

WATERPROOFING UNDER GREEN (GARDEN) ROOFS



Part 1 of 2

By Justin Henshell, FAIA, CSI, FASTM

ABSTRACT

Green vegetative roofs have become increasingly popular, encouraged by government and private groups who have focused on their ecological benefits. But in stressing these benefits, many proponents have ignored or dismissed the importance of the underlying waterproofing membrane upon which the success or failure of the green roof assembly depends.

This article discusses the background of green roof waterproofing membranes and their associated components. Due to its length, it will be published in two parts. The first section (published herein) reviews green roof history, the various membrane systems, and attributes of waterproofing systems under green roof systems that differ from those commonly used for roofing and below-grade waterproofing. The second section, to be published in the February issue of *Interface*, proposes recommended physical properties of the waterproofing membranes under green roof systems in order to establish a minimum level of performance. To emphasize the importance of a leak-proof green roof system, this section of the article will include some case histories of membrane failures.

INTRODUCTION

The roof of a building has been described as its fifth side and according to Maxwell Baker, the renowned Canadian roof guru, that fifth side should be green. Green roofs are becoming increasingly popular and have spawned numerous articles on their composition and design. Much has been published about the plantings, stormwater management, drainage layers, and ecological benefits, yet very little attention is given to the waterproofing membrane. Of the 175 citations listed in the bibliography published by Greenroofs.com, a mere three or four discuss the waterproofing membrane, and at least one of these dismisses its watertightness as relatively unimportant.¹

Despite the emphasis on ecological benefits, experience tells us that nothing will discourage the enthusiasm for green roofs as much as a leak in the boardroom below.

Green roofs have been popular in Europe, particularly in Germany, for over 30 years and are currently being promoted in the United States by many governmental and private groups, as well as some waterproofing manufacturers. Despite advocacy by the landscape architect M. Paul Friedberg in 1969 and Maxwell Baker in 1980, green roofs have been slow to receive public acceptance by the construction industry because of their cost, lack of engineered soils, difficulty in maintenance, and history of waterproofing failures.

As a practical matter, green roofs, in one form or another, have been around for many years, albeit under different names and guises. They have been called rooftop gardens, earth-sheltered buildings, and landscaped plazas. Dick Fricklas notes that underground parking garages have been covered with green belts and parks throughout

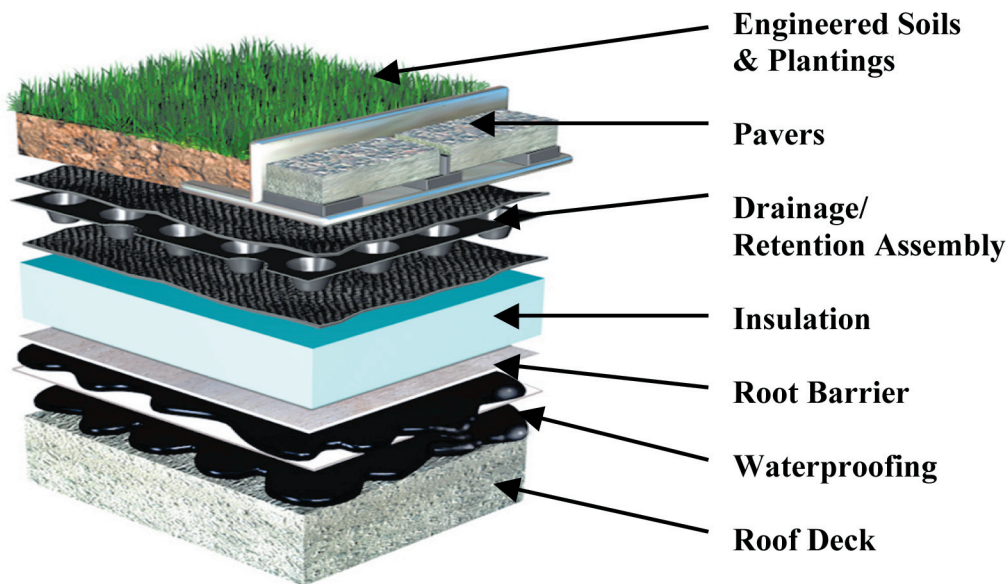


Figure 1: Typical components of an extensive Green Roof System (Barrett Company)

the country for many decades. Bas Baskaran calls them Garden Roof Systems (GRS), a term used throughout this paper. Fundamentally, a GRS incorporates planting over a waterproofing membrane above occupied spaces. Other components that are usually present in the waterproofing assembly are drainage and moisture retention panels, insulation, and root barriers (Figs. 1 and 2.)

