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Green Roof Specifications and Standards

Establishing an emerging technology

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Earlier this year, the city of Chicago, Illinois, and Green Roofs for Healthy Cities co-hosted the first green roof infrastructure conference and trade show in North America. (At least six green roofs already exist in Chicago, including one covering city hall, and an additional 42 are in the planning stage.) Over 500 architects, landscape architects, roofing contractors, city planners, developers, and others attended the conference to learn and share on the subject, and generate support for green roofs throughout North America.

Photo 1

Increased interest in green roofs

Several U.S. companies are licensees for European green roof systems and methods, where the technology has existed for the past 40 years. In fact, limited land resources (as compared to North America), expensive sources of energy, and ancient sewer systems overwhelmed by stormwater runoff have all contributed to the success of the green roof industry in Europe.

Over 800 green roofs can be found in Germany alone, a leader in building codes and incentives for green roof installation. In Asia, Japan has become a center for green roof technology. Its capital, Tokyo, is the first city to mandate building vegetation must constitute 20 percent of all new construction.

Green roofs have been installed across America in steadily increasing numbers over the past decade, and research is being conducted in North American universities on the impact of green roofs on the environment, economy, and energy resources. Some major American corporations, like Ford Motor Co., The Gap, and H.J. Heinz Co., have recently installed green roofs, and the approved design for the new World Trade Center includes a rooftop garden. However, despite breakthroughs in green roof elements making them more readily available in the United States, little is known about green roofs and even less about their installation standards.

History of green roofs

Green (vegetated) roofs have been in existence since ancient times. "The first known historical references to manmade gardens above grade were the ziggurats (stone pyramidal stepped towers) of ancient Mesopotamia, built from the fourth millennium until around 600 B.C." In France, gardens planted in the 13th Century thrive atop a Benedictine abbey. Norwegians developed sod roofs centuries ago as a means of thermally insulating their buildings. In fact, sod homes are still used as protection against extremely cold winters in Norway and the United States. Five roof gardens were installed atop the seventh floor of the Rockefeller Center in New York City, New York, between 1933 and 1936. Designed to be 'viewscapes' for the enjoyment of skyscraper tenants (at higher rents, of course), these gardens continue enhancing the view in New York City.[1]

Description of systems

The green roof industry has developed two general classifications for rooftop vegetation systems:

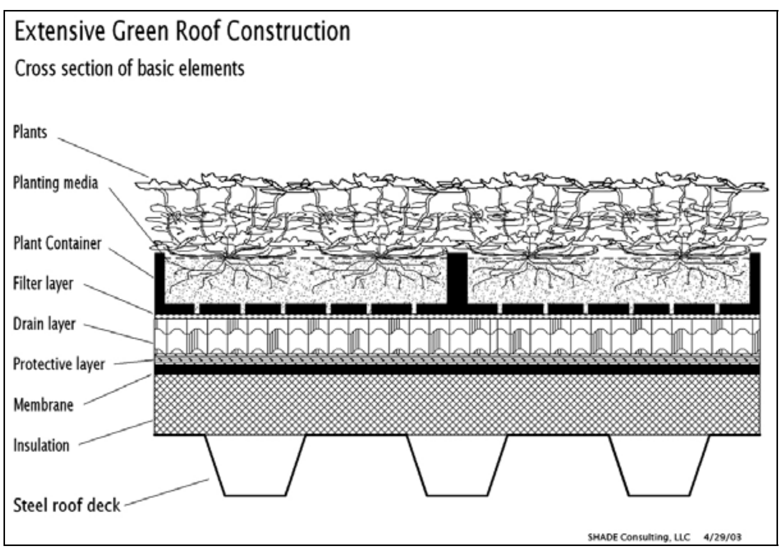

Figure 1

Extensive

Also known as low-profile or performance, this type of green roof contains only one or two plant species and minimal planting medium. It is commonly designed for maximum thermal and hydrological performance and minimum weight load while being aesthetically pleasing. Typically, only maintenance personnel have access to this type of roof. It is installed on flat and pitched roofs (Photo 1), like the Norwegian sod. Commercially available systems use planting media ranging in depth from 41 mm (1.6 in.) to 102 mm (4 in.), and total wet roof loads range from less than 49 kg/m^2 (10 lb/sf) to approximately 98 kg/m^2 (20 lb/sf). Deeper, extensive systems exist but are becoming less common. The basic components of an extensive system are shown in Figure 1.

