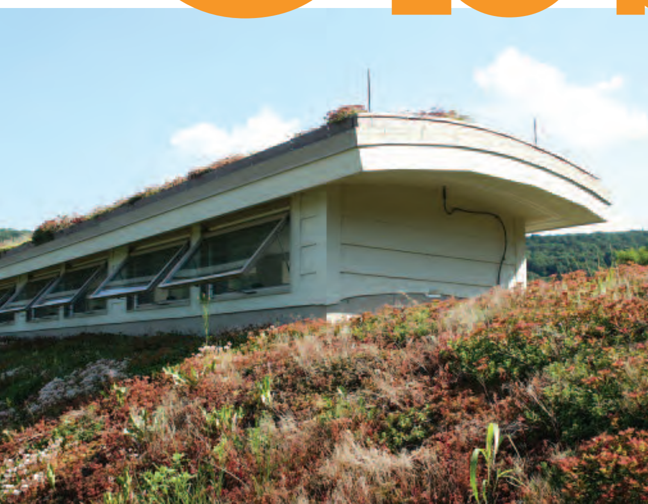
Obstacles & opportunities



Vegetative roof systems face obstacles to industrywide acceptance

by Elizabeth J. Grant, Ph.D.

Despite the recent popularity and widely touted benefits of vegetative roof systems, there still is some trepidation regarding the use of such systems among many in the construction industry. The concerns are not unfounded given a building's first line of defense against the elements is its roof.

In his 1989 book *Roofing: Design Criteria, Options, Selection*, Robert D. Herbert wrote "over 50 percent of post-construction problems can be attributed to roofing or related systems" and "approximately 65 percent of all lawsuits brought against architects during one recent period originated with roofing problems."

Although these statistics are dated, the explanation Herbert gives for these phenomena during the 1980s, namely the introduction of a large number of new roofing technologies in a brief time period, may be analogous to the current situation facing vegetative roof systems.

Vegetative roof systems, though viable alternatives to traditional roof systems, face some obstacles to widespread acceptance.

Components

There is an important functional distinction between vegetative roof systems and more traditional roof systems. Traditional roof membranes generally fall into the category of weatherproofing. Conversely, the membranes required beneath vegetative roof systems, which periodically support damp growth medium, can be considered waterproofing membranes. Many vegetative roof system membrane suppliers classify vegetative roof systems as waterproofing.

Waterproofing typically requires a thicker membrane than weatherproofing and requires especially careful installation and detailing. And obviously, additional materials are needed to sustain the vegetative portion of vegetative roof systems.

The NRCA Vegetative Roof Systems Manual, Second Edition identifies a series of components recommended for vegetative roof systems of different depths ranging from extensive to intensive. Following are design considerations for some of the critical layers located above the waterproofing membrane, namely the root barrier, drainage layer, filter fabric, growth medium and plantings.

Root barrier

The root barrier separates plant roots from the underlying waterproofing membrane. Plant roots naturally seek any and all available water, and many failures of early vegetative roof systems have been attributed to roots puncturing membranes and penetrating vulnerable joints in the waterproofing membrane, such as seams, edges and curbs.

In their book *Planting Green Roofs and Living Walls*, Nigel Dunnett and Noël Kingsbury observe that microorganisms found in vegetative roof systems may digest bituminous, organic roof components, contributing to root penetrations. A continuous physical separation between roots and the waterproofing membrane is essential.

For example, rolls of PVC film can be

Photos courtesy of Elizabeth J. Grant, Ph.D., Virginia Tech, Blacksburg

Photo 1: The Jordan N. Carlos Middle School Art Building at Woodward Academy, Atlanta, features a vegetative roof system within trays elevated above the roof membrane.

installed above a prepared roof surface and heat-welded to provide an impervious barrier. Another more conservative approach is to install a vegetative roof system within plastic or metal trays that are slightly elevated above the roof membrane, effectively isolating plant roots from the waterproofing membrane, as was done atop the Jordan N. Carlos Middle School Art Building at Woodward Academy in Atlanta (see Photo 1).

