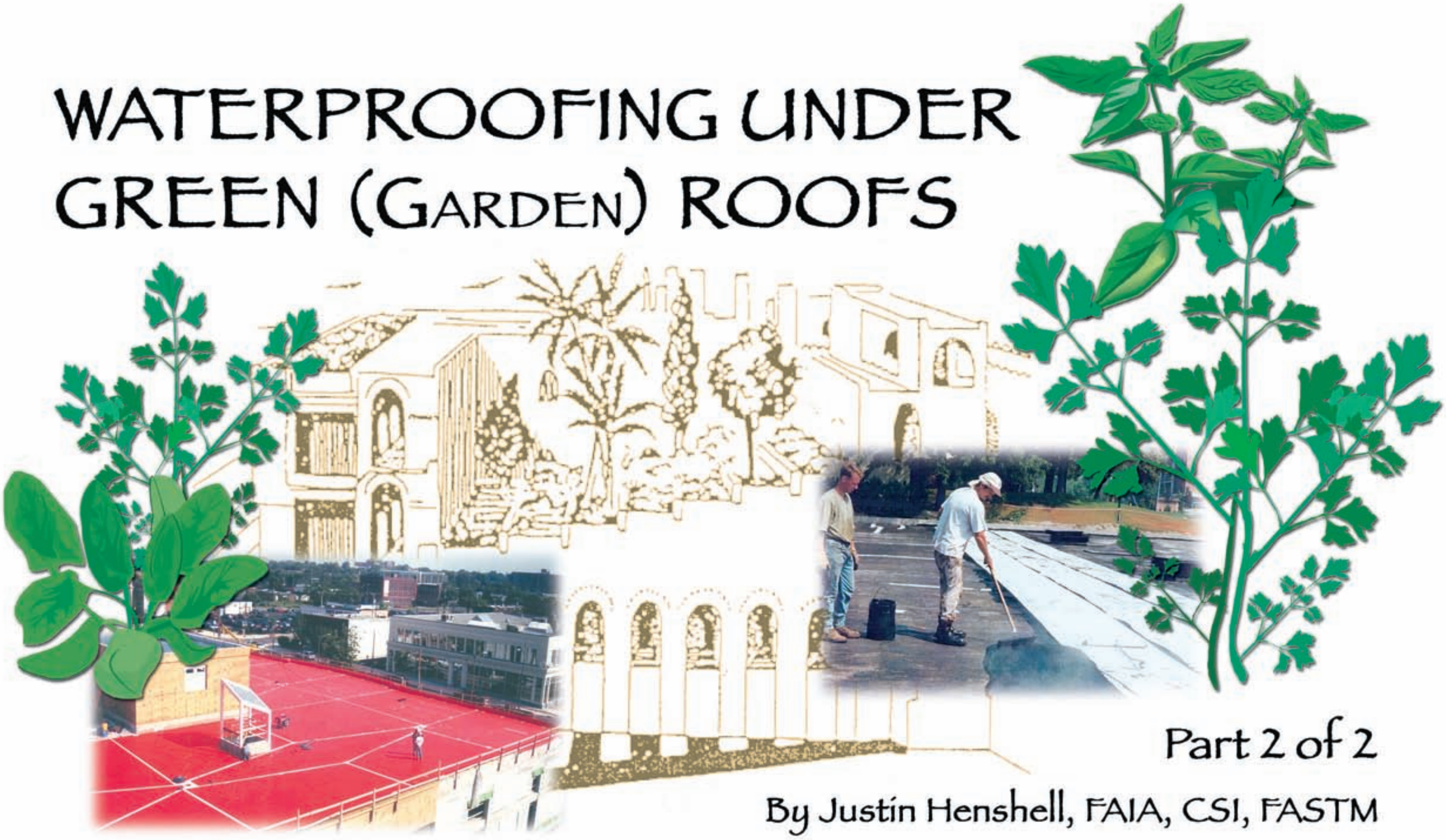
WATERPROOFING UNDER GREEN (GARDEN) ROOFS