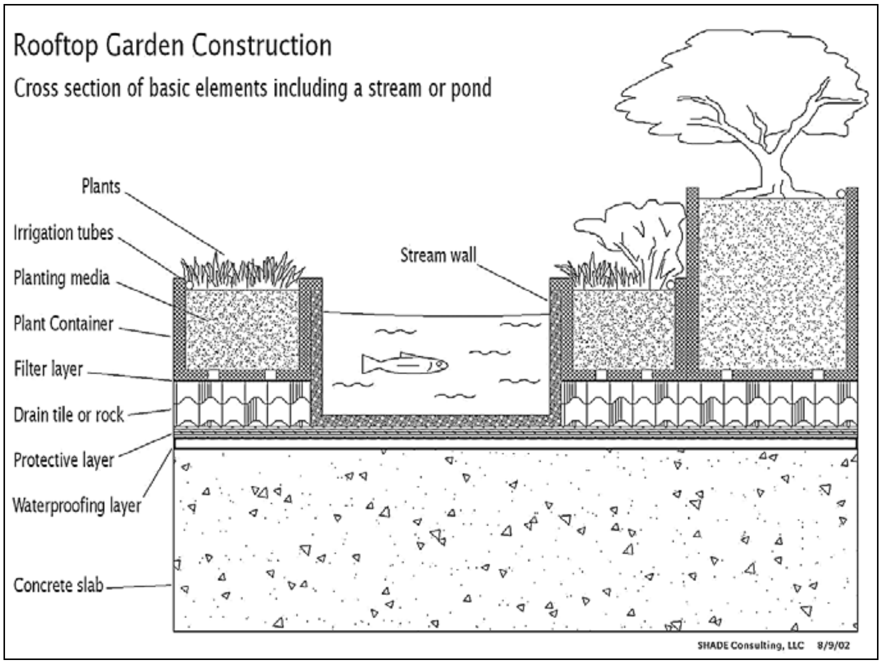

Figure 2

Intensive
Also known as high-profile or rooftop garden, this type of green roof typically contains a variety of plant types and is designed as a park-like setting (Photo 2). Some rooftop gardens support fairly large trees and water features requiring substantial structural reinforcement. A good example is Central Park atop the parking garage at the Kaiser Center in downtown Oakland, California (Photo 3). It has public access and has been a popular place for lunch since it was built in 1961.

The minimum planting medium depth for an intensive green roof is usually greater than that of an extensive system, with the maximum depth dictated by the application design. The design also dictates the structural requirements for the roof, especially if the roof is to have public access. The basic components of an intensive system are shown in Figure 2.

Throughout the rest of this article, the term ‘green roof’ will be used for extensive systems, and ‘rooftop garden’ for intensive systems. Other terminology used to describe a system includes:

Roofscape
This describes the landscape of the rooftop or the overall appearance of the roof.

Modular system
In this system, the vegetation and planting medium are contained in special trays covering all or most of the green roof. In a non-modular system, the planting medium is a continuous layer over the entire green roof. The rooftop garden below is a modular system.

Photo 2

Eco-roof
Another name for a green roof, this term is often used because many green roof designs involve plants that are not green for the entire year, particularly in northern regions.

Description of components
The components used in green roofs are generally the same as those in rooftop gardens, differing only in depth and project-specific design application (Figures 1 and 2), and include the following:

Vegetation
Almost any plant can be put on a roof. The only limitations are climate, structural design and maintenance budgets, and the roofscape designer's imagination. Since green roofs are typically lightweight, they often contain ground cover that can thrive in very shallow soils with little to no maintenance. Sedum, a succulent ground cover, has become very popular for use on green roofs in North America. Also commonly used are a variety of hearty wildflowers and shallow-rooting grasses. At times, rooftop vegetation may go dormant and lose foliage, as do plants on grade.

Planting medium
Not to be confused with soil, the planting medium is distinguished by its mineral content, which is synthetically produced, expanded clay. The clay is considerably less dense and more absorbent than natural minerals, providing the basis for an ultra-lightweight planting medium. Perlite is a common form of expanded clay and is found in garden nursery planting mix (not planting soil). The types of expanded clays used in green roofs are also used in hydroponics.

A large number of planting medium ‘recipes,’ many of them proprietary, are commercially available. The bulk densities of these mixes range from 400 kg/m^3 (25 lb/cf) to 900 kg/m^3 (56 lb/cf) for dry mixes where water absorbencies can be 20–200 percent by weight. Soil is also commonly used in high-maintenance rooftop gardens.

Filter layer
Somewhere between the planting media and drain layer lies a filter, which not only allows water to flow through while retaining the planting medium, but serves as a root barrier. The filter usually comprises one or two layers of non-woven geotextile, where one of the layers may be treated with a root inhibitor (*i.e.* copper or a mild herbicide). As in many landscaping applications, filter fabric can also be used to control erosion at the surface of the planting medium.

Containment
In modular systems, containment refers to actual plant containers. In non-modular systems, the planting medium is supported by the drain layer and contained at the perimeter by a metal or plastic barrier, or the roof parapet.