The roofing industry has developed several other strategies to inhibit root penetration of waterproofing membranes. Chemical root inhibitors added to waterproofing membranes or filter layers are one option. Mechanical barriers composed of copper sheets or foil, frequently laminated to waterproofing membranes, also are effective. Often, the membrane material acts as the root penetration barrier as is the case with some single-ply roof membranes.

Germany has a stringent test methodology, the FLL Guideline, that subjects membranes and barrier sheets to root penetration. In the FLL test, membranes or other barrier sheets or coatings are placed in transparent containers as part of a specified vegetative roof system test and then subjected to possible root penetration by particular plant varieties for two years in a greenhouse or four years outdoors to determine the presence and/or number of root penetrations through the root barrier.

To be certified root-resistant, a membrane must have no root penetrations during the test phase. A manufacturer's FLL certificate for a particular product becomes part of the contractor's submittal packet to be reviewed by the design professional.

Although there are no similar requirements in North America, manufacturers who provide waterproofing membranes frequently cite FLL certification as proof of a product's root resistance.

Drainage layer

Dunnett and Kingsbury generically describe vegetative roof system drainage layers and point out why these layers are critical in extremely low-sloped roofs.

First, they say vegetative roof systems, especially extensive systems, generally are planted with drought-tolerant species. Adequate drainage is required to avoid

Photo 2: This filter fabric is covered with a thin layer of growth medium and plantings.

drowning these plants' roots during and after storm events. Second, drainage of growth medium is necessary to maximize the thermal insulating value provided by this layer.

Dunnett and Kingsbury present three general drainage material categories. Granular materials are a simple traditional method of drainage and provide additional root space for plants. Porous mats are made of spongy materials that absorb excess water and release it once they become saturated. Plastic or polystyrene modules are designed to lift the planting and growth medium layers off a roof's surface, permitting water to flow freely along the waterproofing layer.

The many available systems are diverse. Some simply provide drainage while others are designed to hold a certain amount of water to help plants survive between rain events. Some allow for the incorporation of irrigation systems, and some also serve as root barriers, effectively separating the vegetative roof system from the underlying waterproofing membrane.

Filter fabric

The filter fabric's role is to contain the growth medium and plant matter and prevent clogging of the drainage layer and the roof's drainage system.

In *Roof Gardens: History, Design, and Construction*, Theodore Osmundson writes that filter fabric must be water-permeable, decay-resistant, portable, inexpensive, tough and durable.

Osmundson, Dunnett and Kingsbury refer to semi-permeable polypropylene fabric as the most typical and effective modern material used for this purpose. Quite often, the filter layer is combined with the drainage layer immediately beneath it; some companies offer these two components in one integrated modular piece.

Growth medium

Working upward, the next layer above the filter fabric on a vegetative roof system is growth medium. In Photo 2, I am holding the edge of a piece of filter fabric covered with a thin layer of growth medium and plantings.

In a technical paper presented during the 2004 Greening Rooftops for Sustainable Communities Conference, David Beattie and Robert Berghage summarize the requirements for growth medium as follows: It must satisfy the needs of the plants it supports; it must not impose excessive weight on the underlying roof structure; and it must provide an optimum balance between water retention and drainage.

Beattie and Berghage emphasize that though German standards for growth medium may be used as general guidelines, there are supplementary requirements in North America that must be addressed. In particular, designers must consider the materials' cost and availability and local hydrology of the area in which a vegetative roof system is installed.

Plantings

Vegetation is the definitive and most complex element that distinguishes vegetative roof systems from their traditional counterparts.

Osmundson discusses the challenge posed to landscape designers when faced with selecting plants for vegetative roof systems. There are several universal requirements for vegetative roof plants in his estimation: They must not possess invasive roots that can puncture or otherwise compromise waterproofing systems; drop large quantities of leaves or fruit (a potential maintenance concern with roof gardens); or exceed the load capacity of the structure supporting them.