GRS also provide water runoff control, reduced heat absorption, and many other ecological benefits. Most green roofs are low-sloped, but some are installed on steep slopes (over 3:12) where the waterproofing component acts to shed water rather than excluding it. This article is limited to the discussion of waterproof membranes on low-slope substrates.

HISTORY

Paradoxically, the archetypical waterproofing project, the Hanging Gardens of Babylon, anticipated modern waterproofing problems nearly 25 centuries ago (Fig. 3). In the more recent past, at the beginning of the twentieth century, waterproofing projects under landscaping have involved more mundane uses such as planting over underground parking garages. Currently, the extensive use of GRSs in Europe and pressure from our environmentalists have focused attention on resurrecting the Hanging Gardens for contemporary buildings.

Present-day waterproofing for green roofs is based on our knowledge derived from waterproofing hardscaped plazas.

Prior to WWII, plazas over occupied spaces were waterproofed with coal tar pitch. The system usually consisted of four or five plies of tar-saturated rag felts and alternate moppings of coal tar pitch. The membrane was then covered with a concrete slab cast directly over the final mopping. This was the “split-slab” system that survives today under mechanical room floors, sidewalk vaults, and with some parking garages.

The system succeeded because fuel was cheap and, in the absence of

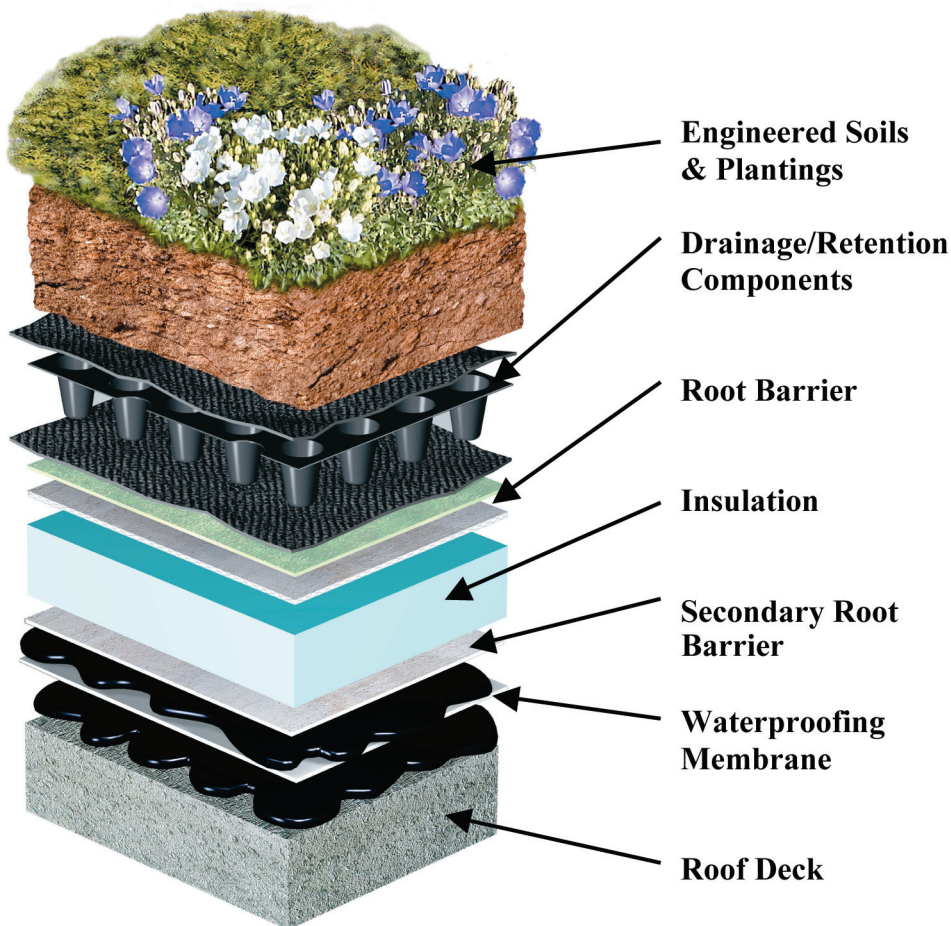


Figure 2: Typical components of an intensive Green Roof System (Barrett Company)



Figure 3: The Hanging Gardens of Babylon

insulation, the structural and wearing slabs were always at or very close to the same temperature. Consequently, there was very little differential movement between the slabs. What movement there was occurred from shrinkage cracks and traffic loads.

