.2-6 for this construction.

B. Non-combustible fire partitions spaced a maximum of 2000 ft^2 (186 m^2) in combustible concealed spaces where automatic sprinklers cannot be installed.

2.3.4 Provide video surveillance in a constantly attended location of roof-top areas with vegetative roofs, roof-top decks with combustible construction or furnishings, and combustible concealed spaces.

2.3.5 Provide exposure protection on adjacent buildings following Data Sheet 1-20 where there are insufficient fire breaks and/or sufficient combustibles for a fire to damage adjacent buildings.

2.3.6 Provide a standpipe system in the stairwell with hose connections at the roof level or roof fire hydrant near a roof access hatch. Follow Data Sheet 4-4N, *Standpipe and Hose Systems*, for standpipes and Data Sheet 3-10, *Private Fire Service Mains and Connections*, for roof fire hydrants.

2.4 Operation and Maintenance

2.4.1 Irrigation

2.4.1.1 Provide rooftop hose bibs for vegetative roof systems designed to be self-sustaining without regularly scheduled irrigation (i.e., most Extensive systems). This allows for irrigation during initial stages of plant propagation and during occasional drought conditions.

2.4.1.2 Provide a permanent irrigation system for vegetative roof systems that require regular irrigation (i.e., Intensive and Simple Intensive systems)

2.4.2 Fertilization, Pesticides, and Plant Care

2.4.2.1 Fertilize as necessary during the initial establishment of the vegetation over the first and second growing seasons; after that time, occasional fertilization, perhaps once or twice annually, might be necessary. Consult the roofing manufacturer in order to determine which chemical fertilizers and pesticides, if any, are acceptable and will not damage the waterproofing assembly or void the warranty.

2.4.3 Leak Test and Inspection

2.4.3.1 Conduct a standing water leak test (also known as flood test) prior to the installation of the above-membrane components (drainage panel, growth media, vegetation, etc.) This test involves flooding the entire vegetative roof area with not less than 2 in. (50 mm) of standing water for a period of at least 24 hours with drains and scuppers blocked. Ensure drains or scuppers allow for emergency overflow if the water level exceeds the specified test level (for instance, due to an overnight rain). Ensure the structure can adequately support the hydrostatic load encountered during the flood test, including the effects of ponding.

Prior to draining the standing water, the owner's representative, manufacturer's representative, and contractor should inspect the roof for leaks from below, and from the roof surface; this will include walking all membrane seams. Once the standing water has been drained, inspect the roof and walk all membrane seams again. If areas are found that are suspected of leaking, the contractor will perform test cuts according to the manufacturer's directions. If test cuts are determined to be wet, the contractor will patch the test cut per the manufacturer's specifications and the flood test will be repeated. In addition to leak detection, include inspection for adequate slope to drain.

2.4.3.2 Inspect, test and maintain fire protection and detection system(s) according with FM Property Loss Prevention Data Sheets 2-81, *Fire Protection System Inspection Testing and Maintenance* and Data Sheet 5-48, *Automatic Fire Detection*, respectively.

2.4.4 Warranty

2.4.4.1 Ensure the manufacturer's warranty includes the initial vegetation viability if the entire system (waterproofing assembly as well as vegetative roof cover, including vegetation and growth media) is provided by a single source. In addition to the standard waterproofing warranty, ensure the warranty states that the proposed vegetative roof cover is completely compatible with the waterproofing assembly. Also, ensure the warranty for the vegetative roof cover states that the proposed waterproofing system is compatible with the vegetative system (including plant climate zone, roof slope, and irrigation and maintenance requirements).

If the waterproofing and vegetative roof cover are not provided by a single source, ensure the waterproofing assembly will be warranted separately, independent of any warranty for the vegetative roof cover.

2.4.5 Inspection and Maintenance of Vegetative Roofs

2.4.5.1 Provide maintenance as needed to keep the vegetative roof plants alive and healthy, including the following:

A. Follow the system provider's maintenance guidelines.

B. Remove dead and overgrown material. Vegetation on high rise buildings is more susceptible to drying because of regular exposure to winds.

C. For extensive vegetative roofs, maintain coverage of the growth media by vegetation with no areas of exposed growth media greater than 4 in. (100 mm) diameter.

2.4.5.2 Inspect the vegetation and other roof components, including roof drains, at least twice a year and as soon as it is safe following wind and hailstorms. Wind can cause scouring of the vegetation and hail can accumulate at roof drains and prevent proper drainage from melting hail and precipitation.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 Geographic Restrictions

Vegetative systems should not be installed in wildland fire areas because burning embers and high winds may ignite the vegetation.

3.2 Selecting Vegetative Roof and Roof Waterproofing Assemblies

Among the many characteristics required of vegetative roof plants, the most critical are good fire resistance, good drought resistance, and a non-aggressive vertical root system that will be unlikely to penetrate and compromise underlying waterproofing layers. Consult a landscape or horticultural professional familiar with vegetative roof systems regarding the selection of an appropriate comprehensive vegetation system.

FM Approved fully adhered or mechanically attached membrane roof assemblies designed for the design wind uplift pressures are recommended because the growth media can be prone to scour from wind and water action and therefore may not be a reliable source of uniform ballast for waterproofing components.

Also, if it is decided to return to a conventional roof system in the future, a properly designed waterproofing system with proper fire and hail ratings allows for the removal of above-membrane vegetative roof components without compromising the integrity of the roof system.

Vegetative roof systems can be specified with fluid-applied asphalt-based membranes, torch-applied bitumen membranes, thermoplastic (PVC or TPO) single-ply membranes, or thermoset polymer-based (EPDM) single-ply membranes. Asphalt-based and bituminous membranes and materials are subject to attack and premature degradation from soil-borne microbial activity; therefore, root barriers are necessary to protect these membranes.

3.3 Wind Securement of Vegetative Components

The vegetative roof components above the roof waterproofing membrane need to be secured against wind uplift. Netting, a tie-down system, or ballasting by the weight of the modules or growth media. This ballasting may be referred to as secondary ballast since it secures only the vegetative roof components when the roof waterproofing assembly is adhered or mechanically secured (recommended) for the wind uplift pressures. It is primary ballast if it ballasts a loose-laid roof waterproofing assembly, which is not recommended.

3.4 Non-Vegetative Border Zones and Fire Breaks

Non-vegetative border zones are recommended for several reasons: (1) to provide maintenance access because vegetative roof vegetation is not intended to support foot traffic, (2) to provide additional resistance to high wind uplift pressures, (3) as a means of reducing scour of growth media, (4) to reduce the potential generation of windborne debris at roof perimeters and corners, and (5) to provide a fire break at rooftop equipment, penetrations, and structures.

3.5 Supporting Structure

Due to the nature of vegetative roof systems, particularly Intensive systems (which include a deep layer of growth media), the associated dead load can be substantial. Particular care must be taken to coordinate the supporting structural components with the drainage system in order to avoid excessive deflection and localized ponding. Some structural materials, such as concrete, are prone to long-term deflection (creep) when subjected to sustained loads over a long period of time.

3.6 Gravity Loads

Gravity loads include dead loads, live loads, and some environmental loads (e.g., snow, rain, ice).

For structural design and analysis using Load and Resistance Factor Design (LRFD) or ultimate limit states design methodologies, it is necessary to properly classify the various loads associated with code-required factored load combinations. Load factors are determined by the classification of the load and can vary by code. For example, the factor for dead load could be 1.2, while the factor for roof live load, rain load, or snow load could be 1.6.

The vegetative roof assembly (including vegetation, saturated growth media, drainage mats, trees and all captured and retained water) and hardscaped areas with walking paths, tile and paver decks are classified as dead load. Transient water is considered roof rain load. Note that live load reduction is not applicable to environmental loads such as rain and snow.

3.7 Seismic Loads

Vegetative roof systems can add a substantial amount of mass to the roof of a building. Since the mass of a building is one of the factors that controls the seismic (earthquake) loads induced into a building's lateral load-resisting system, the increased mass of a vegetative roof system will cause an increase in seismic load. The weight of a building that is used when calculating seismic load typically includes the total dead load, a percentage of the storage live load and snow load, and a minimum allowance for moveable office partitions (where applicable).

Seismic design and analysis involves examining various load combinations to achieve the following conditions:

A. Maximum seismic base shear

B. Maximum seismic overturning and uplift

For the first condition, the greatest base shear loads are achieved under a maximum gravity load condition. Therefore, when considering a vegetative roof system, include the full weight of the entire roofing assembly, including the fully-saturated growth media and captured water, when determining the dead load used for maximum seismic base shear seismic calculations. Transient water, which is considered part of the roof live load, need not be included when calculating seismic loads.

For the second condition, the greatest overturning of uplift loads can be achieved when the counteracting dead loads are minimized in a reasonable fashion. Therefore, exclude the entire weight of the above-membrane vegetative roof system when determining the dead load used for maximum seismic overturning and uplift calculations. This provision is intended to address a potential future condition where the vegetative roof system has been replaced with a conventional roof system.

3.8 Roof Drainage

The provision for more stringent drainage design (vegetative roof system as proposed, versus a roof with a traditional roof cover) is intended to address the risk of insufficient drainage capacity for a roof that was originally designed as a vegetative roof system but is either partially or completely replaced with a traditional roof cover at some time in the future.

Easily accessible inspection chambers in drainage outlets are an important part of ensuring the drainage system will function at capacity as designed. Root growth, displaced growth media and stone ballast, dead foliage, and general debris can act to substantially reduce the discharge capacity, allowing water to pond and create a collapse potential.

The provision for the differential in the elevation between primary and secondary drainage inverts (2 to 6 in. [50 to 150 mm]) is intended to ensure that the primary and secondary drains will not become clogged by debris concurrently. Also, that the maximum depth of retained water will be kept to a level that will not overload the supporting structure nor create a mechanism for ponding water.

3.9 Roof Slope

Structural concrete deck is preferred over steel roof deck to support vegetative roof systems. Structural concrete deck has more strength and stiffness, and better resistance to water ingress and corrosion, than steel roof deck. Given the nature of vegetative roof systems, which includes relatively large dead loads due to saturated growth media and retained water, these properties (strength, stiffness, and leak resistance) are of particular importance. When using steel roof deck, the minimum slope is increased (from 2% to 3%) in order to minimize the likelihood of ponding water and the subsequent potential for progressive deflection and collapse.

3.10 Vegetation

This section contains information to supplement the manufacturer's instructions for vegetative roof systems.

3.10.1 Climate

In the United States, vegetation can be selected based partly on the USDA Plant Hardiness Zone Map; however, the effects of solar radiation, wind, and frost can create a microclimate that will be more challenging for vegetation on a roof than for the same plants at grade level. The existence of a distinct microclimate is one of the reasons native vegetation frequently does not thrive on a vegetative roof.

3.10.2 Extensive Roof Vegetation

Extensive green roof vegetation is limited to a few families of specialized hardy plants that can thrive in shallow soil. Extensive vegetative roofs usually are not intended as accessible roofs since the vegetation does not support traffic.

Plants used successfully on an Extensive vegetative roof system have characteristics such as wind resistance, frost resistance, drought resistance, resistance to radiation, a shallow roof systems, and good regenerative capabilities. As noted above, the microclimate on a vegetative roof may exhibit significant differences from the local climate at grade. The combination of direct and reflected radiation, as well as higher wind velocities, can create a challenging environment above grade. The lack of such things as ground water (access through capillary action), natural soil aeration devices, and a deep thermal mass also can create a difficult environment for plant growth. For these reasons, planting extensive vegetative roofs with local native vegetation is frequently unsuccessful. However, specialty plants, such as Sedums, have exhibited good success rates due to their hardiness.