In addition, they should be self-perpetuating, resistant to dry and wet conditions, compatible with the particular growth medium contemplated and hardy enough to survive freezing.

To this list Dunnett and Kingsbury add tolerance of temperature extremes and high winds, ability to quickly cover the growth medium and self-repair if damaged, efficient evapotranspiration (conversion of liquid water to water vapor) if the vegetative roof system is intended as a storm water management device, and suitability to the particular microclimate in question.

Because of the construction industry's intrinsically conservative nature and the inherently limited number of plants meeting these stringent criteria, plant selection for extensive vegetative roof systems largely has been limited to sedums or grass mixes that have survived the test of time on central European roofs. These plants are optimized for the rooftop environment, growing naturally in harsh, rocky environments with shallow soil.

The question remains whether a broader range of plants, possibly including more indigenous species with potential benefits to local biodiversity, might be appropriate for use in vegetative roof systems, particularly those with slightly deeper (semi-intensive) substrates.

A shift in approach

Another obstacle vegetative roof systems face is related to water retention and drainage.

In the past, dead-level roofs were commonplace in the U.S. and ponding water was considered acceptable in some instances, according to Stephen Patterson and Madan Mehta's 2001 book *Roofing Design and Practice*.

And Osmundson recounts that many roof gardens built during the 1930s and 1940s were waterproofed with virtually water-impregnable coal tar pitch.

Since health hazards sometimes associated with coal tar's use have become a concern, this system has largely fallen out of favor and, along with it, dead-level roofs. The prevailing wisdom, as articulated in building codes, now suggests that no water be permitted to remain on roof surfaces. This mindset has generated requirements to provide positive drainage at all roof locations, created the ubiquitous ¼-in-12 (2-degree) slope requirement for low-slope roof systems and necessitated the provision of overflow drains in the event the primary drainage mechanism fails.

In light of this progression of events, it is fair to question why many cities and municipalities, as well as some roofing professionals, have been so quick to embrace vegetative roof systems, which temporarily retain water. Because of this shift in approach, it is important to understand how vegetative roof systems function with respect to drainage.

Plumbing codes govern the layout and size of roof drainage systems. Vegetative roof systems significantly reduce the average overall volume and velocity of storm water runoff compared with traditional roof systems.

However, during a lengthy or intense storm, a vegetative roof system can become saturated, allowing a large amount of rain to flow across the surface of the growth medium or through the system to the waterproofing membrane. Moreover, a vegetative roof system is much less effective at reducing storm water runoff when its growth medium is frozen or already saturated from a previous storm.

Because drainage systems must be designed to avoid structural failure caused by potential ponding water and saturated growth medium, reductions based on the inclusion of a vegetative roof system usually cannot be made to the required size and positioning of drainage elements. Even if a vegetative roof system reliably and consistently reduces the volume and rate of storm water runoff, roof system designers still must consider the possibility of future changes to the roof system's function during the building's life span.

For instance, Matthew Kuhl explains in his paper "Bank One Center: A Green Roof Tutorial" presented at the Second Annual International Green Roof Infrastructure Conference: Greening Rooftops for Sustainable Communities that possible, though unlikely, future removal of the vegetative roof system at the Bank One Center (now Chase Tower) in Chicago was the reason for designing roof drainage to the standards required of a traditional roof system.

For reroofing applications, roof slope requirements sometimes are relaxed. According to the exception in the *2006 International Building Code* (IBC) Section 1510.1: "Reroofing shall not be required to meet the minimum design slope requirement of one-quarter unit vertical in 12 units horizontal (2-percent slope) in Section 1507 for roofs that provide positive drainage."

IBC defines positive roof drainage as "the drainage condition in which consideration has been made for all loading deflections of the roof deck, and additional slope has been provided to ensure drainage of the roof within 48 hours of precipitation."