Drain layer
Between the planting medium and roof membrane is a layer through which water can flow from anywhere on the green roof to the building’s drainage system. Some systems simply use a layer of large-diameter expanded clay, but most green roof companies now use a corrugated plastic drain mat with a structural pattern resembling an egg carton or landscape paver. The minimum drain layer thickness is usually less than 20 mm (0.8 in), but a thicker mat can provide additional insulation and root restriction.

Protective layer
The roof’s membrane needs protection, primarily from damage during green roof installation, but also from fertilizers and possible root penetrations. The protective layer can be a slab of lightweight concrete, sheet of rigid insulation, thick plastic sheet, copper foil, or a combination of these, depending on the particular design and green roof application. Some green roof systems do not necessarily require a protective layer.

Insulation
The thermal protection provided by the vegetation, planting medium, and drain layer sufficiently eliminates the need for additional insulation in warm, dry climates. However, building codes usually require a certain level of added insulation, regardless of the overall roof design.

Waterproofing
A green roof can be installed with any kind of waterproofing system, but single-ply membranes have become very popular in recent years and are specified by nearly all green roof companies for their cost effectiveness and simplicity. As such, the waterproofing layer is typically assumed to be a membrane.

Irrigation

Watering systems used in landscaping can be adapted to rooftop applications, but several commercial green roof designs combine passive irrigation methods with active components. Passive irrigation describes the process of storing rainwater in the drain layer, which eventually wicks back up through the planting medium while excess is allowed to drain off. One type of water storage medium is a polypropylene fiber mat directly below the planting medium which acts as a sponge. Other types include small reservoirs in the drain mat filled with expanded clay up to the bottom of the planting medium. Irrigation is rarely necessary, however, when drought-tolerant plants like sedums are used.

All these elements need not be acquired as individual units, as some products and designs on the market combine the functions of two or more components. For instance, the contours of the bottom of a modular container may form a drain layer, or a water storage mat might also be used as a filter layer. Combination designs can often reduce the weight and cost of a system.

Green roof system standards

Green roofs provide exceptional benefits through their thermal, hydrodynamic, and protective characteristics, but the only way their economic impact can be fully appreciated is by allowing variances to established standards and codes for roof systems incorporating vegetation.

Since the individual components of a green roof can be selected or created for a wide range of design possibilities, complying with standards at the component level is a reasonable approach. Exceptions to this would include clarifications in building codes for the total dead-weight (wet and dry) and live loads, fire safety, and provisions for membrane inspection or monitoring. Fire safety is a topic still debated, partly because of misunderstandings regarding the overall construction and type of vegetation used in green roofs. For example, tall grasses are often considered a fire hazard while succulents are fire resistant.[2]

Currently, green roof systems are not addressed by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). A Green Roof task group established in October 2001 by ASTM International Subcommittee E06.71 on Sustainability has created a statement of work to explore ways in which to assess green roofs (WK575–February 2003).

Component specifications and standards

Vegetation

The vegetation performs a similar function as a ‘cool’ roof by transferring solar energy to the atmosphere, only more effectively. On a summer day, leaf temperatures of any plant are usually less than 5 C (9 F) higher than the surrounding air temperature, making total leaf coverage and approximate plant height the only significant design criteria for cooling properties.

The other thermal design consideration is leaf retention. Many plants have an additional advantage over cool roofs in that they lose their leaves in the winter, allowing the sun to warm the roof. Selecting plants for maximum thermal benefit is location specific. ASHRAE 90.1-99, *Energy Standard for Buildings Except Low-Rise Residential Buildings*, currently allows for reduced insulation in roof systems using a reflective cool roof in warm climates, but it should be expanded to include vegetation in a broader range of climates.

In some cases, certain plants should be prohibited from use on rooftops for health or fire safety reasons, just as in landscape designs for courtyards or areas adjacent to buildings. A set of system design guidelines for horticultural issues, primarily plant health, would be useful in educating both clients and installers on the proper component specifications (including plant type) for a certain application and its climate. Many green roof companies work with local horticulturists and nurseries to ensure the selected plants thrive.

Planting medium

The thermal mass of the planting medium plays a significant role in dampening the impact of ambient temperature fluctuations. This property can dramatically affect heat transfer through roof systems in climates where the outside air temperature tends to oscillate about the set indoor temperature. ASHRAE has been continually improving its tables for adjusting R-values for high-mass walls, but local building codes still tend to use straight R-values because of the difficulty in applying thermal mass to specific cases. With planting media, the situation is further complicated by the fact that as moisture content increases, so does their thermal mass but not their R-value, which decreases. Water retention is another important parameter which can vary with the type and amount of vegetation, medium composition, and climate. Since absorption and flow rates are site and system specific, estimations of water retention characteristics must be calculated for individual cases. Planting medium depth and composition must also be appropriate for the selected vegetation. This specification would be part of the previously mentioned horticultural guidelines.