Sedums are succulent alpine plants that are regenerative, have shallow, non-aggressive root systems, are drought- and wind-resistance, and are relatively resistant to fire. Fire-resistant plants have foliage with a high-moisture, low-resin content; this is exhibited by supple leaves with watery sap. Sedums can be propagated using seeds or cutting. Sedums can also be cultivated offsite, then planted in the form of plugs or pre-vegetated mats. Plugs have a higher up=front cost but are preferred over cuttings and seed due to a better propagation success rate (roughly 80% for plugs, 50% for cuttings) and the resulting enhancement of erosion control against wind and water.

3.10.3 Intensive Roof Vegetation

Intensive vegetative roof vegetation typically is more diverse and less specialized than Extensive vegetative roof vegetation. Intensive vegetative roof vegetation includes ground covers, grasses, shrubs, and even small trees.

3.11 Growth Media (Engineered Soil)

Growth media is the material that supports and nourishes the vegetative roof vegetation; it provides water and nutrients to the plants, as well as anchorage for the root system.

Growth media consists of two components: mineral soil and organic soil. The proportions of mineral and organic soils vary significantly depending on the manufacturer; the organic content can range from 8% to 25% for Extensive vegetative roof systems. The organic content for Intensive vegetative roof systems is up to 50% greater than for Extensive systems. The mineral and organic soils usually are pre-mixed prior to placement on the roof. The depth of growth media usually ranges from 3 to 6 in. (75 to 150 mm) for Extensive systems, and from 8 to 24 in. (200 to 600 mm) for Intensive systems. Simple Intensive systems typically are classified by a depth of growth media from over 6 in. (150 mm) to less than 8 in. (200 mm). Growth media has an as-installed density of 5.5 to 6.0 psf/in. (1.1 to 1.2 kg/m^2 per mm) when dry, and 7.5 to 8.0 psf/in. (1.4 to 1.5 kg/m^2 per mm) when saturated.

Wind action can cause significant scour of the growth media, depriving the vegetation of moisture and nutrients, exposing plant roots and underlying roofing materials to UV radiation, and removing the ballasting effect the growth media may provide for the above-membrane roofing components.

3.11.1 Typical Specifications for Growth Media

The following are typical conditions specified for growth media:

A. Soluble salt content no greater than 0.34 oz per gal (2.5 g/l) of extracted water for Extensive vegetative roof systems, and 0.48 oz per gal (3.5 g/l) for Intensive systems.

B. A pH within the following ranges: 6.5 to 8.0 for Extensive systems, and 5.5 to 8.0 for Intensive systems.

C. Fully-saturated air content of not less than 10% by volume.

D. Water storage capacity (by volume) in its installed, compacted state: from 25% to 65% for Extensive systems, and 45% to 65% for Intensive systems.

E. Rate of water permeability in its installed, compacted state: not less than 0.12 in. per minute (3 mm/min) for systems with up to 6 in. (150 mm) of depth, and not less than 2.4 in. per hour (60 mm per hour) for systems with over 6 in. (150 mm) of depth.

3.12 Vegetative Roofing Components

3.12.1 Moisture Retention Mat

A moisture retention mat is used to provide moisture to the growth media and the plant roots. The moisture retention mat typically is made of recycled polypropylene fibers stitched to a needle-punched, thermoplastic fabric sheet carrier, and is installed loose-laid. The moisture retention mat is designed to allow for unimpeded root penetration.

In some vegetative roof assemblies, the moisture retention mat is designed to also serve as the protection fabric for the waterproofing membrane.

3.12.2 Drainage Panel and Filter Fabric

Drainage panels, also known as drainage retention panels, have a two-fold purpose: (1) they allow for proper drainage of water from the overlying saturated growth media, and (2) they retain water to provide the root system with access to moisture during dry periods.

The drainage panel typically is molded from rigid thermoplastic (usually polyethylene or polystyrene) with “domes” and “cups” impressed into the shape. The domes are perforated to allow for air circulation to, and water drainage from, the growth media. The cups are designed to capture water, which can then be transferred to the growth media and root system through capillary action and absorption.

Filter fabric is used to retain growth media and prevent fine particles from being washed out of the growth media into the underlying drainage panel. Filter fabric typically is a non-woven geo-textile fabric made from thermoplastic (e.g., polyethylene or polypropylene) fibers.

3.12.3 Protection Fabric

Protection fabric is used to protect the root barrier and waterproofing membrane from damage due to growth media aggregate, hardscape materials, drainage panel edges, and damage during installation. Protection fabric is a water-permeable, durable synthetic fiber material with good resistance to puncture. The protection fabric is sometimes provided as an integral part of the drainage panel. It should weigh no less than 0.75 lb/yd^2 (285 grams/m^2).

3.12.4 Root Barrier

Root penetration into membrane laps and seams is one of the most common ways in which the integrity of the waterproofing system can be compromised. Root barriers are designed to provide protection from plant root migration under waterproofing membranes.

Vegetative roof systems contain microorganisms in the growth media and root system that can attack and degrade bituminous and asphalt-based roofing products. Root barriers are used to protect underlying waterproofing materials from harmful microbial activity. Root barriers often are required to have heat welded lap seams; therefore, thermoplastics such as PVC, TPO, and polyethylene are commonly used. Root barrier sheets typically are installed loose-laid.

Root barriers are usually recommended by the waterproofing membrane manufacturer. The waterproofing membrane may simultaneously act as a root barrier and waterproofing membrane if recommended by the membrane manufacturer.

3.12.5 Protection Board

Fire and thermal barrier properties of protection board are of particular importance given the presence of several layers of combustible material associated with typical vegetative roof assemblies.

3.12.6 Insulation Board

Rigid insulation board must have adequate compressive strength to properly support the weight of the saturated vegetative roof, hardscape materials (such as roof gravel and pavers), superimposed roof live loads, and environmental loads. For systems with over 8 in. (200 mm) of growth media, two separate layers of insulation typically are provided. In addition to the below-membrane insulation, an above-membrane layer of insulation boards is provided as additional protection for the waterproofing membrane.

3.13 Irrigation

Extensive vegetative roofs are designed to be viable without supplemental irrigation. However, during the first one or two growing seasons, and at times of extreme drought, access to irrigation (such as rooftop hose bibs) will be necessary.

Intensive vegetative roofs are not expected to be viable without regular irrigation and maintenance.

3.14 Leak Testing

Leaks in the waterproofing system can be difficult to detect and locate in a conventional roofing system. Leaks in vegetative roof systems are particularly troublesome due to the covering of growth media and vegetation. In addition to the flood test described in Section 2.3.3B, a method of leak detection called electric field vector mapping (EFVM) is available.

3.15 Inspection and Maintenance

The recommendation for having no exposed growth media greater than 4 in. (100 mm) in diameter for extensive systems follows ANSI/SPRI RP-14 2016, *Wind Design Standard for Vegetative Roofing Systems*.

3.16 Loss History

Several losses have occurred to vegetative roofs from fire, wind, collapse, and water damage. In 2022 an outdoor wooden deck on the 11th floor of an apartment building caught fire damaging the building's exterior.

There are several published cases in which vegetative roof systems did not function as designed and were required to be repaired or restored. Most of those cases involved the improper selection and maintenance of vegetation.

Vegetative roofs that were damaged include the following:

2017. Seattle, Washington, USA. A rooftop garden on a 13-story building in downtown Seattle ignited from improperly discarded smoking materials. A tree and grass subsequently caught fire. The fire department extinguishing the fire without damage to the building other than to the roof-top garden.

2017. Wildland fire in California, USA ignited dead vegetation on a vegetative roof. Fire damage was limited to the vegetation.

2012. Roof Collapse. A vegetative roof at a shopping mall collapsed from a heavy load of soil during construction work.

2010. Water damage. The waterproofing membrane under a vegetative roof leaked, damaging the interior of a hospital and parts of the roof. The vegetative roof delayed finding the roof leak, increasing the water damage.

1997. Wind from storm Lothar damaged 4000 ft^2 (372 m^2) of a 560,000 ft^2 (52,000 m^2) warehouse in Germany that had an extensive vegetative roof. Roof was designed to FLL guidelines "to withstand very high winds." Fire & Wind on Extensive Green Roofs, Jorg Breuning, Green Roof Service LLC - Green Roof Technology. Report includes a picture of the damage.

2022. Rooftop Deck. Revere, Massachusetts, USA. A wooden rooftop deck on the 11th floor of an apartment building caught fire. The fire damaged the exterior of the abutting 16-story building.

4.0 REFERENCES

4.1 FM

Data Sheet 1-2, *Earthquakes*
Data Sheet 1-28, *Wind Design*
Data Sheet 1-29, *Roof Securement and Above-Deck Roof Components*
Data Sheet 1-34, *Hail Damage*
Data Sheet 1-42, *MFL limiting Factors*
Data Sheet 1-54, *Roof Loads for New Construction*
Data Sheet 2-81, *Fire Protection System Inspection, Testing and Maintenance*
Data Sheet 9-19, *Wildland Fire*

FM Approval Standard 4477, *Vegetative Roof Systems*

4.2 Other

ASTM International. E2397-05 *Standard Practice for Determination Dead Loads and Live Loads associated with Green Roof Systems*.

ASTM International, ASTM C1491-18, *Standard Specification for Concrete Roof Pavers*, 2018.

ASTM International. E2399-05 *Standard Test Method for Maximum Media Density for Dead Load Analysis of Green Roof Systems*.

ASTM International. *Hot Dip Galvanized Coils and Sheet Quality Norms*.

American Concrete Institute (ACI). *Building Code Requirements for Structural Concrete and Commentary*. ACI 318.

Forchungsgesellschaft Landschaftsentwicklung Landschaftsbau e.V. (FLL). *Guidelines for the Planning, Execution, and Upkeep of Green-Roof Sites*.

National Roofing Contractors Association. *The NRCA Vegetative Roof Systems Manual*. Third edition. 2017.

National Roofing Contractors Association. "Testing Vegetative Roof Systems." (accessed July 2022).

Single-Ply Roofing Industry (SPRI). ANSI/SPRI RP-14 2016, *Wind Design Standard for Vegetative Roofing Systems*.

University of Nevada Cooperative Extension. "*The Combustibility of Landscape Mulches*." Available online at https://naes.agnt.unr.edu/PMS/Pubs/1510_2011_95.pdf (accessed July 2022).

APPENDIX A GLOSSARY OF TERMS

ACI: American Concrete Institute

ASTM: American Society for Testing and Materials

Border zone: An area without vegetation and growth media, usually surfaced with hardscape materials, and typically located at roof edges, roof penetrations, rooftop equipment, skylights, and expansion joints.

Basic wind speed, V: Three-second gust speed at 33 ft (10 m) above the ground in Surface Roughness Exposure C.

Captured water: The quantity of water retained in the drainage layer of a vegetative roof system (once new water addition by rainfall or irrigation has ceased) that cannot escape except through evaporation or plant transpiration. Captured water contributes to the dead load of the system.

Dead load: Loads consisting of the weights of all materials of construction, building finishes, and fixed service equipment. In the case of vegetative roof systems, the entire roof assembly (including growth media, roofing materials, and captured water) is considered dead load.