Part 2 of 2

By Justin Henshell, FAIA, CSI, FASTM

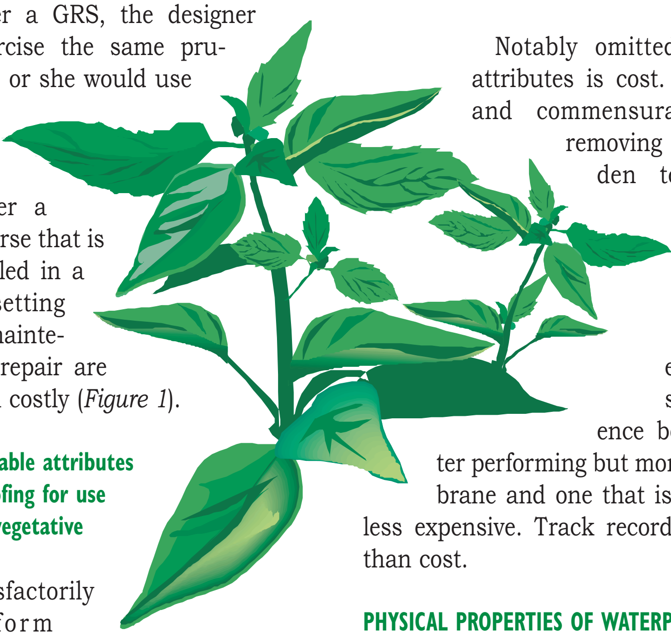
This is part two of a two-part series on waterproofing membranes under green (garden) roofs. The first part, published last month, traced the history of waterproofing membranes under plazas and earth-covered, below-grade spaces, and discussed the various types of waterproofing systems currently marketed and their advantages and disadvantages for use under green roof systems. This part covers the attributes of candidate membranes and offers a list of minimum physical properties proposed to satisfy the specific needs for those membranes exposed to continuous moist environments, aggressive chemicals, root invasion, and abusive maintenance. Additionally, it discusses failures and offers case studies to illustrate them.

Unless otherwise noted, all photographs and illustrations are taken from *The Manual of Below-Grade Waterproofing Systems* by Justin Henshell, published by John Wiley & Sons, Inc. in 2000, or were taken by the author.

As noted in the first section of this article, waterproofing membranes differ from roofing in that they must perform in a continuously moist environment. Moreover, very few, if any, waterproofing membranes are UV resistant.

Waterproofing membranes under GRSs differ from those used for waterproofing hardscaped plazas in that they must resist root intrusion, fertilizers, fungus, and bac-

Figure 1: Exposing membrane for repair.



teria in soils and abuse from landscapers. Performance in low temperatures is rarely a consideration.

In selecting a waterproofing membrane under a GRS, the designer should exercise the same prudence as he or she would use when selecting a membrane under a wearing course that is to be installed in a mortar setting bed – the maintenance and repair are difficult and costly (*Figure 1*).

Primary desirable attributes for waterproofing for use under green vegetative roofs:

- Satisfactorily perform under moist conditions and alternate wetting and drying.
- Resist acids, alkalis, and other chemicals, including those commonly contained in fertilizers.
- Resist fungus and bacteria in soils.
- Possess low water absorption.
- Have low permeance to water vapor.
- Resist root intrusion (*Figure 2*).
- Resist puncture (critical during installation).
- Act as self-flashing or use a flashing system that minimizes seams.
- Utilize flashing that is capable of resisting UV degradation.
- Be easily repaired.

Secondary attributes:

- Possess a moderate degree of elongation and elasticity (e.g., crack bridging ability is important, but lead sheets with soldered seams have all the primary attributes for a good GRS, but have very little elasticity).
- Fire resistance. Of minor importance since membranes are protected by the overburden.
- Low temperature flexibility. After installation over occupied spaces, the membrane will not be subjected to significant low temperatures.

Figure 2: Root intrusion.

Notably omitted from these attributes is cost. The difficulty and commensurate costs of removing the overburden to investigate and repair waterproofing problems are always high enough to offset the difference between a better performing but more costly membrane and one that is marginal but less expensive. Track records count more than cost.