However, the question remains: Is it good practice to allow vegetative roof systems to retain water for a significant length of time?

Although it is their capacity to delay storm water runoff that makes vegetative roof systems attractive, initial experimental results indicate the length of time water spends in such systems may be relatively short.

Karen Liu's National Research Council Canada study of a 6-inch-deep extensive vegetative roof system with a ¼-in-12 (2-degree) slope in Ottawa demonstrated a 95-minute delay in roof runoff after a light rain event of 0.76 of an inch occurring during 6½ hours and a mere four-minute delay after a more intense storm of 0.84 of an inch during 21 minutes. This finding, though it requires replication, indicates properly designed vegetative roof systems are not necessarily more prone to long-term water retention than typical roof systems.

Anecdotal evidence would suggest vegetative roof systems can suffer from the effects of localized water retention as in the case of the Brewery Block 4 Ecoroof in Portland, Ore., presented by Kathy Bash at the 2004

Greening Rooftops for Sustainable Communities Conference.

In this project, the flanges of roof drains, which were set 1 inch above the waterproofing membrane as a result of a coordination error, allowed water to pond in the areas surrounding the drains. As a remedy, the growth media and plant layers were elevated above these areas of ponding with spaced rigid insulation and specialized drainage layers.

Despite this correction, portions of the roof near the drains remained saturated for extended time periods and suffered plant loss and moss and algae growth. This circumstance led to a design revision on subsequent projects and serves as a caution to roof system designers to minimize temporary ponding even when it is permitted by code on reroofing projects.

Beyond these concerns, there is a range of additional issues relevant to vegetative roof systems that should be researched for each individual job. A project-specific code review at the earliest stages of programming and design is one effective way to identify these issues.

In addition to addressing drainage requirements, the code review should consider the following:

- A roof system's allowable dead and live loads, including the saturated weight of growth medium
- Roof system occupancy
- Possible regulatory influence of additional parties with a vested interest in the project (such as a condominium association)
- Mitigation of fire risk
- Feasibility of a reroofing strategy where applicable

Combined with appropriate and conservative specification and detailing, examination of project-specific requirements is a positive step toward minimizing the occurrence of design errors and omissions. It also encourages early and essential dialogue between the parties involved with roof system design and construction and the building officials regulating the work.

Quality assurance

There are additional practical means of reducing the risk of vegetative roof system failure.

For example, monitoring and quality assurance of vegetative roof system installation and, specifically, the waterproofing membrane can be included in the project along with performance of an electric field vector mapping (EFVM) survey upon job completion to confirm to the owner the roof is leak-free. Such strategies often are offered to vegetative roof system owners to lessen anxiety about potential leaks and ensure systems are properly installed.

EFVM is performed by creating a low-voltage electrical field at a roof's surface using a loop of uninsulated wire attached to an electrical pulse generator. The roof structure, insulated from the roof surface by the membrane and often other layers such as insulation, acts as a second electrical field. A technician carrying two electrodes attached to a potentiometer surveys the roof for leaks by positioning the electrodes within the electrical field created on the roof surface. Any breaches in the membrane cause a directional change on the potentiometer, allowing the technician to pinpoint their locations even if holes are too small to be detected visually.

The advantages of this system when compared with traditional methods of leak detection are considerable. It can be performed before or after installation without any damage to vegetative layers. It avoids the potential hazards of a traditional flood test, which include possible damage to the roof substrate if a defect is present in the membrane, and unlike flood testing, it can be performed on steeper sloped roof systems. It also precisely locates holes in the membrane, which other methods fail to do.

Its main limitation is its incompatibility with some waterproofing membranes, such as EPDM and aluminized coatings, because of their high electrical conductivity. This technology, when widely accepted in North America, may help alleviate some of the worries associated with vegetative roof systems.

