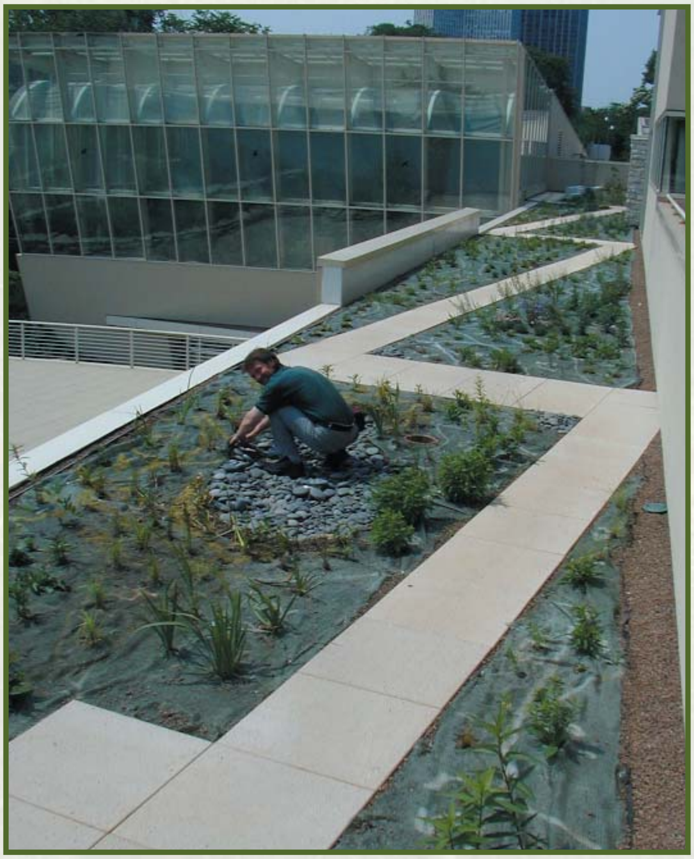
GREEN ROOFS: A New American Building System

by Charles D. Miller, P.E.

Green roofs, sometimes also referred to as "living" or "vegetated" roofs, are composite systems that combine a waterproofing system with a vegetated-cover system. First popularized in Europe, vegetated roof covers offer a wide range in function and appearance. Green roofs are traditionally divided into two categories: "extensive"—6-inches (152 mm) thick or less, and "intensive"—10-inches (254 mm) thick or more.



Photos courtesy of Roofscapes, Inc.

Benefits

The benefits of green roofs include their capacity to:

- extend the service life of the underlying waterproofing system;
- improve the efficiency of roof insulation;
- reduce rainfall runoff impacts;
- reduce sound reflection and transmission;
- provide urban habitat for birds and plants, thereby improving air quality and the local ecology;
- reduce urban heat-island effects; and
- enhance property values.

Experience in Europe shows that uniformly vegetated extensive green roofs with 3 inches (76 mm) of media provide the highest benefit-to-cost ratio. Improvements associated with thicker and more intensively landscaped systems are marginal.

From a heat-flow perspective, the performance of green roofs as insulators depends greatly on a number of variables, including moisture content and temperature regimen. The physical processes producing the benefit are many and varied, but the general characteristic of green roof materials and foliage is a high capacity to absorb heat (i.e., thermal mass effect). Green roofs generally provide a greater benefit in summer than in the winter. Their capacity to virtually eliminate the daily variation in temperature on the roof deck, however, is a year-round phenomenon that serves to extend roof life by reducing thermal cycling. By way of comparison, green roofs are up to twice as efficient as white or reflective roof surfaces in reducing thermal gain, which is why jurisdictions like the City of Chicago are advancing green roofs for their potential to reduce interior temperatures during the summer.

Green roofs also produce a dramatic reduction in both the quantity of rainfall runoff and the rate of runoff.[1] This benefit has spurred the widespread implementation of green roofs in Germany. On an annual basis, rainfall runoff quantity will be reduced by 60 percent or more in most regions, with a similar reduction in runoff rate. To the extent that green roofs can reduce runoff rate, other devices like stormwater basins, below-grade detention storage, etc., can be reduced in size or eliminated. In urbanized areas the potential savings are three-fold: reduced site-development costs, increased commercial space (which would otherwise be consumed by stormwater detention basins) and lower public infrastructure demands for stormwater mitigation strategies.