Drainage panel/drainage layer (drainage/retention panel): Panel typically molded from rigid thermoplastic in a corrugated "egg carton" profile that provides for water retention, root aeration, and overflow drainage from the growth media. Some drainage panels are supplied with an integral filter fabric. In lieu of a drainage panel, systems can consist of a layer of granular material (expanded slate and clay, pumice, crushed brick) to perform the same functions. The granular media used for the drainage layer is typically required to meet specific requirements for gradation, porosity, hydraulic conductivity, and alkalinity.

EFVM: Electric Field Vector Mapping. A method of leak detection based on the electrical conductivity of a moist cover material (growth media) and the electrical insulating properties of the waterproofing membrane.

Environmental load: Variable loads due to earthquake, flood, wind, snow, rain, and ice. These loads are not typically subject to reduction in the same manner as live loads.

EPDM: Ethylene propylene diene monomer (or ethylene propylene diene terpolymer). A thermoset elastic monomer commonly used for single-ply roofing membranes.

Extensive vegetative roof: Classification of a vegetative roof system where vegetation typically consists of low-growing ground cover such as mosses, herbaceous plants, and hardy alpine succulent plants from the Sedum family. Extensive vegetative roof systems are intended to be self-propagating and require little or no maintenance once established. Growth media for Extensive systems is less than 6 in. (150 mm) in depth.

Growth media (mixed media, media, or engineered soil): The material used to support the growth of vegetation

Hardscape: Materials and features, such as stone ballast (roof gravel), concrete pavers, gravel stops, curbs, and grating used for bordering or enclosing vegetative roof areas and intended to support foot traffic

HDPE: High-density polyethylene. A thermoplastic material typically used for root barriers, and sometimes for drainage panels.

Heat welded: A process of bonding two layers of thermoplastic material together, typically using hot air or heated platens, to form a watertight seam.

Intensive vegetative roof: Classification of a vegetative roof system where vegetation can consist of a large range of plants types, including ground cover, herbaceous plants, grasses, woody shrubs, and small trees. Intensive vegetative roof systems are intended to simulate landscaped park facilities and typically require continuous maintenance, including irrigation and fertilization. Growth media for Intensive systems is greater than 8 in. (200 mm) in depth.

LEED: Leadership in Energy and Environmental Design. A green building rating system sponsored by the U.S. Green Building Council (USGBC).

Live load: Variable loads produced by the use and occupancy during the life of the structure. Live loads on a roof include those loads produced by people, moveable maintenance materials and equipment, and other moveable object such as planters. Occupancy loads (produced by people) are typically subject to live load reduction based on the size of the contributing (tributary) area. The reduced occupancy live load can be as low as 40% of the full live load. However, governing building codes, model codes, and FM Data Sheets place several exemptions and restrictions on the level of live load reduction based on the structural properties and use of the building, and on the magnitude of the code-required minimum live load.

Maximum media density: The density of growth media after it has been subjected to a specific amount of compaction and hydrated by immersion to simulate prolonged exposure to both foot traffic and rainfall

Maximum media water retention: The quantity of water held in growth media at the maximum media density

Media: See growth media.

Noncombustible material: A material that complies with any one of the following:

(1) The material, in the form in which it is used and under the conditions anticipated, will not ignite, burn, support combustion, or release flammable vapors when subjected to fire or heat.

(2) The material is reported as passing ASTM E136, *Standard Test Method for Assessing Combustibility of Materials Using a Vertical Tube Furnace at 750°C*.

(3) The material is reported as complying with the pass/fail criteria of ASTM E136, *Standard Test Method for Assessing Combustibility of Materials Using a Vertical Tube Furnace at 750°C*, when tested in accordance with the test method and procedure in ASTM E2652, *Standard Test Method for Assessing Combustibility of Materials Using a Tube Furnace with a Cone-Shaped Airflow Stabilizer at 750°C*.

Permeability: The coefficient which, when multiplied by the hydraulic gradient, will yield the apparent velocity with which water (at 68|SNF or 20|SNC) will move through a cross-section of growth media.

PVC: Polyvinyl chloride. A thermoplastic polymer commonly used for single-ply waterproofing membranes and root barriers.

Retained water: The quantity of water that is retained, typically for several hours to several days, once new water additions by rainfall or irrigation have ceased, and that will eventually diminish primarily by gravity run-off. Retained water is that quantity of water that remains on the roof after the passage of transient water, minus the quantity of captured water. Retained water contributes to the dead load of the system.

Saturation point: The moisture content at which the tension in a growth media is zero, but a free water surface has not developed.

Simple Intensive (semi-intensive) vegetative roof: A vegetative roof system where vegetation typically consists of low-growing ground cover, herbaceous plants, grasses, and small shrubs. Simple Intensive systems require maintenance programs similar to those required for Intensive systems. Growth media for Simple Intensive systems is generally from 6 to 8 in. (150 to 200 mm) in depth.

TPO: Thermoplastic polyolefin (or flexible polyolefin). A thermoplastic polymer-based material commonly used for single-ply waterproofing membranes.

Transient water: The quantity of water required to completely fill the drainage layer, minus the quantity of captured water, when new water additions by rainfall or irrigation are actively occurring. Transient water can be held for only a period of minutes and begins to drain once the saturation point of the growth media has been reached and the drainage layer has reached its captured-water capacity. Transient water contributes to the rain load of the system.

USDA: United States Department of Agriculture.

APPENDIX B DOCUMENT REVISION HISTORY

The purpose of this appendix is to capture the changes that were made to this document each time it was published. Please note that section numbers refer specifically to those in the version published on the date shown (i.e., the section numbers are not always the same from version to version).

October 2025. Interim revision. Minor editorial changes were made. Updated figures in Appendix F, *Using RoofNav to Select Vegetative Roof*.

October 2024. Interim revision. Added guidance for elevated hardscapes and decks when installed over specific FM Approved roof systems.

January 2023. Interim revision. The following changes were made for this revision:

A. The title of this Data Sheet was changed to *Vegetative Roof Systems, Occupied Roof Areas and Decks from Vegetative Roof Systems*.

B. The restriction on vegetative roof systems to areas where the wind speed is less than 100 mph (63 m/s) has been removed and guidance added for growth media when the wind speed is greater than or equal to 100 mph (63 m/s).

C. Added guidance for intensive vegetative roof systems including decks and when areas are elevated above the roof assembly.

February 2020. This document has been completely revised. The following changes were made:

A. Changed the title to *Vegetative Roof Systems* (was *Green Roof Systems*).

B. Reorganized the entire document.

C. Added recommendation to install vegetative roofs in areas not susceptible to wildland fire as defined in Data Sheet 9-19, *Wildland Fire*.

D. Increased the safety factor for securing vegetative components.

E. Increased the separation distances subdividing large vegetative roof areas, and between vegetative roof areas and rooftop equipment.

April 2011. Made changes to Section 2.2.2 regarding wind speed restriction; and Sections 2.1.2.2 and 2.2.16 regarding FM Approved roofing assemblies.

January 2007. Made clarifications to Sections 2.1.2 and 2.2.16 regarding FM Approved roofing assemblies; to Section 2.2.3 regarding wind uplift; and to Section 2.2.5 regarding ASTM test procedures for load calculations.

September 2006. New reference was added to the section C.2, Some Green Roof Internet Sites.

May 2006. This is the first publication of this document.

APPENDIX C SUPPLEMENTARY INFORMATION

C.1 Background and Benefits

Vegetative roof systems have been in use for approximately forty years in Europe. Outside Europe, however, vegetative roofing is considered a relatively new technology. There are very few complete standards for vegetative roof systems currently available. The standard most often referenced is the FLL standard (see Section 4.2 for complete references). The FLL standard was developed in Germany and is considered to be the most established and comprehensive resource for technical guidance and specifications for the above-membrane assembly (including vegetation, growth media, and drainage portions) of vegetative roof systems.

The use of vegetative roof systems in the United States has been encouraged by the Leadership in Energy and Environmental Design (LEED) green building rating system developed by the United States Green Building Council (USGBC). The USGBC is a coalition of building owners, developers, manufacturers, design professionals, environmental groups, public and private utilities, educational institutions, and government agencies.

The LEED program has been developed to promote environmental sustainability in building construction through the use of design practices and building materials. The program involves a point-rating system intended to measure the level of environmentally sustainable site planning, as well as energy efficiency, conservation of building materials, reduction in the use of environmentally hazardous materials or processes, improved indoor air quality and environment, water conservation, and improved storm water surface run-off and filtration methods. The LEED rating system awards points on a project-specific basis.

Vegetative roof systems offer the following environmental benefits recognized by the LEED system:

Storm water management and water quality. The primary goal is to reduce storm water run-off and improve the water quality of discharge water bodies. Vegetative roofs decrease storm water runoff intensity, and therefore reduce peak floodwaters, by retaining rather than directly shedding and draining precipitation. The retention of precipitation moderates the runoff to storm sewers and reduces the potential for overtaxing the local wastewater treatment system, which can result in the release of untreated wastewater to outflow water bodies. Typical vegetative roofs can retain over 60% of the initial precipitation they receive. Mitigating the storm water runoff is generally thought to be the primary justification for the use of vegetative roofs in Europe.

Urban “heat island” effect. In large, densely developed, industrialized cities, roof areas can comprise 30% of the total land area and 50% of the total impervious surface area (the balance being made-up of paved roads, parking lots, etc.). As dark, impervious roofs and bituminous pavement absorb solar radiation, they combine to create an urban microclimate (a heat island) that can cause ambient air temperatures to be 5|SNF to 10|SNF (3|SNC to 6|SNC) warmer than the surrounding suburban and rural areas. Vegetative roof surfaces generate lower ambient air temperatures than conventional roofing by absorbing less direct solar radiation and through the cooling effect of evapotranspiration. Mitigating the urban heat island effect is generally thought to be the primary justification for the use of vegetative roofs in North America and Japan.

Energy conservation. A vegetative roof reduces the transfer of heat from exterior to interior space by means of its thermal mass and by evapotranspiration. Tests conducted at the National Research Council of Canada and Pennsylvania State University have indicated that, when compared to a flat black roof, a vegetative roof can reduce interior building temperatures by several degrees, with energy savings of up to 10% during peak ambient summer temperatures.

In some Western European countries, governments assess a rain tax on property owners based on the amount of impervious surface cover on their property that contributes storm water runoff to the local storm sewers; impervious surfaces include paved roads and parking lots, and roof covers such as single-ply membranes and bituminous asphaltic built-up roofs. Vegetative roof systems retain a significant amount of precipitation, reducing the amount of runoff to local storm sewers, and therefore are not considered impervious surfaces. Thus, the use of vegetative roofing allows property owners to reduce the rain tax on their property.

Over 75 European municipalities offer subsidies and tax incentives to encourage vegetative roof installations. The use of tax incentives is beginning to take hold in the United States, albeit only at lower municipal levels so far.

C.2 Types of Vegetative Roofs

Vegetative roofs can be categorized into three types:

- Extensive
- Intensive
- Simple Intensive

Each type is defined primarily by the depth of the growth media layer, but also by the kind of vegetation.

C.2.1 Extensive Vegetative Roofs

These are the least costly and most common of the vegetative roof systems with growth media less than 6 in. (150 mm) in depth, but typically ranges from 3 to 4 in. (80 to 100 mm). They require minimal maintenance once the vegetation has become well established (usually after two or three growing seasons).

These can be grown-in-place on the roof, or fully grown mats or modular plastic trays can be installed.