Addressing obstacles

As part of my doctoral work at Virginia Tech, Blacksburg, from 2003 to 2007, I conducted a literature search, investigated case studies and interviewed vegetative roof system experts to reveal the benefits of vegetative roof systems that were relevant parameters in the design process. These parameters included storm water management, energy savings, acoustical performance, system weight, contribution to Leadership in Energy and Environmental Design (LEED®) certification, and cost. My research also identified potential obstacles to implementation.

A comparison of the findings from my interviews with the results of a 2004 survey by Jennifer Strauss Hendricks delivered at the 2005 Greening Rooftops for Sustainable Communities Conference illuminates many misperceptions that may prevent vegetative roof systems from being installed.

Hendricks surveyed 240 architects and building owners in the Chicago and Indianapolis metropolitan areas who are members of the Building Owners and Managers Association International about their perceptions of vegetative roof systems' risks and benefits. Hendricks' study revealed flaws in designers' and building owners' rationale that may lead to avoidance of vegetative roof system technologies.

Storm water

In my interviews, I found the storm water reduction potential of vegetative roof systems consistently factored into the design process.

Hendricks reported architects ranked storm water runoff 4 out of 5 on a scale of importance where 5 was "very important" as a decision-making factor in building design. Despite this, fewer than 30 percent of building owners believed reduced storm water quantity was a benefit to society afforded by vegetative roof systems versus traditional roof systems, and only slightly more than 10 percent of building owners saw reduced storm water fees as a benefit of vegetative roof systems to the individual building owner.

This disconnect points to the importance of ongoing efforts to estimate the percentage of annual runoff reduction expected when implementing various vegetative roof systems.

Energy savings

Because of the small size and specific thermal characteristics of the projects designed by the experts I interviewed, energy savings proved irrelevant as a benefit of vegetative roof systems for those projects. This was not entirely unexpected because the better insulated a building, the smaller the effect a vegetative roof system will have on its overall thermal performance.

However, because vegetative roof systems moderate temperatures, they can enhance the efficiency of mechanical cooling systems, maximize the efficacy of typical roof insulation materials and even improve the performance of roof-mounted photovoltaic arrays. In the future, increasingly sophisticated energy modeling tools capable of simulating vegetative roof systems' performance may give designers and building owners a better idea of the energy savings that can be expected from their projects.

Hendricks observed that reduction of the heat island effect and mitigation of global warming were not named as societal benefits of vegetative roof systems by a majority of building owners surveyed. Although it would be desirable to accurately quantify energy savings on a per-project basis, as well as to assign value to the broader thermal effects of vegetative roof systems on their surroundings, it appears neither reduction of energy use for building thermal conditioning nor mitigation of heat islands are prominently considered in an owner's decision to install a vegetative roof system.

Photo 3: The vegetative roof system atop Chicago's City Hall

However, if a municipality embraces reduction of heat islands as a top priority, this may indirectly become a motivator for the installation of vegetative roof systems in that area. This situation has occurred most notably in Chicago where high-profile projects such as the roof atop Chicago's City Hall, shown in Photo 3, have catalyzed the construction of many others.

Acoustical performance

Although Hendricks does not list noise abatement as an advantage of vegetative roof systems, acoustical concerns are relevant in a small number of installations, mainly those constructed close to airports. The experts I interviewed also did not consider acoustical benefits when designing vegetative roof systems.

Despite this, acoustical performance may soon become more of a driving force in dense urban areas. There is an emerging body of literature addressing the possibility of using vegetative roof systems to mitigate traffic noise, exemplified by research conducted by Timothy Van Renterghem and Dick Botteldooren of Belgium's Ghent University.

System weight

The weight of vegetative roof systems is an important issue for building owners in Hendricks' study. She observed that though cost was the most important consideration in building design decision making, concerns about weight and system failure far outranked cost as owners' obstacles to vegetative roof system installation.

This result is interesting in light of the modern advances in growth media that have supported increasingly light vegetative roof systems.