Moreover, the organic felts were strong enough to resist minor cracking, and the cold flow properties of the coal tar pitch sealed minor ruptures.

In 1949, when the miners' strike choked off the supply of coal, the steel mills that

produced coke—from which coal tar pitch was produced—began using their coke for fuel, and the roofing and waterproofing industry was forced to turn to other bitumen alternatives. One of these was the introduction of low-slope or dead-level asphalt by Bird and Johns Manville (Aquadam), which was less expensive than pitch. At about the same time, the supply of cotton and wool rags used for felts, changed to rayon and other artificial fibers that could not withstand the heat of the bitumen saturants. Felt manufacturers then turned to waste paper and wood fibers which were not as strong. Laminating these weaker felts with asphalt—that had greater water absorption than pitch—resulted in a membrane that was considerably less effective than the coal tar pitch membrane it supplanted.

The post war building boom caused many changes in construction. The size of mechanical devices and equipment demanded more space to accommodate air-conditioning plants. Basements multiplied to sub-basements and then sub-sub-basements. Zoning codes were revised to promote more open spaces, which spawned plazas over the basements. Later, activities such as theaters and computer rooms that

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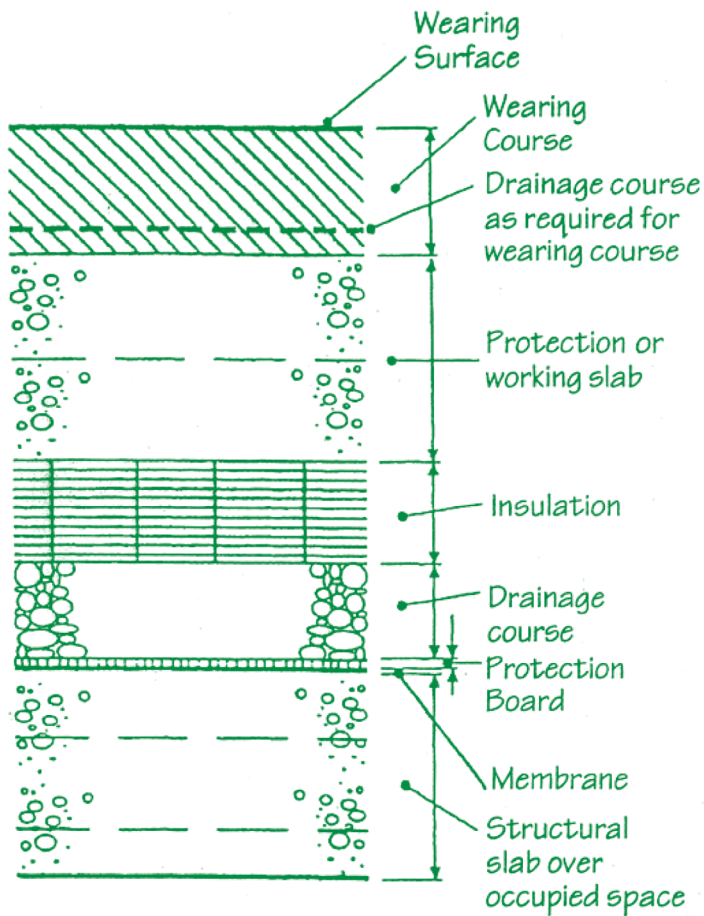


Figure 4: Typical plaza deck assembly (ASTM International)

did not require windows were relegated to the spaces under those plazas. Many of these activities required environmental controls and greater thermal resistance of the plaza assemblies.

The old split slab construction with its asphalt and paper felts proved not strong enough to resist the concrete shrinkage and traffic forces. And when insulation was added to the assembly, it increased the differential movement between the structural and wearing slabs. As a result, the failure rate of plaza waterproofing membranes multiplied exponentially.