Extensive vegetative roof vegetation typically consists of low-growing, herbaceous (non-woody) plants, including succulents, mosses, and grasses. Ideal plants are those that are tolerant to drought and temperature extremes, exhibit good growth and survival rates, demonstrate successful self-propagation, provide good groundcover density, and have a strong horizontal root system but a non-aggressive vertical root system. These qualities are most often possessed by succulent plants, particularly those from the Sedum family. Sedums are hardy alpine plants that are well-suited to many vegetative roof environments and are commonly specified for that use.

See Figure C.2.1-1 showing modular trays being installed and Figure C.2.1-2 for components in a typical extensive roof system.

Find additional information at the National Institute of Buildings Science's Whole Building Design Guide at https://www.wbdg.org/resources/extensive-vegetative-roofs.

Fig. C.2.1-1. Modular trays being installed

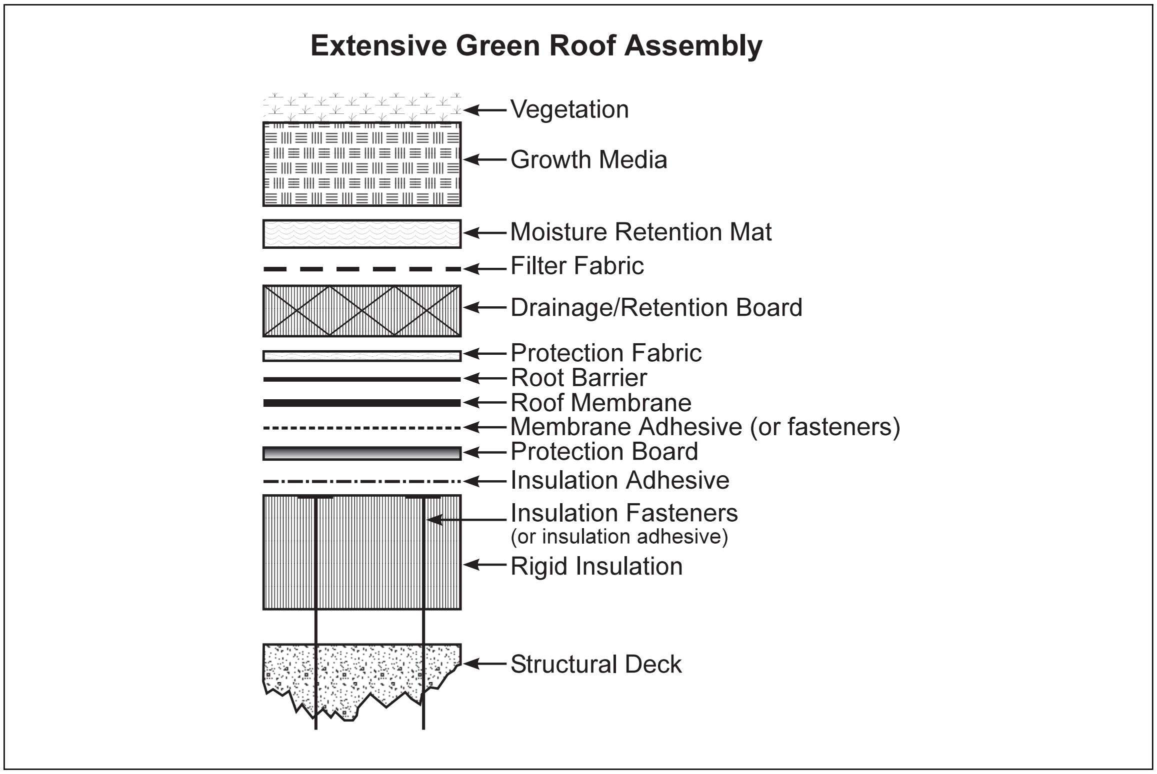

Fig. C.2.1-2. Sample extensive vegetative roof assembly

C.2.2 Intensive Vegetative Roofs

Growth media is 8 in. (200 mm) or more in depth, but can be well over 12 in. (300 mm). See Figure C.2.2-1 for components in a typical intensive roof system.

Intensive vegetative roofs systems require substantial maintenance at regular intervals including irrigation, mowing, fertilizing, and weeding.