Standards and Guidelines

Because the market in the U.S. for green roofs is in its infancy, most Americans are unfamiliar with them. The combination of few companies with extensive installation experience and the large number of different systems now entering the market can make it difficult to obtain good information about green roof systems. Evaluating the claims of different providers and making meaningful comparisons between products can be challenging, especially since there are not yet any accepted standards or measures of performance to reference.

In the absence of American standards, many green roof customers rely on the guidelines and standards developed in Germany. In particular, the detailed standards and guidelines published by FLL[2] cover most aspects of green roof design. These include tests and standards for assessing the root resistance of waterproofing materials, determining the water retention properties of growing media, predicting the maximum weight of green roof systems, ensuring adequate drainage capacity, etc. These standards are most appropriately applied in northern temperate areas of North American. Several groups, most notably ASTM International, are working to adopt standards that will be more broadly applicable throughout the U.S. (see sidebar).

Weight Considerations

It is not difficult to design green roof systems that have a maximum weight of less than 13 pounds per square foot (36.5 kg/m^2). However, green roofs weighing 18 pounds per square foot (87.9 kg/m^2) or more are most common. Many buildings constructed prior to 1960 incorporated conventional roofing systems that included layers of felt and asphalt topped with stone ballast. Depending on the locality, these roofing systems weigh 10–15 pounds per square foot (48.8–73.2 kg/m^2). As a result, it is often possible to remove existing waterproofing systems and replace them with green roofs without having to resort to structural reinforcement of the roof deck.

The weight of a green roof system includes the weight of all its components. In order of decreasing contribution to overall load, they include the growing medium, plants, water retention, waterproofing, and synthetic components such as fabrics and membranes

The guidelines set forth in the *International Codes*™ treat the weight of a green roof, including all retained moisture, as a dead load. How should this weight be determined in the absence of an American standard procedure? The FLL specifies a laboratory test to assess the maximum weight contributed by the media. The test involves compressing the material into a mold with a 10-pound Proctor hammer, immersing the sample for 24 hours and then draining it briefly before measuring its weight. Due to the conservative nature of this test, I recommend using it to evaluate the structural adequacy of roof structures.

In extensive green roofs the weight of plant foliage, laden with moisture, rarely exceeds 2 pounds per square foot (9.8 kg/m^2). However, when designing intensive green roofs with large shrubs and trees, careful consideration must be given to the mature weight of such plants. During and immediately following rainfall, water will accumulate in the drainage layers of green roofs. This temporary increase in weight might be more appropriately addressed as a live load. However, in green roof design it is usually included in the calculation of dead load. This load factor may vary widely among different green roof systems and should be specified by the system provider. The dead load associated with the green roofs must be added to appropriate live loads such as snow, wind and human foot traffic to evaluate the feasibility of a green roof design. The *International Codes* provide guidelines for assigning these loads appropriately.

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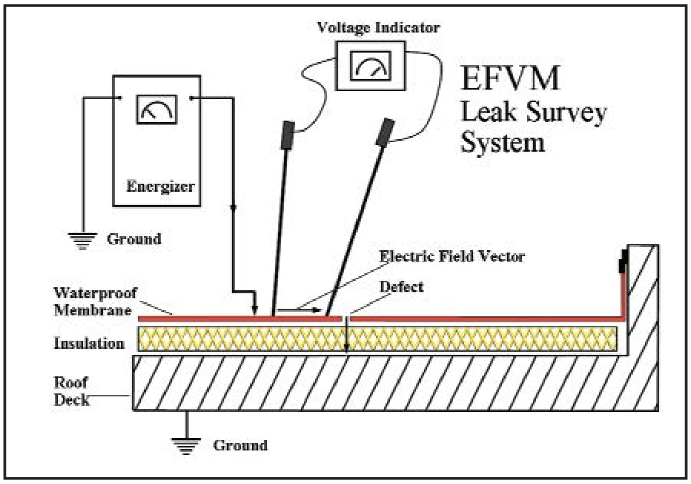

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Preventing and Detecting Leakage

The issue of leakage involves two separate factors: compatibility between the overlying vegetated cover and the underlying waterproofing materials; and the ability to detect, isolate and repair any problem areas.