PLAZA WATERPROOFING DESIGN

When Charles Parise published his seminal paper on plaza waterproofing in 1971, and it was subsequently developed into an ASTM standard in 1978, it revolutionized the design of plaza waterproofing. Initially, it focused on liquid-applied membranes and was then expanded to include built-up bituminous membranes in 1983.

Instead of the conventional split slab construction, composed of a membrane sandwiched between two concrete slabs, the standard advocated a drainage course over the membrane and required that the slab be sloped to drain. It also advocated locating insulation above rather than under the membrane (Fig. 4). This became practicable due, in part, to the development of extruded polystyrene insulation that would retain much of its thermal resistance properties after continuous immersion in water.

WATERPROOFING MEMBRANE SYSTEMS

Dating back to the Hanging Gardens of Babylon, lead sheets were the preferred waterproofing medium. Haisley points out that coal tar and asphalt waterproofing systems have been used since the 18th century in France, and they set the standard for two hundred years. Because of their self-healing properties, coal tar pitch membranes became the waterproo-



Figure 5: Self-adhering rubberized asphalt sheet membrane.

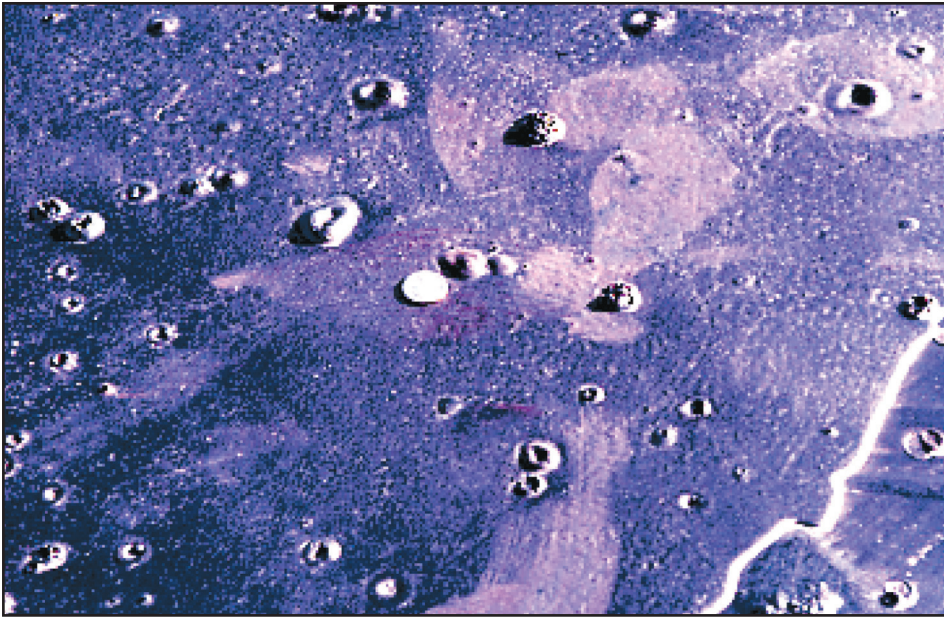


Figure 6: Blisters in liquid-applied membrane



Figure 7: Delamination of liquid-applied membrane

ing bitumen of choice. However, their use today has greatly declined as a result of EPA concerns over carcinogens. The asphalt/felt membranes proved inadequate. The plaza waterproofing industry needed substitutes for the coal tar pitch.

A number of manufacturers sought to fill the void. About 1966, W.R. Grace introduced a self-adhesive, single-ply, rubberized asphalt sheet marketed as Bituthene that soon replaced the built-up asphalt/felt systems for waterproofing plazas (Fig. 5). It competed with Carlisle's butyl and Gates'

Neoprene single-ply waterproofing membranes. In the early 1980s, Sarnafil introduced its single-ply PVC waterproofing sheet from Switzerland.

The 1960s saw the introduction of cold-applied polyurethanes and hot-applied rubberized asphalt systems. The latter were produced by Uniroyal and the Bakor Division of Bakelite Thermosets, Ltd., predecessors of American Hydrotech, Inc. (Uniroyal), Henry Co. (Bakor/Monsey) and Barrett Company (Shell Kraton).