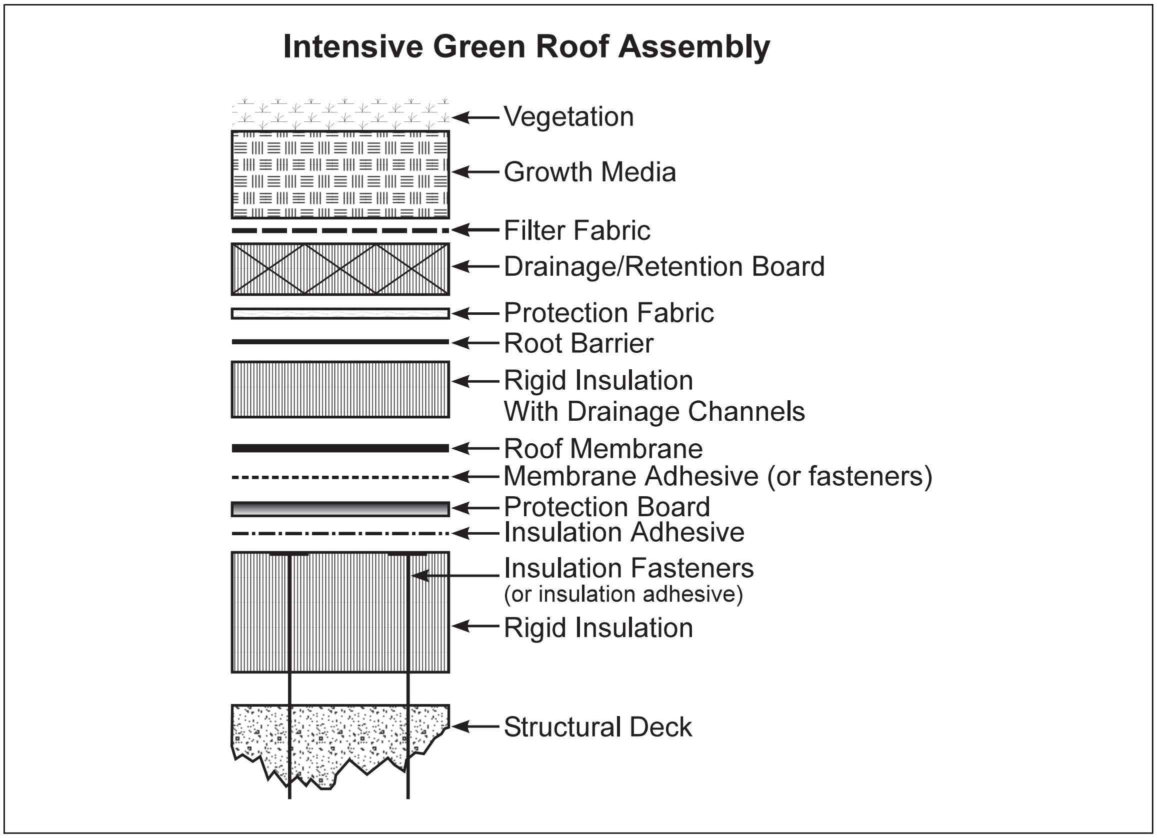

Fig. C.2.2-1. Sample intensive vegetative roof assembly

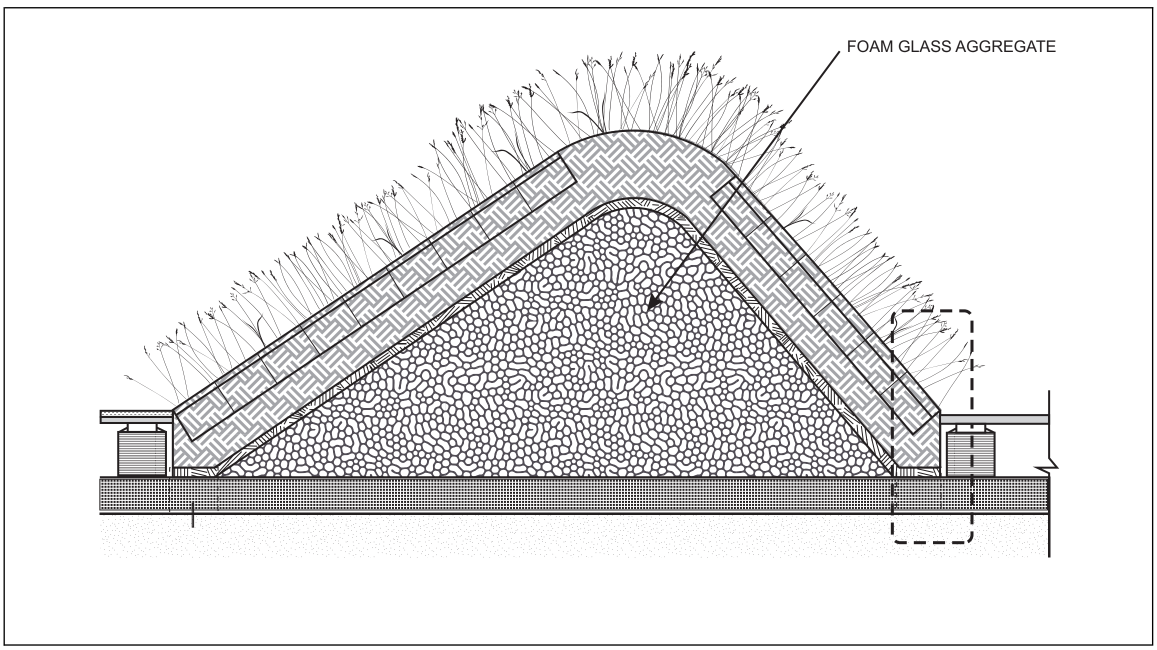

Fig. C.2.2-2. Extensive vegetated roof with small hill and no concealed space

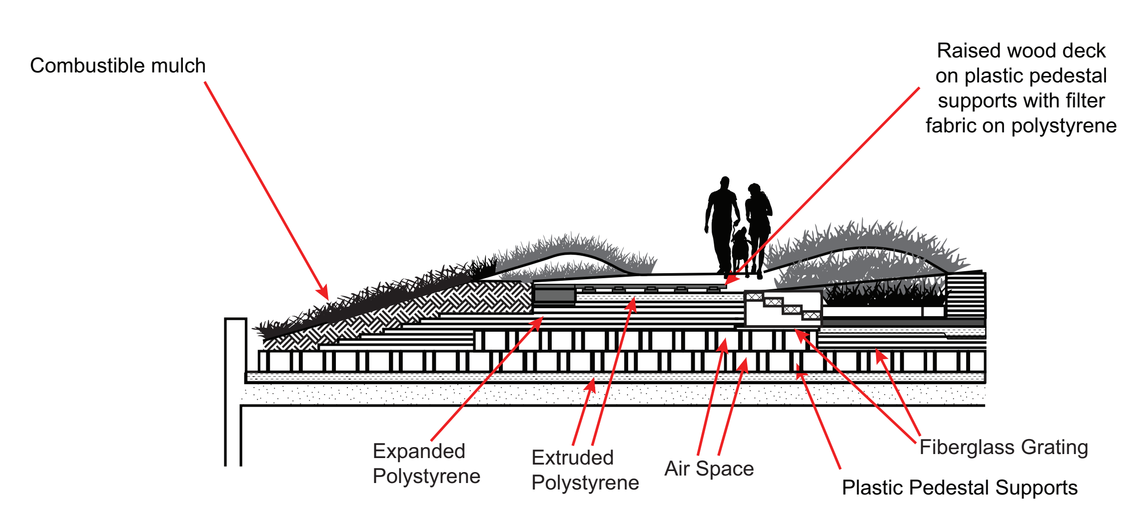

Fig. C.2.2-3. Extensive vegetated roof with combustible concealed spaces

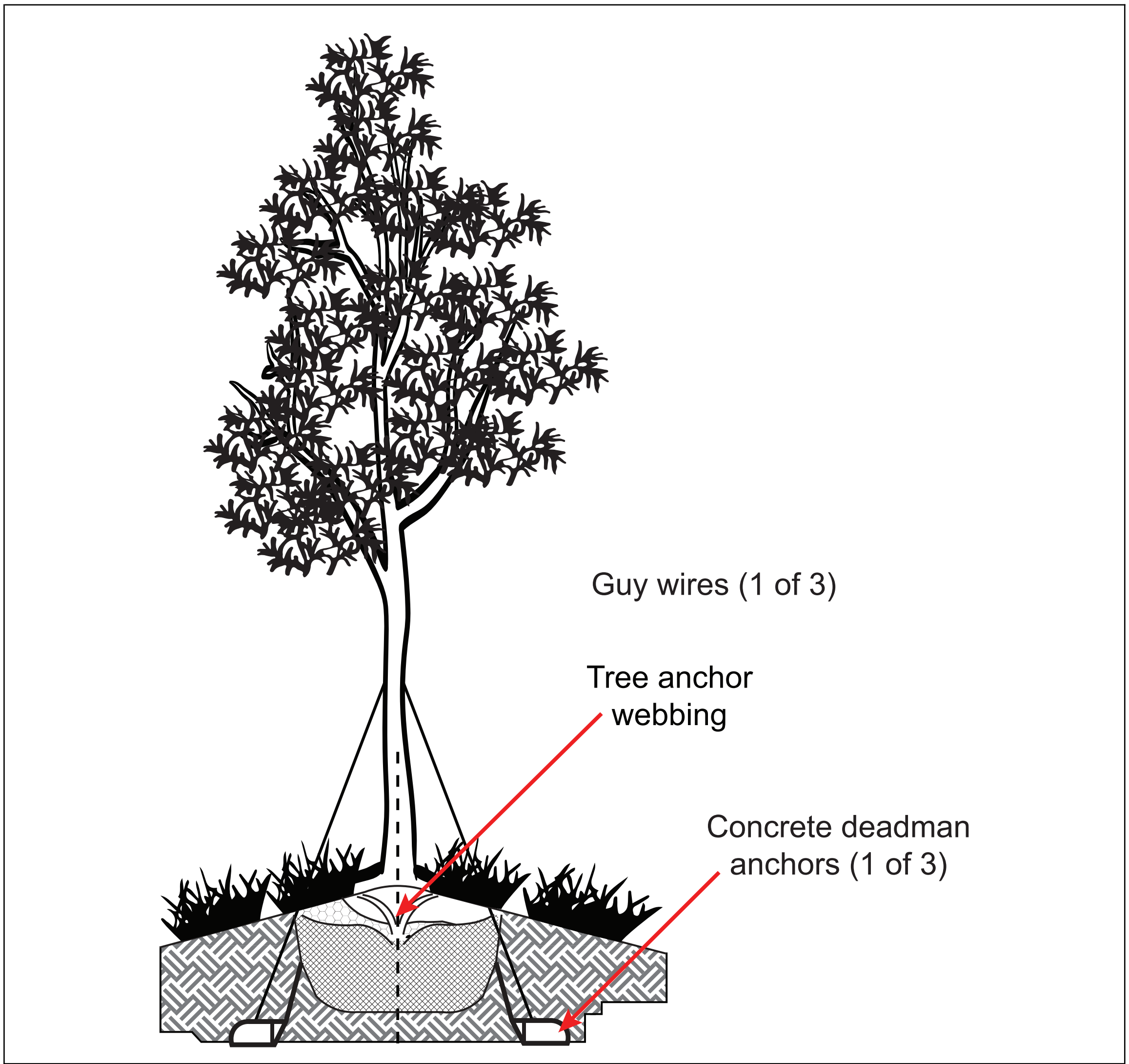

Fig. C.2.2-4. Tree trunk and root ball secured with concrete deadman weights

Fig. C.2.2-5. Wood deck on plastic pedestals on extruded polystyrene (covered by landscaping fabric) forming a combustible concealed space

Fig C.2.2-6. Rooftop concrete pavers elevated ½ in. (13 mm) above extruded polystyrene (covered with landscape fabric) using plastic pedestals

C.2.3 Simple Intensive (Semi-Intensive) Vegetative Roofs

This is a hybrid system, composed of both Extensive and Intensive vegetative roof characteristics in varying degrees with growth media generally from 6 to 8 in. (150 to 200 mm) in depth.

C.3 Roofing Assembly

A vegetative roof system consists of two major groups of components:

A. Above-membrane vegetative roof system. These components include the vegetation, growth media, moisture retention mat, geotextile filter fabric, drainage retention panel, protection fabric, and root barrier. For systems with deep layers of growth media (i.e., Intensive systems), a layer of rigid insulation is often added below the root barrier (bearing directly on the roofing membrane). The above-membrane components typically are loose-laid.

B. Roofing base assembly. These components include the waterproofing roof membrane, protection board, rigid insulation, thermal barrier, and the supporting structural roof deck. The components can be fully adhered, mechanically attached.

The waterproofing membrane may be directly attached to the roof deck with the insulation above. These are known as IRMA (Inverted Roofing Membrane Assembly or Protected Membrane Roof Assemblies).

C.4 Selected Vegetative Roof Internet Sites

Green Roofs for Healthy Cities
www.greenroofs.org (accessed August 2022).

The Greenroof & Greenwall Industry Resource Portal
www.greenroofs.com (accessed August 2022).

Landscaping and Landscape Development Research Society (FLL)
Bonn, Germany (German language only)
www.fll.de (accessed August 2022).

Michigan State University
Green Roof Research
East Lansing, Michigan
https://www.canr.msu.edu/news/the_green_roof_a_worthwhile_investment (accessed August 2022).

Pennsylvania State University
Center for Green Roof Research
University Park, Pennsylvania
www.plantscience.psu.edu/research/centers/green-roof (accessed August 2022).

U.S. Green Building Council (USGBC)
Washington, DC 20036
www.usgbc.org accessed August 2022).

University of Applied Sciences
Green Roof Centre
Neubrandenburg, Germany
www.gruendach-mv.de (accessed August 2022).

University of Georgia
Institute of Ecology
Athens, Georgia
www.ecology.uga.edu (accessed August 2022).

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‘‘Federal Technology Alert: Green Roofs.’’ DOE / EE-0298. U.S. Dept. of Energy, Office of Energy Efficiency and Renewable Energy (EERE). Federal Energy Management Program, 2004. Available online at https://www.nps.gov/tps/sustainability/greendocs/fta_green_roofs-sm.pdf (accessed August 2022)..

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Scholz-Barth, Katrin. ‘‘Green Roofs: Stormwater Management from the Top Down.’’ *Environmental Design & Construction* (January/February 2001).

United States General Services Administration *“The Benefits and Challenges of Green Roofs on Public and Commercial Buildings”*. Available online at https://www.gsa.gov (accessed May 2019).

Wark, Christopher G., and Wendy W. Wark. “Green Roof Specifications and Standards.” *Construction Specifier* (August 2003). Available online at https://www.researchgate.net/publication/284388900_Green_roof_specifications_and_standards (accessed August 2022).

APPENDIX E PHOTOS OF VEGETATIVE ROOF PROJECTS

Fig. E-1. Extensive vegetative roof, Chicago City Hall, Chicago, Illinois, USA (C 2005, Roofscapes, Inc., used by permission; all rights reserved)

Fig. E-2. Extensive vegetative roof with sedums (courtesy of Genzyme Corp.)

Fig. E-3. Extensive vegetative roof Life Expression Wellness Center, Sugar Load, Pennsylvania, USA (C 2005, Roofscapes, Inc., used by permission; all rights reserved)

Fig. E-4. Extensive vegetative roof at time of installation; Montgomery Park Business Center, Baltimore, Maryland, USA (Courtesy of Katrin Scholz-Barth).

Fig. E-5. Extensive vegetative roof 10 months after installation; Montgomery Park Business Center, Baltimore, Maryland, USA (Courtesy of Katrin Scholz-Barth and Kai-Henrik Barth)

Fig. E-6. Extensive vegetative roof 2 years after installation; Montgomery Park Business Center, Baltimore, Maryland, USA (Courtesy of Katrin Scholz-Barth)

APPENDIX F USING ROOFNAV TO SELECT VEGETATIVE ROOFS

F.1 Use Ratings Calculator to determine the recommended wind, fire and hail ratings.

See Figure F.1-1.

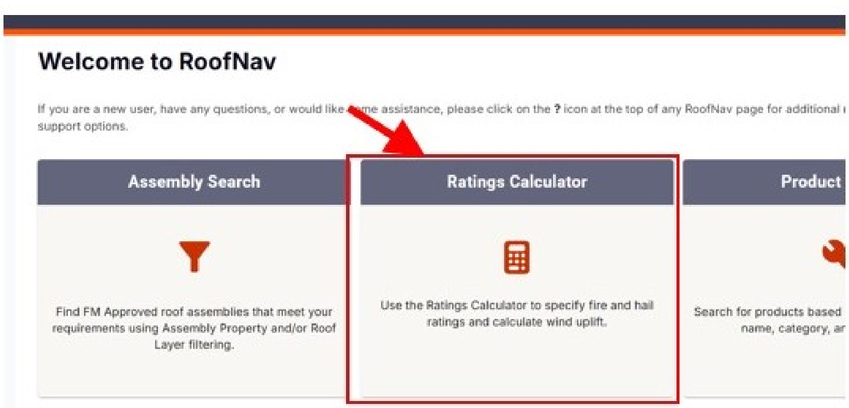

Fig. F.1-1. Ratings calculator

F.2 Using RoofNav's Assembly Search to select vegetative roofs

F.2.1 Follow Figures F.2.2-1 through F.2.2-7 to obtain a list of FM Approved roofs with vegetative surfacing. These figures can only be used together when there is no concealed air space between them. (e.g., the vegetative surfacing cannot be elevated above the waterproofing assembly with pedestals.) If a concealed air space exists, follow recommendation 2.2.2.3.3 to determine the appropriate waterproofing assembly and select the assembly using the steps outlined in Appendix F.4.

F.2.2 Select an assembly with the recommended ratings from the Ratings Calculator. Note that the vegetative surfacing has not been tested for wind resistance; only the waterproofing assembly has been tested for wind uplift.