During my interviews, roof system designers discussed projects in which several vegetative roof system types could have been chosen without exceeding the available structural capacity of the existing roof deck.

It is not surprising roof weight and

possible roof system failure, which are related to a building owner's potential legal liability, feature so prominently in Hendricks' survey, especially because the questions were not anchored to specific information about lightweight extensive vegetative roof systems in comparison with traditional roof systems.

Contribution to LEED

A minority of the architects and none of the building owners in Hendricks' study had been involved with any LEED-certified building projects, yet two-thirds of the architects responded they were "somewhat or very likely" to design a vegetative roof system during the next five years, and 19 percent of the building owners had considered installing one.

None of the projects discussed in-depth by my interviewees involved LEED certification. Further research is necessary to determine whether seeking LEED certification has a measurable influence on the decision to install a vegetative roof system.

Cost

The difference in the cost of vegetative roof system types was a factor in all the projects referenced by experts I interviewed, limiting the depth of growth medium selected. In Hendricks' survey, initial costs, heating and cooling costs, and maintenance costs were given high importance values by building owners and architects as decision-making variables regarding vegetative roof systems.

Hendricks argues that because a majority of survey respondents viewed vegetative roof systems as having higher initial and maintenance costs when compared with traditional roof systems, this result combined with the high importance assigned to these parameters suggest a significant barrier to vegetative roof system installation.

Hendricks asserts that though nearly half of her survey respondents believe vegetative roof systems have higher replacement costs than traditional roof systems, this belief does not account for the expected extended life span of waterproofing membranes afforded by vegetative roof systems, which actually reduces replacement costs in the long term.

Until a large number of vegetative roof systems have sufficient and successful tenure in North America, demonstrating their purported ability to double or triple membrane life as compared with traditional roof systems, this benefit may be difficult to defend.

The obstacle represented by higher initial costs was acknowledged by all my interviewees and surmounted only by supplementing the project budget with grant money. Life-cycle cost analysis, which would have likely reflected the reduced replacement costs of vegetative roof systems over time, was alluded to in one case but did not strongly influence the decision to install a vegetative roof system.

Additional considerations

An additional parameter mentioned in the interviews I conducted also featured prominently in Hendricks' study. Hendricks' survey respondents ranked "Traditional/tried and true" above "Cutting-edge technology" as a desirable characteristic. Similarly, the designers I interviewed stated they chose specific vegetative roof systems based on their proven performance in the German market and the designers' personal familiarity with them.

When taking on a new technology, it is prudent to consult or partner with experts in the field. The designers I interviewed explained this often means cooperating with expert suppliers who have experience with waterproofing and who have the European contacts and experience to assist with the design process.

As a greater number of vegetative roof systems are installed in North America, it can be anticipated that these systems will gradually move away from their current "cutting-edge" status and join other roof technologies, such as single-ply roof membranes, that were once considered revolutionary but now are commonplace.

Making the decision

Hendricks concludes there is a lack of fit between building owners' and architects' interest in and intentions regarding vegetative roof system technology and these systems' actual demonstrated characteristics and benefits. She calls for education of both groups about the "real monetary and physical costs and benefits to the individual" to permit vegetative roof systems to become a viable choice.

My dissertation, a decision-making framework for vegetative roof system selection developed with financial support from The Roofing Industry Alliance for Progress, helps designers choose among generic vegetative roof systems by identifying the advantages they afford over one another and traditional roof systems. It does so by linking judgments about the relative worth of vegetative roof systems and traditional roof systems to the value of the difference in their actual, not perceived, attributes.

I use a decision-making system called Choosing By Advantages developed by Jim Suhr, co-founder and president of the Institute for Decision Innovations, in constructing the framework to help avoid the errors that can arise when designers and owners make choices based on assumptions rather than project-specific facts. I hope this decision-making framework and other similar tools will help the industry achieve a comfort level with vegetative roof systems that will lead to the widespread adoption of this promising technology in North America.

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