Many polyurethane, liquid-applied

waterproofing systems were marketed in the 1960s to compete with the single-ply membranes. Most of them were one- and two-component urethanes and tar modified urethanes. Two Canadian companies, Uniroyal and Bakor, introduced hot-applied, rubberized asphalt systems in the early 1960s. Today there are a number of companies marketing hot rubberized waterproofing systems, notably American Hydrotech, Inc. that uses the Uniroyal technology; Henry Co., that purchased Bakor/Monsey, the predecessor of Bakor; and Barrett Company that uses Kraton (formerly Shell) technology.

Many of the cold systems prematurely failed for a number of reasons, one in particular being a lack of reinforcement which enables the membrane to accommodate movement at cracks in the substrate. Another was the application of protection boards installed shortly after application of the single-component urethane membranes. The premature installation of the boards sealed off contact with the moisture-laden air required to obtain a cure. Premature application of protection boards also trapped air bubbles between the board and the partially cured membrane that resulted in craters and a diminished thickness of the membrane.

The success of the liquid systems is highly dependent on workmanship. Poor workmanship often causes blisters that are a primary cause of cold, liquid-applied membrane failures (Fig. 6). Blisters are also caused by sub-membrane voids that hold water in the concrete slab. Craters formed by burst blisters reduce the membrane's thickness and permit water to penetrate to the concrete. There it migrates laterally and peels the membrane from the concrete substrate (Fig. 7). Some of these problems can be solved by back-rolling.

The hot-applied systems form a watertight membrane immediately on cooling and thus avoid most of the problems inherent in the cold-applied systems. Moisture on or in the substrate is still a problem because it promotes foaming, which leads to pinholing and blisters. The better systems incorporate a reinforcing sheet in the membrane. It is embedded in the first coat and covered with a second application of hot modified asphalt (Fig. 8). The increased thickness markedly reduces the potential for crack propagation. The tradeoffs in construction convenience



vs. dependable curing are counterbalanced by the fact that the polymer-modified asphalt requires a jacketed kettle for uniform heat distribution. This introduces a problem not faced by the cold-applied systems. Many contractors who own the jacketed kettles are unwilling to undertake small projects. Moreover, bringing kettles to the top of a high-rise building (particularly one that is occupied) poses logistical problems that are not easy to overcome. To counteract these disadvantages, manufacturers are currently marketing more kettle sizes and have increased their availability.

As an alternative to hot-applied systems, Laureco, Inc. markets a cold-applied membrane system composed of two plies of chloroprene-modified asphalt sheets adhered



Figure 8: Hot-applied liquid membrane (American Hydrotech)

with a modified bitumen adhesive that, after application, is claimed to fuse into a seamless, single 4mm- (160 mil) thick sheet.

In the past ten years, there have been an influx of liquid-applied latex rubber waterproofing systems. These are mostly confined to the residential market where

hydrostatic pressures are low or non-existent. Some may be suitable for GRS in thicker gauges, but as of this writing, none of them have a proven track record of more than 10 years.

A polyester-reinforced, liquid polyester system introduced from Europe has found a

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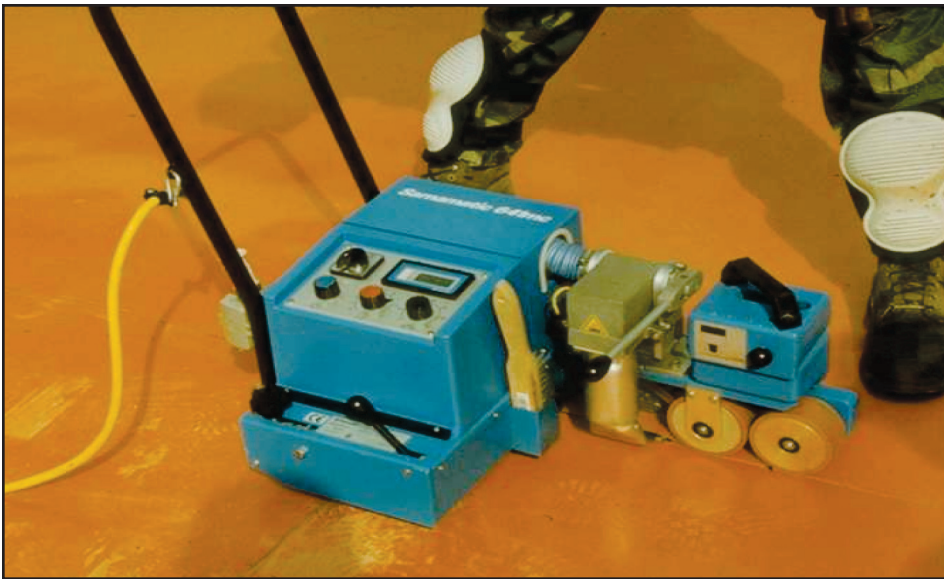