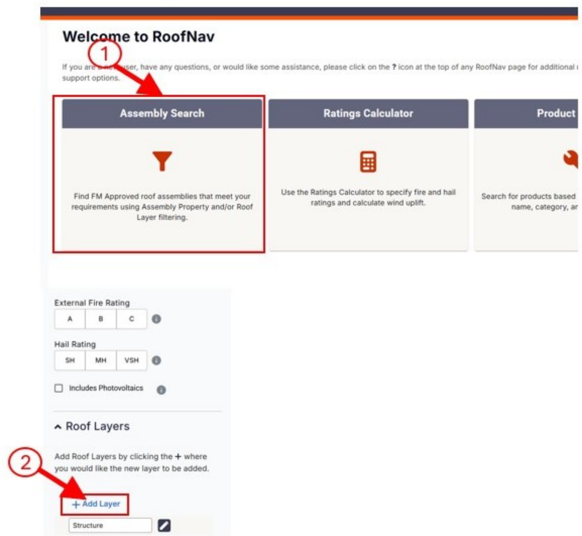

Fig. F.2.2-1. Assembly search/roof layer selection

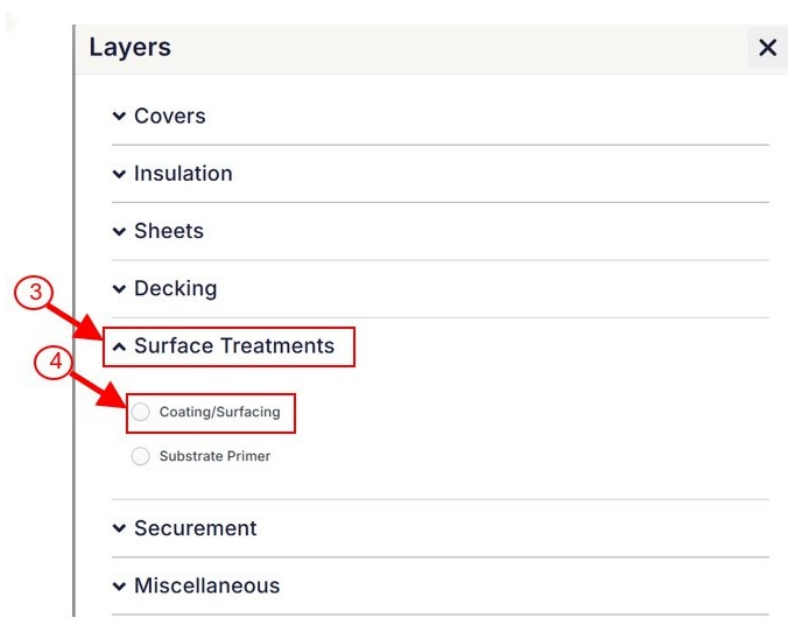

Fig. F.2.2-2. Roof layer specification

Fig. F.2.2-3. Coating/surfacing configuration

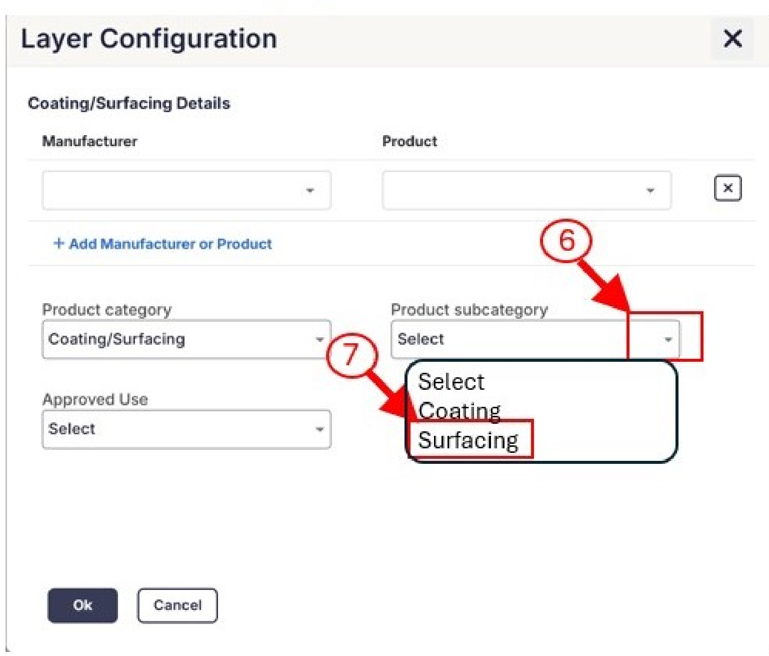

Fig. F.2.2-4. Product subcategory selection

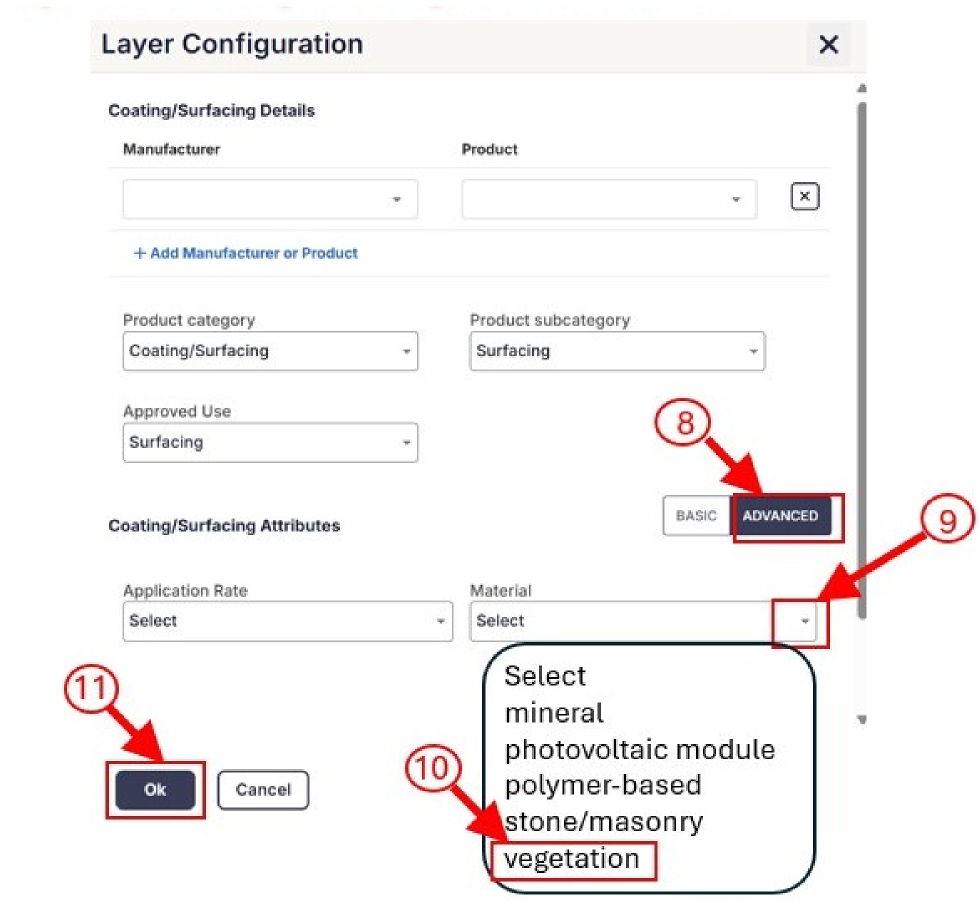

Fig. F.2.2-5. Coating/surfacing attribute selection

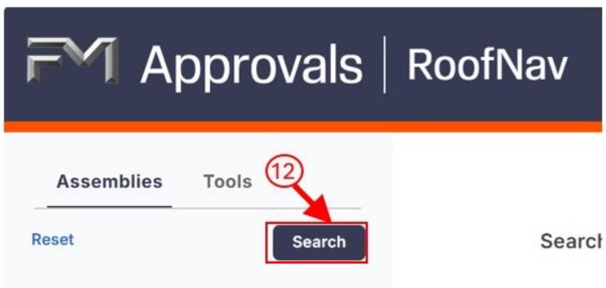

Fig. F.2.2-6. Assembly search

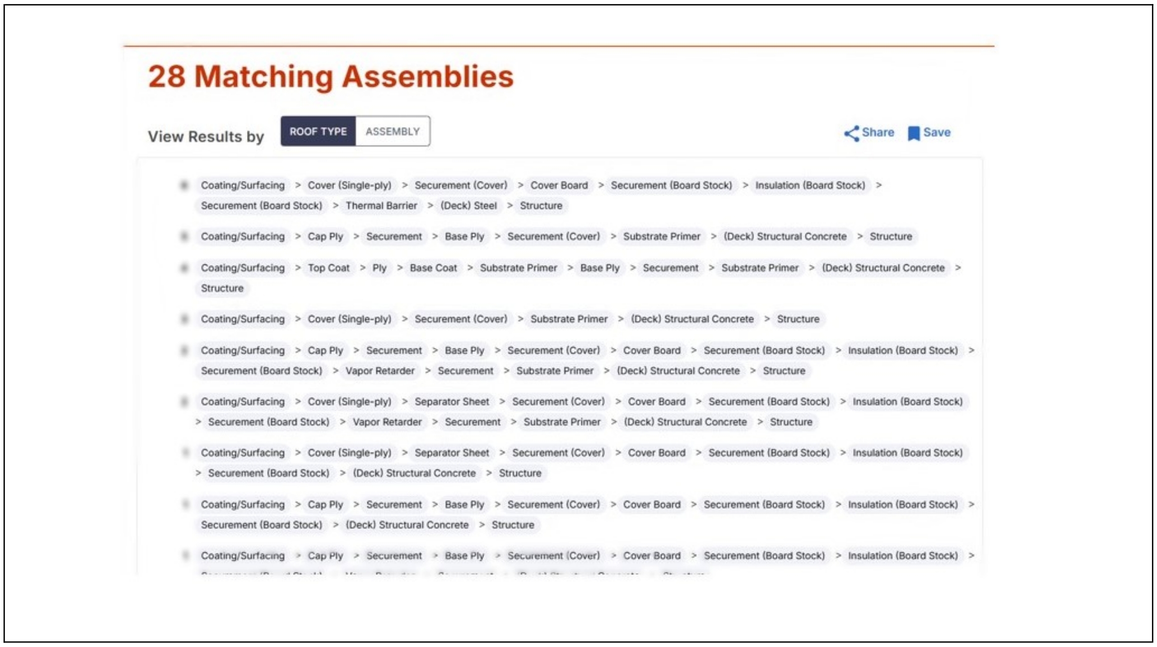

Fig. F.2.2-7. Search results

F.3 Using RoofNav's Product Search to select vegetative roofs

F.3.1 Select vegetative and roof waterproofing assemblies (separately) as follows:

Select Product Search, the drop downs as indicated by the red arrows in Figure F.3.1-1, and Search Results.

On the Search Results screen, select the FM Approved vegetative surfacing that will be used. See Figure F.3.1-2.

Use Roof*Nav's* Assembly Search to select an FM Approved roof waterproofing assembly of the type and manufacturer noted in Roof*Nav*'s Product Detail Report. A Roof*Nav* number will be indicated only for the waterproofing assembly.