Materials used in conjunction with green roofs should be certified for use in waterproofing, as opposed to dampproofing or weatherproofing. Many conventional waterproofing materials are suitable for use in combination with green roof installations. In most instances, however, green roof waterproofing systems will incorporate thicker membranes or multiple layers, and the level of quality control in the installation and testing of the completed waterproofing will generally also be at a higher level. The additional up-front cost is offset by the fact that, once protected with a vegetated cover, the waterproofing system will last for a very long time. How long? No one can be sure, since the oldest examples in Germany and Switzerland are now only about 35 years old. However, when uncovered after 35 years, the underlying waterproofing materials have been found to be in excellent condition. Experienced green roof installers speculate that these systems will last for 50 years or more.

Protection against root penetration is a critical concern. Many otherwise excellent waterproofing materials will not stand up to years of root attack, so a supplemental root-barrier system is essential. Such systems fall into three categories: thermoplastic membranes (e.g., polyethylene), roofing membranes impregnated with root-inhibiting chemicals and copper foils.

Thermoplastic membranes certified for use in Germany as root-barriers are typically about 30 mils thick and have hot-air welded seams. Some American companies offer waterproofing membranes or supplemental root-barriers that have been certified by FLL for root resistance. Copper foils are relatively new in the green roof industry so, once again, since no American standards exist it is a good idea to look to the FLL guidelines.

Should a problem develop, effective methods have been established for locating the source of leakage, even under feet of cover. Electric field vector mapping (EFVM) is a new and powerful tool for improving quality control on waterproofing systems, and is now available in the U.S. Although unfamiliar to most Americans, it has achieved a long record of success in Europe. Unlike most other leak detection methods, EFVM can quickly and accurately locate the point of water entry. Alternative approaches like infrared surveys can determine where water has accumulated in the insulation, but may not be as useful in actually finding the waterproofing defect. The benefits of EFVM can be summarized as follows:

- it can be used after the vegetated cover systems are installed;
- it can be used, to locate defects precisely, enabling efficient repairs;
- because ponding water is not part of the procedure, there is no hazard of overloading structural decks during testing;
- it can be used on steeply sloping roof surfaces where flood testing is impossible; and
- repairs can be tested immediately.

Once the source of leakage has been detected, thin vegetated covers can be removed locally to expose the damaged area and make repairs.

Conclusion

When appropriately designed and constructed, green roofs are extremely durable roofing systems. Hopefully, we will see more widespread acceptance of these systems in the U.S. and the development of appropriate American standards in the near future. Until these systems become more familiar to American builders, however, it is prudent to rely on the standards and guidelines which have been developed in Europe over the past 40 years. ◆

Notes

1. Miller, C, and Pyke, G., *Methodology for the Design of Vegetated Roof Covers*, Proceedings of the 1999 International Water Resource Engineering Conference, American Society of Civil Engineers.
2. Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau e.V. (Landscaping and Landscape Development and Research Society), Richtlinien für die Plannung, Ausführung und Pflege von Dachbegrünung (Guidelines for the Planning, Installation and Maintenance of Green Roofs), 1995.

***Charles D. Miller, P.E.**, is a member of the Technical Advisory Committees for the Center for Green Roof Research at the Pennsylvania State University and the Green Roofs for Healthy Cities Coalition, a Toronto-based research and public policy organization. He is also a member of the ASTM Subcommittee E06.71 on Sustainability, Buildings; and the German Roof-Gardening Association.*

Miller is the founder and president of Roofscapes, Inc., which offers the Roofmeadow® family of green roof systems through its national network of licensed green roof installers. For more information, write to Roofscapes, Inc., at 7114 McCallum Street, Philadelphia, PA 19119; phone (215) 247-8784; fax (215) 247-4659; e-mail cmiller@roofmeadow.com*; or go to* www.roofmeadow.com*.*

In 2001, ASTM International added a Green Roof Task Group to its Subcommittee E06.71 on Performance of Buildings, Sustainability. The group is charged with the development of a Standard Practice of the Assessment of Green Roofs. The resulting standard is intended to address both technical requirements and considerations for sustainable development.

The members of the task group include a cross-section of the green roof industry roofing material specialists, horticulturists and engineers. The group has been using the well-established German FLL guidelines as the foundation for its work, which has recently focused on establishing a technical basis for assessing the performance characteristics of drainage layers and growth media in green roof systems. Particularly challenging is the problem of extending the European knowledge base to encompass the diverse regional conditions across North America. ◆

A 2.5-inch (63.5 mm) deep green roof system installation for The Fencing Academy of Philadelphia. The installation was a retrofit on a modified bituminous membrane waterproofing system.