Figure 9: Hot air welder (Sarnafil)

niche for difficult waterproofing applications. However, the benefits are so far outweighed by their cost as to make them a one-of-a-kind solution.

Liquid-applied membranes have many attributes that make them among the most suitable candidates for waterproofing in GRSs. They are seamless and thus less subject to root intrusion that can compromise sheets that are lapped and adhered. Urethanes, modified urethanes, and modified asphalts generally have good resistance to chemicals used in fertilizers.

Waterproofing differs from roofing in that the former must be capable of performing in a continuously moist environment, whereas the latter must perform when subject to UV radiation. Most roofing materials are formulated to

resist UV but not ponding water. For this reason, APP modified bitumen roofing sheets and most SBS bitumens are unsuitable for use in GRSs. Some manufacturers of SBS modified bitumen roofing products have promoted their systems for use on plazas where the hydrostatic head is relatively small compared to below-grade systems. A potential drawback is that water can wick into the reinforcing and disbond laps, and roots can easily penetrate the adhered seams.

Single-ply thermoplastic membranes such as PVCs, KEEs, and HDPE are good candidates for GRS applications because their seams are heat-fused (Fig. 9) and thus impervious to root intrusion—an advantage not shared by thermosetting sheets with adhered seams. Additionally, most thermoplastic membranes are loose-laid (although some may be fully adhered) and thus are also unaffected by crack propagation and moisture conditions in the substrate. Thermoplastic membrane manufacturers recommend compartmenting the loose-laid systems by using adhered strips at discrete intervals to localize leaking and improve leak detection.

HDPE and KEE membranes that are used for lining canals, ditches, and ponds are not energetically marketed for GRSs, although they have many suitable attributes. HDPE that is laminated to bentonite and rubberized asphalt fails to satisfy the criteria because the sheets are too thin to be welded. Thicker HDPE appears to be promising, but one authority claims that most so-called high density polyethylene sheets on the market are really medium-density (MDPE) sheets with a lower dimensional stability than that specified in the ASTM standard. HDPEs that are not cross laminated suffer from even greater shrinkage. HDPE sheets thicker than .5mm (20 mils) can be dual track wedge welded, and seams can be air or spark tested for integri-



Figure 10: Compartmenting of loose-laid PVC membrane (Sarnafil)



ty. Seaman produces a KEE .9mm-thick (36 mils) fabric reinforced sheet with a 30-year track record for use as a geomembrane in ditch and pond lining. Sarnafil markets a PVC sheet with a good track record in Europe and the U.S. for below-grade waterproofing, and promotes it for GRSs (Fig. 10). PVC sheets should be of significantly greater thickness than those used for roofing and above ground applications—at least 2mm (80 mils).

Bentonite, which swells upon contact with water, is encapsulated in geotextiles or laminated to HDPE. It has been used for waterproofing for many years. Because it must be confined to resist water penetration, the manufacturer recommends covering it with a 75mm-thick (3") concrete slab. The additional weight can adversely impact on a structure that is already required to support the overburden of soil and vegetation. Furthermore, bentonite does not perform well when subjected to wetting and drying cycles.

Detailing Waterproofing for GRSs

The precepts for installing and detailing waterproofing for GRSs are essentially the same as those contained in the ASTM standards for plazas and below-grade waterproofing — C 898, C 981, and D 5859. The membrane should be carried continuously under all elements on the roof. This includes retaining walls, pools and fountains, lighting fixtures, built-in seating, and the like.

Regardless of how effective a membrane waterproofing system is, its watertight integrity is often compromised by poorly designed or constructed flashing at terminations and penetrations. Many GRSs incorporate sprinklers and lighting that are often installed after the membrane is completed, and these are frequently the source of leaks.