PHYSICAL PROPERTIES OF WATERPROOFING MEMBRANES IN GREEN (GARDEN) ROOFS

Table 1 contains suggested minimum physical properties for waterproofing membranes in green vegetative roofs. In addition to possessing the usual properties for plaza (hardscape) waterproofing, consideration is given to the membrane's exposure to fertilizers, root growth, and other hostile elements in the roof environment. Some of these properties were obtained from membrane manufacturers' published literature and some from ASTM D-6630, Low Slope Insulated Roof Membrane Assembly Performance. Carl Cash cautions against putting undue emphasis on physical properties "because they don't predict good future performance." However, he also points out that conversely, poor test performance will usually predict poor membrane performance.

In addition to meeting the requirements in *Table 1*, low slope membranes should pass a flood test per ASTM D-5957. Where flood testing may be inappropriate because of concerns that leaks may damage underlying building components and furnishings, low or high voltage systems can be used instead. See Remo Capolino's article in the August 2004 *Interface.*

OTHER GRS COMPONENTS

Although this paper focuses on the waterproofing membrane for use in a GRS, it would be remiss not to mention three of the more important components of the usual GRS assembly that relate to the membrane.

Insulation

Insulation may be required by local codes. Simple calculations using steady state values to achieve the resistance required by them may be inaccurate because they do not account for the effects experienced over a full year. A discussion of the thermal resistance of a GRS is beyond the scope of this article. Interested readers are referred to "Engineering Performance of Rooftop Gardens through Field Evaluation" by Karen Liu, PhD, for the National Research Council of Canada.

In addition to its use for improving the thermal resistance of a GRS, insulation is desirable for retarding premature, false growth in the northern tier of states. It can also be useful as a protection or early warning to landscapers who are digging to replace dead plantings.

On low-slope green roofs, insulation should be installed over the membrane to avoid problems with condensation from occupied spaces below. However, when roofs are sloped over 3:12, resistance to slippage becomes a real concern. Insulation cannot be loose-laid or slippage will occur. Mechanically-attached insulation should be

Property	Standard	Criteria
Static Indentation Resistance	D-5602 Section 11	watertight at 250N (56 lbs) over concrete @ -18˚C (0˚F)
Dynamic Indentation Resistance	D-5635 Section 12	specimen to be watertight at 10 Kg (22 lbm) over concrete
Vapor Permeance	E-96	<5.7ng/s•m^2 pA (<0.1 perms)
Water Absorption in Plastics	D-570	<3% by weight
Water Absorption in Bituminous-based Materials	D-95	<0.1% by weight
Resistance to Hydrostatic Pressure	D-5385	no leaks at 103 kPa (15 psi) (34.65' head)
Linear Dimension Change	D-1204	<2%
Low-Temperature Flexibility and Crack Bridging for Liquid-Applied Membranes	C-836	Pass
Low-Temperature Flexibility and Crack Bridging for Modified Bituminous Membranes	D-5849 Test Condition for 500 cycles	Pass
Resistance of Plastics to Fungi	G-21 or D-3273 (Tests currently under review for applicability)*	
Resistance to Deterioration from Organisms and Substances in Contacting Soil	E-154, Section 13	<10% increase in water vapor permeability
Resistance of Plastics to Bacteria	G-22	No effect
Resistance to chemicals contained	ASTM D-896 (undiluted 15 N/5P/5Potash)	No delamination, blistering emulsification, or deterioration of adhered membranes
Resistance to root penetration	FLL Guidelines **	No penetrations

* In "Testing for Fungal Growth in Building Products," *ASTM International Standardization News*, July 2004, Pamela Hargrove discusses two standards, ASTM G-21, Practice for Determining Resistance of Synthetic Polymeric Materials to Fungi; and ASTM D-3273, Resistance to Growth of Mold on the Surface of Interior Coatings. She notes the concern that the G-21 method may give false negative results because the direct inoculation severely wets the sample, whereas the test method in D-3273 represents a more realistic exposure environment.

** FLL Guidelines for the Planning and Upkeep of Green-Roof Sites, Procedure for Investigating Resistance to Root Penetrations at Green-Roof Sites, 1995

Table 1: Suggested minimum physical properties for waterproofing membranes in green vegetative roofs.

located under the membrane to avoid puncturing it. Fully-adhered insulation may be placed under the membrane or over it. However, the latter is not feasible in a loose-laid, single-ply waterproofing system.