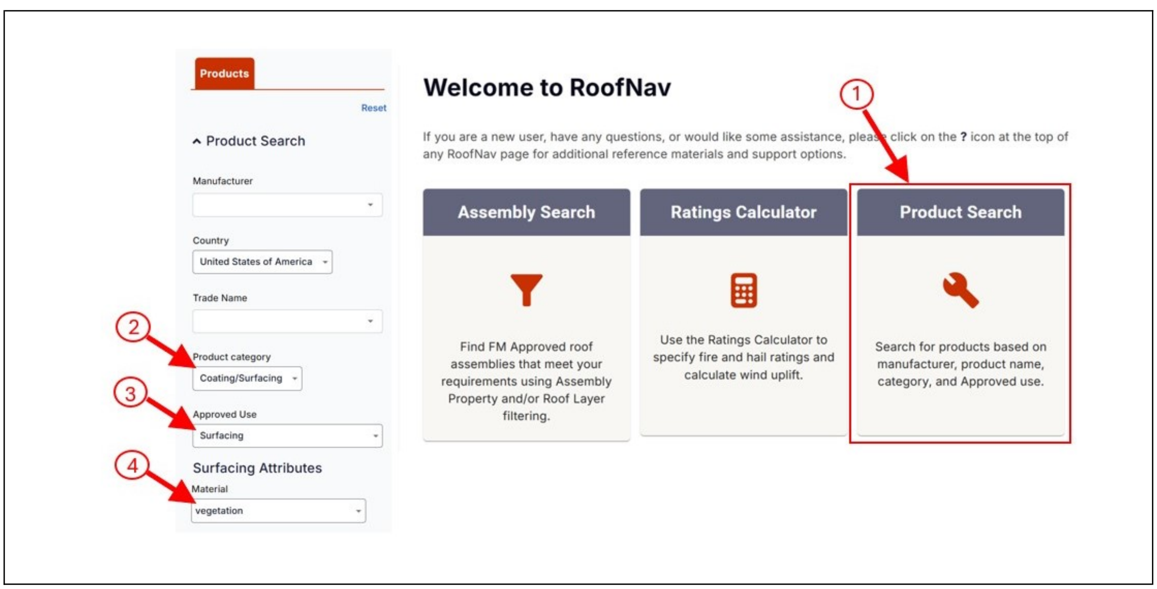

Fig. F.3.1-1. Product search view

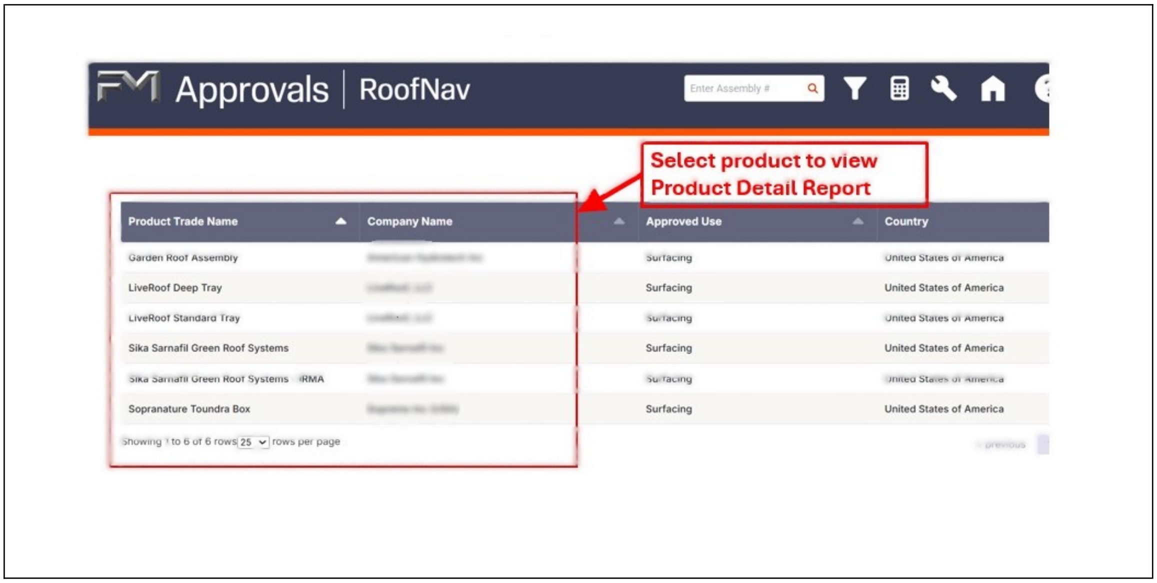

Fig. F.3.1-2. RoofNav's search results

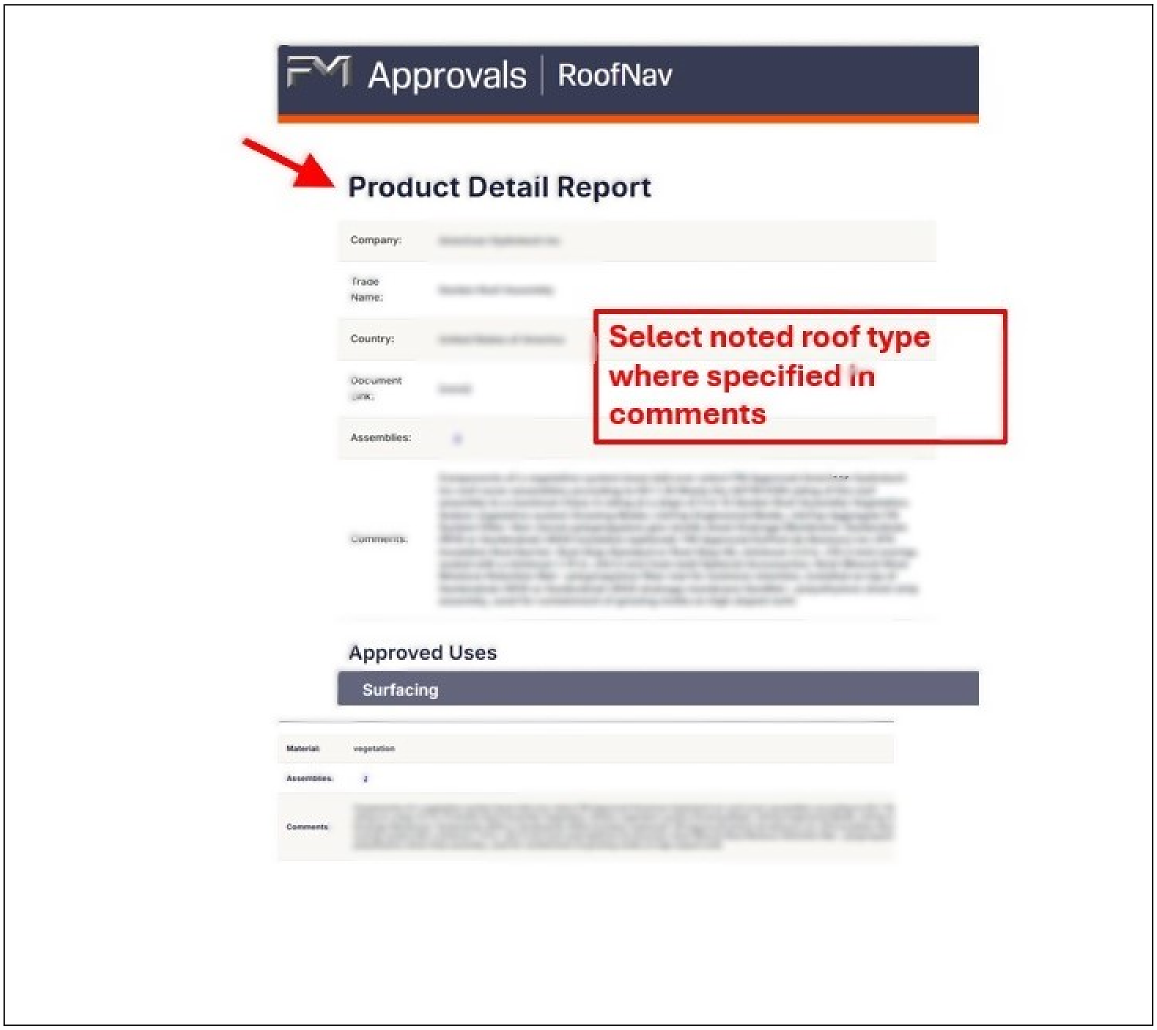

Fig. F.3.1-3. Product detail report

F.4 Using RoofNav to Select FM Approved roof assemblies with concrete paver surfacing

F.4.1. Select FM Approved roof assemblies with concrete paver surfacing as follows:

1. Follow Figures F.2.1 and F.2.2.
2. Follow Figure F.4.1-1 selecting “stone/masonry” in the Material drop down.
3. Select search results as shown in fig. F.4.1-2.
4. Select a roof assembly from the search result on Figure F.4.1-3.