Every GRS requires base and cap flashing at terminations. A few liquid-applied coatings use thixotropic variations of the field waterproofing, but most waterproofing systems, including those that are hot liquid applied, use sheet materials, such as Neoprene, for flashing.

Flashings at penetrations and terminations should extend at least 200mm (8") above the top of the soil (Fig. 11). Shorter terminations are subject to infiltration from snow melt, sprinklers, or wind-driven rain during cloudbursts. Because virtually all waterproofing materials are degraded by exposure to sunlight, base flashing

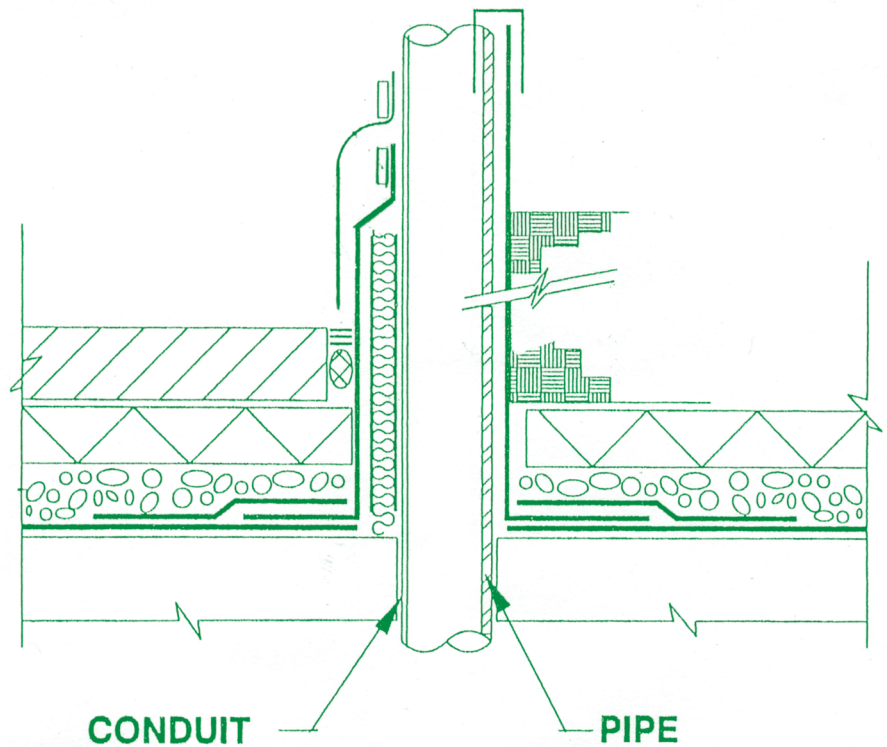


Figure 11: Flashing penetrations through hardscaped and landscaped waterproofed decks