On steep roofs, the drainage medium and root barrier must also be restrained from slipping. Mechanically anchoring or adhering them to insulation or the waterproofing membrane is impractical. A possible alternative is attaching or adhering them to sleepers that have been installed over the membrane and are individually waterproofed or installed on butyl pads.

Protection Layers

Protection boards and sheets compatible with the membrane are a prerequisite to ensuring the watertight performance of the membrane. When vegetation dies, it must be replaced, often by gardeners wielding square-edged spades that can cause immeasurable damage to the membrane and its components. It may be tempting to use the insulation in lieu of sheet or board protection, but when consideration is given to sequencing and the potential for damage during the interval between the membrane completion and the insulation installation, prudence would dictate that a separate protection course be provided.

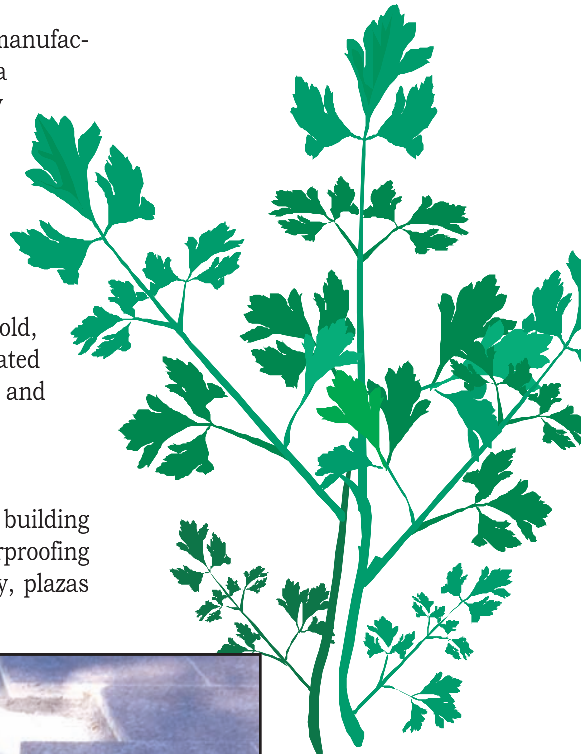


Figure 3: Flashing failure at glass railing.

Root Barriers

Root barriers are a critical part of the GRS assembly to prevent intrusion that can lead to leaking. There are two basic types of root barriers used in green roof assemblies: physical and chemical.

- Physical root barriers can vary from a slab of lightweight concrete to sheets of metal foil or plastic. Sheets require fused or taped seams; otherwise, they may be subject to root intrusion, although some GRS marketers claim that laps of 1.5m (5 feet) or greater are sufficient.
- Chemical root barriers are usually non-woven polypropylene geotextiles coated or embedded with the herbicide trifluralin. Two manufacturers are Tex-R Root Barrier, manufactured by Texel; and Biobarrier, manufactured by Reemay Inc.
- One built-up membrane manufacturer claims to incorporate a root barrier in its assembly and several incorporate a root barrier blended in with the protection sheet. As a matter of interest, Dick Fricklas points out that coal tar pitch is a natural enemy of root growth, mold, and mildew, as demonstrated by its use in mothballs and below-grade pipe wraps.

GRS FAILURES

It will come as no surprise to building pathologists who investigate waterproofing that, despite claims to the contrary, plazas (both hardscaped and landscaped) have a long history of leaking. A majority of the leaking appears to be caused by failed expansion joints and bitumen-clogged weepholes in drains. Some leaks are due to root intrusion of trees and large shrubs into membrane seams. Others are caused by improper flashing of sprinkler and conduit penetrations. Still others are caused by water entry above cap flashings where they are saturated by sprinklers.