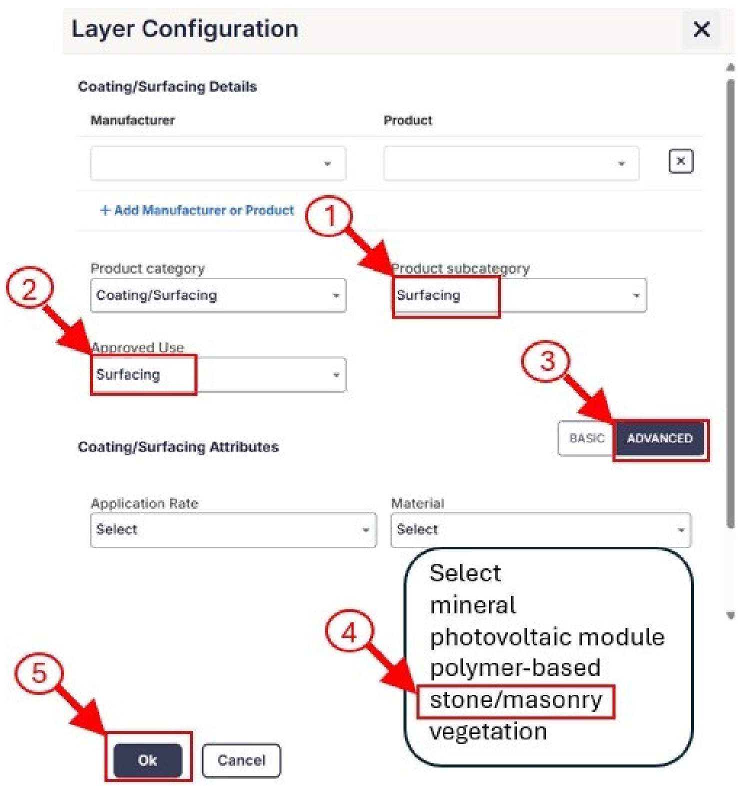

Fig. F.4.1-1. Coating surfacing details

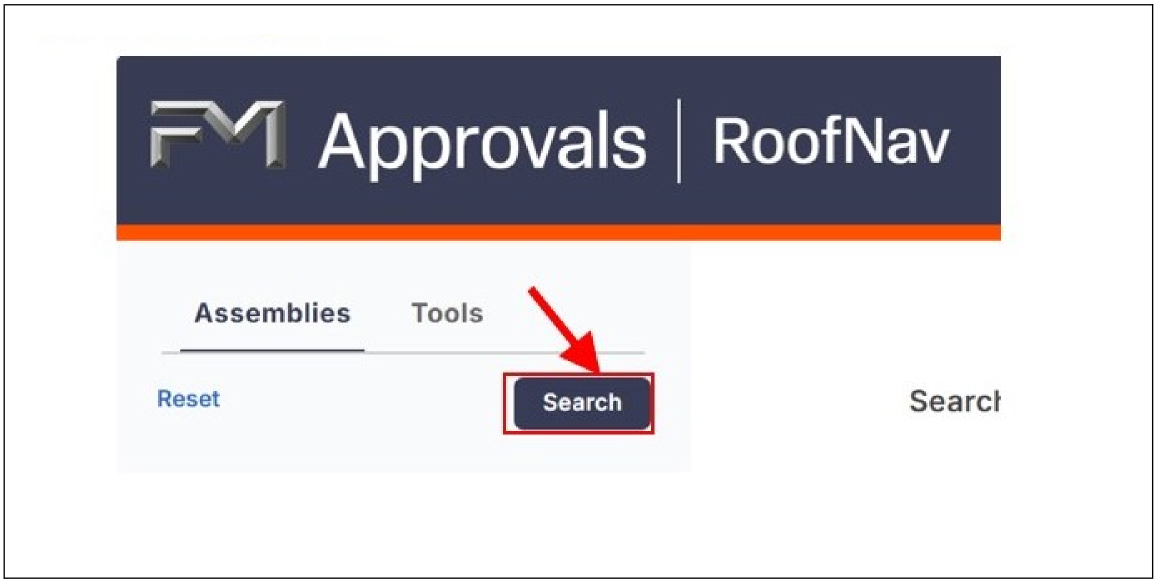

Fig. F.4.1-2. Assembly search

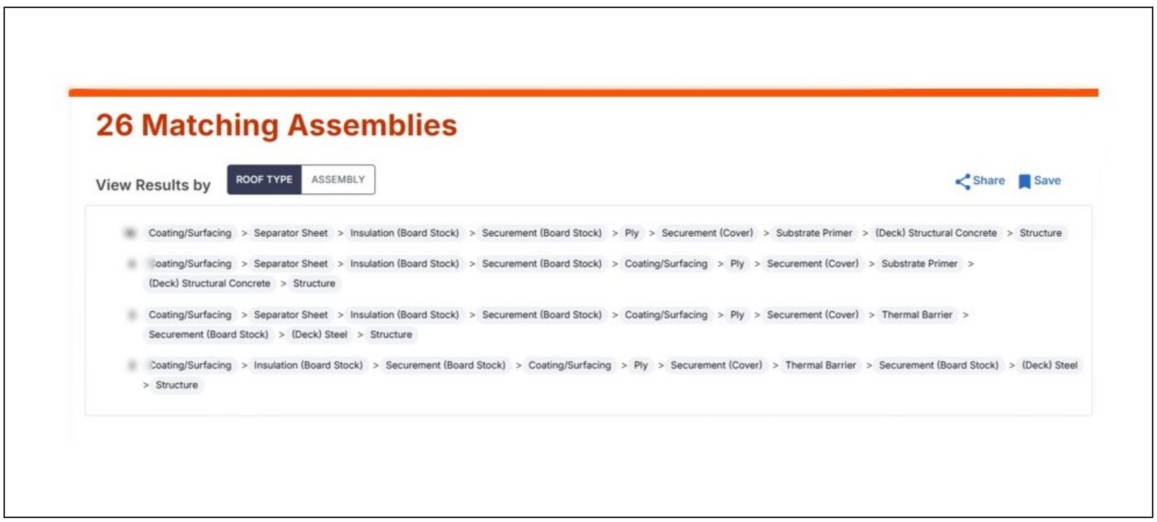

Fig. F.4.1-3. Search results view

APPENDIX G FIRE TESTS OF ELEVATED WOOD DECKS

G.1 These fire tests show the extreme fire hazard when wood or other combustible decks are elevated above the roof deck.

The fire test in section G.3, with plastic pedestals and a 3/8 in. (10 mm) thick layer of latex modified cement on polystyrene boards, was so severe that it cracked the window of the observation room and the test had to be terminated early.

Several factors contributed to the extensive fire damage during the fire test detailed in section G.3, including:

1. The plastic pedestals added significant fuel to the fire.

2. The flue space created by the pedestals and wood deck tiles trapped heat from venting.

3. The deck tiles consisted of narrow strips with gaps that allowed fire from the underside of the wood tiles to spread to the top surface, maximizing radiant heat.

4. The combination of the fuel from the plastic pedestals, the joint in the polystyrene panels and the narrow flue space resulted in melting and loss of structural integrity in the topping layer of latex modified cement.

5. Once the topping layer fractured and collapsed, it allowed direct fire exposure to the extruded polystyrene insulation layers.

6. As the polystyrene upstream of the flame became involved, it resulted in collapse of successive portions of the concrete topping and additional polystyrene fire exposure.

The second fire test used steel pedestals and a 15/16 in. (24 mm) layer oflatex modified cement on polystyrene boards resulting in minimal damage to the polystyrene and its coating.

Fire Test Criteria

The test samples and fire tests conducted by FM were constructed and tested in accordance with ASTM E108, Standard Test Method for Fire Tests of Roof Coverings. The Spread of Flame test was conducted to determine if the roof assemblies would meet the requirements for a Class A exterior fire rating. This test involves exposing the sample for a period of 10 minutes to a flame temperature of 1400°F ± 50°F in conjunction with a one-minute timed average wind velocity of 1056 ± 44 ft/min measured from three locations across the front of the sample.

G.2 Fire Test with wood deck on plastic pedestals and 3/8 in. (10 mm) thickness of latex-modified concrete on extruded polystyrene boards Test assembly details listed from the bottom up, based on the image in Figure G.2-1.

- 3 in. (76 mm) thick tongue and groove extruded polystyrene insulation boards, 2 ft (0.6 m) x 4 ft (1.2 m), with a factory-applied topping of 3/8 in. (9.5 mm) latex-modified concrete. This deck was sloped 1/8 in. per ft.

- Landscaping fabric was placed over the top of the with a longitudinal joint in the center of the sample. The fabric was overlapped 6 in. (150 mm) at that joint.

- Adjustable plastic pedestals spaced 2.0 ft (0.6 m) by 2 ft (0.6 m).

- 2 ft x 2 ft (0.6 m x 0.6 m) Ipe wood tiles were installed on top of the plastic, and the pedestals were adjusted such that the wood tiles were level.

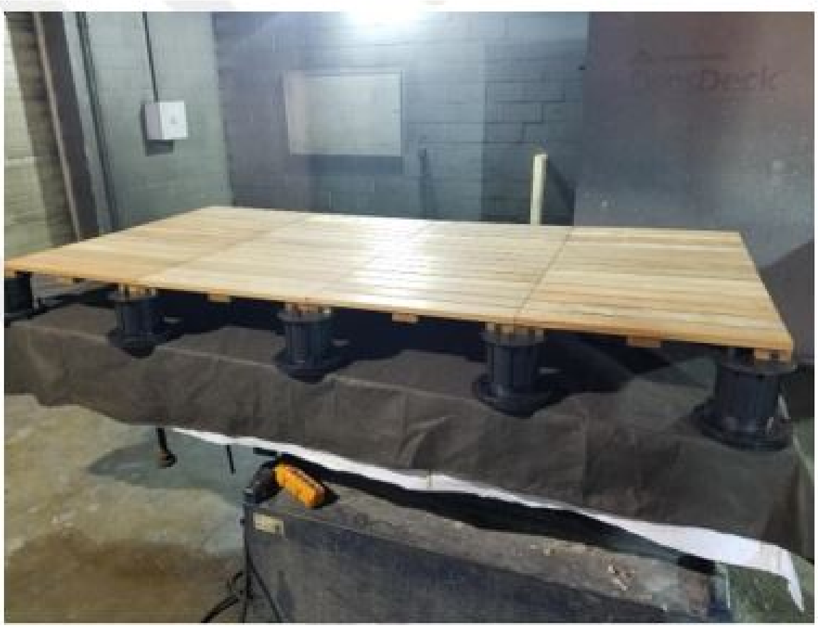

Fig. G.2-1. Final test assembly with plastic pedestals

Fig. G.2-2. Test assembly at approximately 9:24 into the test

Fig. G.2-3. Aftermath of the fire test, prior to disassembly

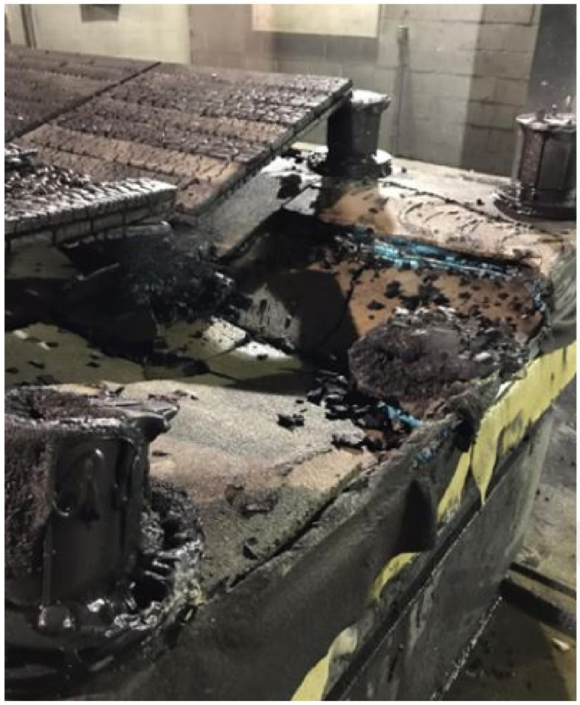

Fig. G.2-4. First row of wood deck tiles removed

G.3 Fire Test with wood deck on steel pedestals on 15/16 in. (24 mm) thickness of latex-modified concrete on extruded polystyrene boards

This test assembly is similar to that in section G.3 with steel pedestals replacing plastic pedestals and 15/16 in. (24 mm) thickness of latex-modified concrete on extruded polystyrene boards replacing a 3/8 in. (10 mm) layer.

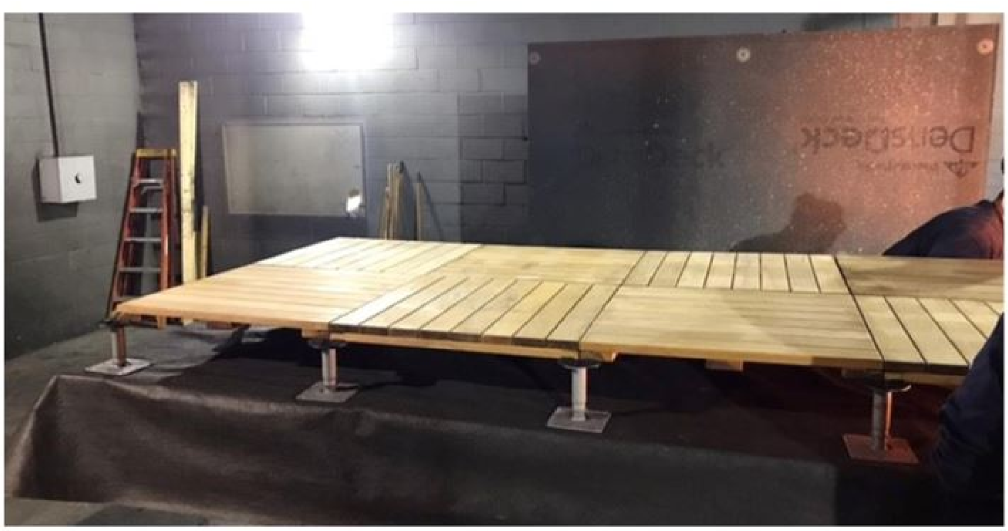

Fig. G.3-1. Final test assembly with steel pedestals

Fig. G.3-2. Close-up of final test assembly showing 15/16 in. (24 mm) layer of latex modified cement on extruded polystyrene

Fig. G.3-3. Test assembly at approximately 9:24 into the test

Fig. G.3-4. Ipe wood deck tiles prior to disassembly

Fig. G.3-5. Leading edge of test assembly showing intact joint

Fig. G.3-6. Modified latex cement surface (Ipe wood tiles and pedestals removed)