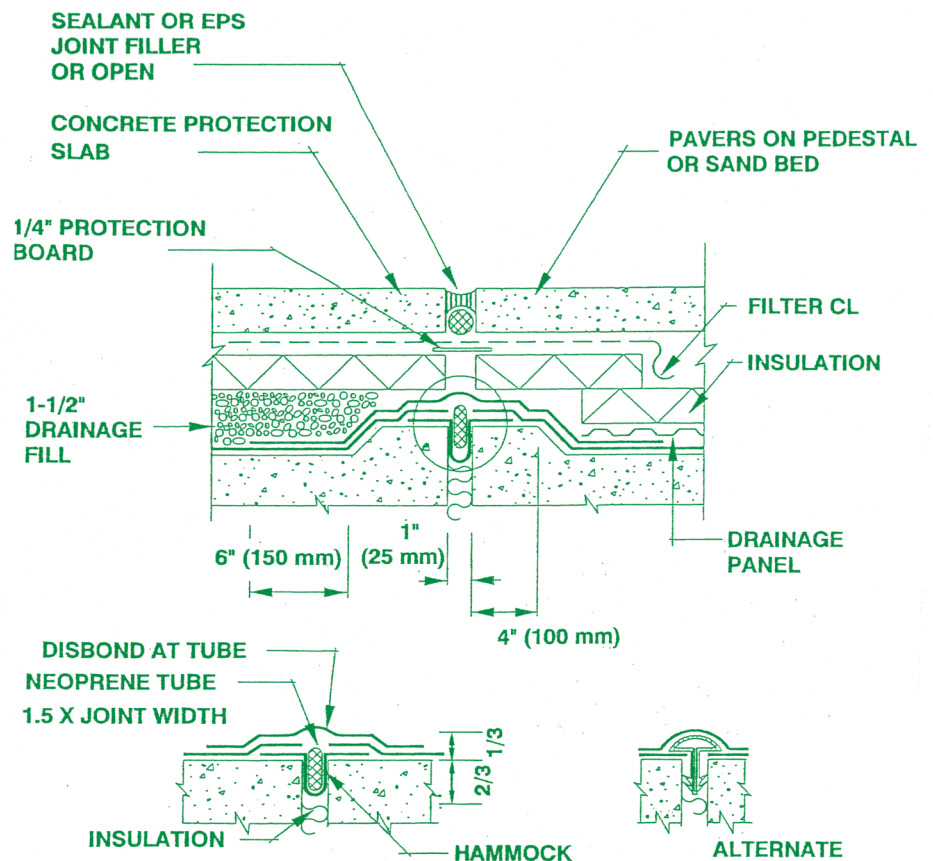
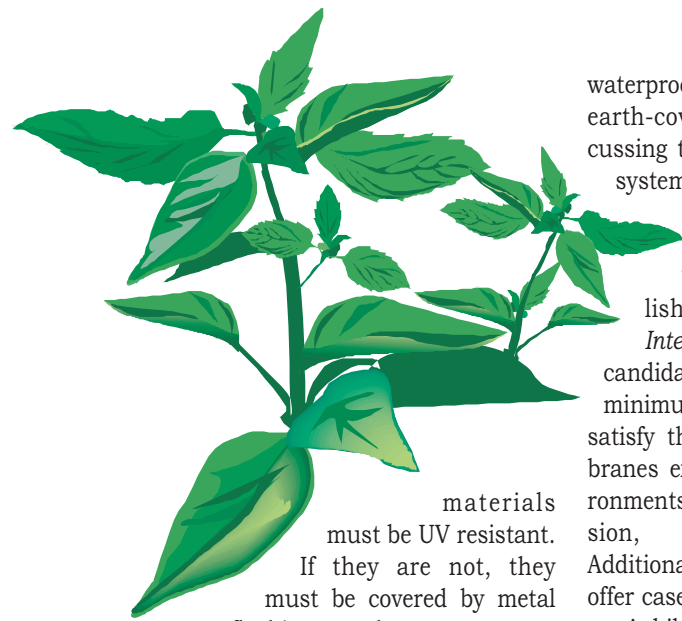



Figure 12: Expansion joint in hardscaped waterproofed plaza



materials must be UV resistant. If they are not, they must be covered by metal cap flashing, wood, stucco, cement parging, or masonry.

Because they are dynamic and thus more vulnerable to failure, expansion joints should be located in paved or other areas that are not covered with the GRS. This allows them to be readily accessed for inspection and repair (Fig. 12). 

This concludes the first section of "Waterproofing Membranes Under Green (Garden) Roofs." It traced the history of

waterproofing membranes under plazas and earth-covered below-grade spaces, discussing the various types of waterproofing systems currently marketed and their advantages and disadvantages for use under green roof systems.

The concluding section, to be published in the February issue of *Interface*, will cover 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 will discuss failures and offer case studies to illustrate them.

A bibliography and acknowledgements are provided at the conclusion of the second

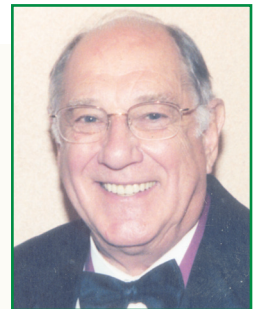
section. Unless otherwise noted, all photographs and illustrations are taken from *The Manual of Below-Grade Waterproofing Systems* by Justin Henshell, published by John Wiley & Sons, Inc. 2000.

REFERENCES

- 1 Green Roof Specifications and Standards by Christopher and Wendy Wark contains the following statements: *A membrane is actually protected, not degraded, by a green roof. ...the membrane is subjected to nothing more than a small amount of moisture. ...mechanical stress is reduced. This helps maintain joint integrity, adherence to the deck, and reduces water vapor transfer.*

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