Case Histories

Designer error is one of the chief sources of waterproofing failure. Specification of an inappropriate system accounted for the failure of a membrane in a police administration building in Florida. Pedestrian and planted plazas were constructed on several levels over occupied spaces. The waterproofing system under the planted areas consisted of sheets of polyethylene covered with gravel and sod. The plastic sheets were minimally secured to the flanges of area drains. When the sheet was exposed, it appeared to have virtually deteriorated to the extent that it was no longer a viable, watertight membrane.

The author also investigated a failure attributed to inadequate detailing at expansion joints and penetrations. This occurred in the waterproofing under an intensively planted garden atop a plaza above the street spanning between an office tower and the World Trade Center plaza. Originally, the entire plaza was waterproofed with a hot-applied rubberized asphalt membrane that leaked. It was replaced with a polyester reinforced membrane that also leaked. Investigation indicated that the leaks were caused by the failure of the flashing at the expansion joints at each end of the bridge, at the glass railings on the sides of the bridge (*Figure 3*), at the drains, and at conduits feeding lighting fixtures in the planted area. At all of these locations, the detailing was either inadequate or absent.

The author investigated another failure in the waterproofing at a landscaped plaza above a garage in Florida due to an ill-

Figure 4: Elevated drainage pipes.

conceived drainage system. The planted areas were drained by perforated pipes extending from leaders through the slab. There were no conventional drains. Because the hubs on the pipe fittings and the radius of the elbow connecting the lateral pipes to the leaders raised the pipes above the slab, there was a reservoir of standing water more than an inch deep (*Figure 4*). Sheet rubber expansion joint covers had been installed flush with the waterproofed slab. The rubber was bonded to the liquid-applied membrane, creating a plane of weakness that was exploited by the hydrostatic head. The inadequate drainage and failure to elevate the expansion joint cover caused the joint to leak.

A poor choice of materials caused leaking in the garage below planters in a courtyard in a hotel in Michigan. The planters were separated from the walks with low concrete masonry walls which also divided the deeper planters from shallower ones. The courtyard was waterproofed with a single-ply butyl sheet membrane that was carried up and over the lower two courses of the concrete masonry units. The masonry walls were reinforced with vertical rebars. The butyl sheet membrane was flashed to the rebars, but the deformations in the bars prevented the sheet flashing from tightly sealing around them. Virtually every bar leaked.

Raymond Wetherholt, RRC, CPWC, PE, investigated a leaking planter lined with a self-adhering rubberized asphalt waterproofing membrane. He determined that the leaking was caused by root intrusion into the seams. There was no protection board or root barrier in the assembly. He also observed the same condition on another project where the waterproofing membrane consisted of two plies of APP modified bitumen applied in cold adhesive with heat welded joints. Water had wicked into the reinforcing and disbonded the seams.

Phil Haisley wrote of investigating a badly leaking 40-year-old terrace garden and recreation plaza in Hawaii. The plaza was originally waterproofed with a tar modified coating that was interrupted by planter walls and curbs, resulting in many exposed edges. Leaking was pervasive. Hollow core concrete planks were found to be filled with water, with many concealed paths for moisture migration.

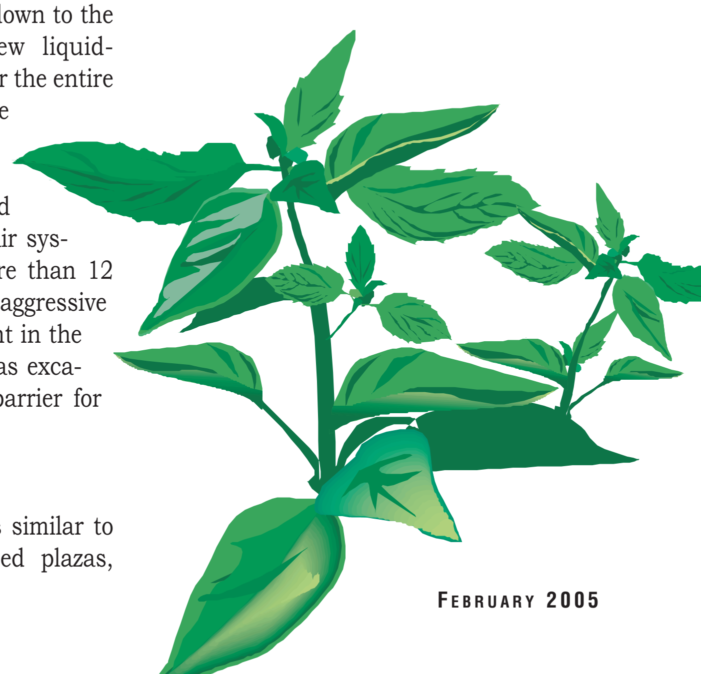
He corrected the leaking condition by drilling the planks to allow drainage, stripping walls, curbs, and planters down to the structure, and applying a new liquid-applied polyurethane coating over the entire deck. Only this time it was made continuous beneath all walls and curbs, with positive seals around all penetrations and rebars. He reports that the repair system has performed well for more than 12 years, except at one spot where aggressive shrub roots penetrated a lap joint in the coating application. This spot was excavated and patched, adding Biobarrier for root protection.

REMEDIATION

Remediating leaks in GRS is similar to remediating leaks in hardscaped plazas, except that locating the leak source and repairing it is complicated by the fact that there are more layers in the assembly to remove and planting must be stockpiled and protected. Since most leaks occur at penetrations and terminations, including drains and expansion joints, locating leak sources can be a fairly routine exercise to the seasoned building pathologist. Since flood tests are ineffective on a membrane covered with overburden, the investigator must rely on his experience with correlating leak sites with probable leak sources that are visible GRS components or those that can be inferred from drawings. Once a suspected leak source is identified and excavation has begun, the investigator must be prepared to encounter ponding and arrange to have the exposed membrane drained, dammed, and dried in order to view and probe the suspect leak source.

When leaks are caused by root intrusion into the membrane, the investigation can be a major undertaking. Where intensive planting includes trees and large shrubs that must be removed, wholesale excavation becomes extremely difficult and costly. Stockpiling plants and soil assumes a major logistical challenge. Sometimes, in order to avoid overloading the structure, the entire overburden—soil, shrubs, trees, and all—must be removed and lowered to grade. Patching becomes further complicated by the need to prevent water from flowing into the area to be patched, keep wind-blown soil off adhesive applications, and seepage from surrounding soil away from patches.

To overcome this problem, Haisley has attempted, with some success, to stop leaking in an intensively planted plaza by injecting the slab from below. Injection might mend holes in an existing membrane if it is



in reasonable condition. This probably works better with adhered membranes than with those that are loose-laid and is of limited use where leaks are due to root intrusion. In these areas, Haisley has recommended excavation and removal of larger trees and plants with aggressive root systems before patching the membrane from above. Unless root intrusion is permanently corrected, this form of remediation simply defers patching or replacing the membrane.

Ed Snodgrass points out the danger that inappropriate plants pose to most membranes. Bamboo, Johnson grass, and similar plants with rhizome roots, which have arrow-shaped points can easily penetrate the most root-resistant membrane and root protection layers. Ed recalls a failed GRS where the contractor had substituted local plants for the specified sedum. Unfortunately, some of the plants were Johnson grass and the roots invaded the membrane.

RECOMMENDATIONS

- Specify membranes manufactured for waterproofing, not those adapted from roofing membranes.
- Specify membranes with proven track records that have at least ten years of successful use in below-grade waterproofing applications.
- Prefer membranes that are seamless or those whose seams are fusion welded.
- Select membranes that have proven resistance to burial in soil and exposure to fertilizers.
- Specify systems that incorporate root barriers with root-resistant seams.
- Specify that liquid-applied system be at least 3mm-thick (120 mils) dry film.
- Specify that PVC membranes be at least 2mm (80 mils) thick.
- Design the membrane to be continuous under all elements and components of the GRS above it.
- Extend flashings and terminations not less than 8" above the top of the soil, not the membrane or the wearing surface.

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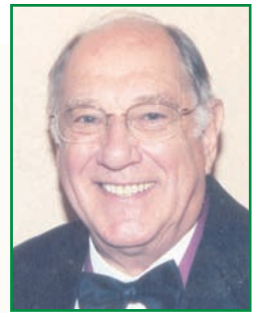

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