Filter layer

The geotextiles commonly used in filter layers are specified for material, flow rate, hole size, strength, and root inhibitor. Green roofs usually employ plants with easy-to-control roots, whereas rooftop gardens may contain deeper rooting plants requiring multiple filter layers. Since root and media particle diameters can vary, filters should be specified for different media and plant types to ensure adequate flow rates for a given planting mix without losing too much silt or allowing excessive root penetration.

Drain layer

The critical specification for a drain layer is the maximum volumetric flow rate, which is determined from rainfall data. Minimum passage area should be standardized for various locations. Since the drain layer supports the planting medium and vegetation, the compression strength should be specified. Many drain mat products are segmented or baffled to get the necessary compression strength, and hence, have insulating qualities that should be considered. (An R-value can be estimated, but an ASTM standard for measuring or calculating the wet and dry R-values for a drain layer should be established.)

Insulation

Results from a study done on commercial buildings in Northern California using DOE-2 and a proprietary roof heat transfer model developed by Shade Consulting indicate an uninsulated green roof could reduce the building heating/cooling system demand for most of the year by 30 percent over a conventional dark roof with R-18 rigid insulation without a radiation barrier (Figure 3).[3] The uninsulated energy savings would increase for desert locations and decrease for colder and more seasonal climates.

Since current standards do not recognize the insulating qualities of green roofs, a local code variance would probably be needed to install one on an under-insulated roof. Rigid insulation can certainly by used as a protective layer.

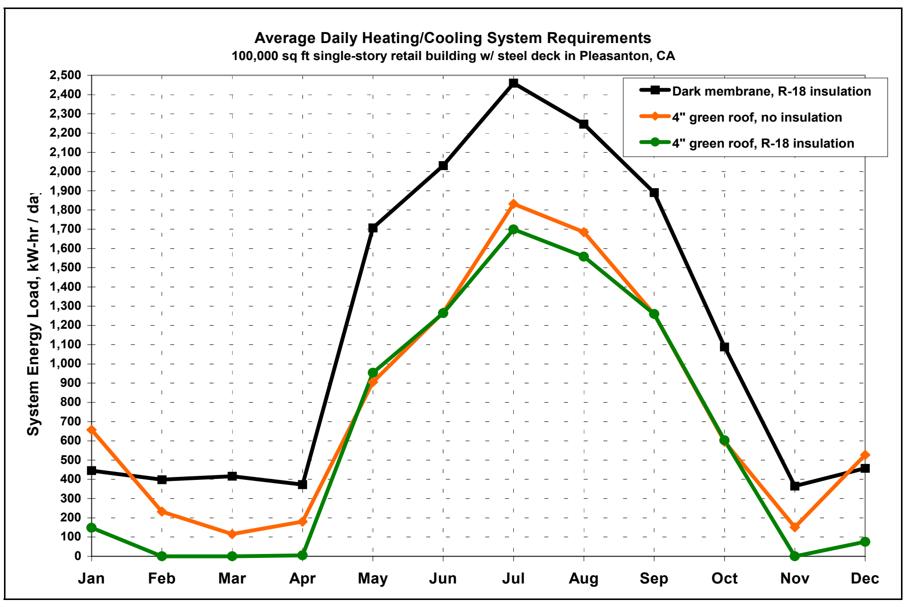

Figure 3

Membrane

A membrane is actually protected, not degraded, by a green roof. Without one, a membrane is subjected to UV radiation, extreme heat cycling, wind, rain, pollution (especially when ponding occurs), and damage from maintenance activities. With a properly designed green roof incorporating a protective layer, the membrane is subjected to nothing more than a small amount of moisture. Since a green roof keeps the membrane surface temperature much closer to the roof deck temperature, mechanical stress within the membrane is tremendously reduced. This helps maintain joint integrity, adherence to the deck, and reduces water vapor transfer.

Currently, no hard data exists showing the life span of a waterproofing system below a green roof. The waterproofing systems in older, well-known rooftop gardens with built-up roofs (BURs), such as those at the Rockefeller or Kaiser centers, have never required any maintenance. Membrane system maintenance for today's green roofs has yet to be reported. To be safe, roofing companies installing green roofs recommend various types of single-ply membranes, dictated primarily by application, installation, and cost considerations.

The design criteria of the system should include provisions in case an exceptional situation develops, such as particularly invasive roots or excessive fertilizer from a rooftop garden. Here, an appropriate protective layer must be selected. Obviously, vegetation that can root through an undamaged, watertight membrane is rarely used in green roof construction. Some companies now offer membranes incorporating a layer of copper foil for added protection against root penetration.

Existing standards and codes for membrane installation are more than sufficient for green roof applications. The only additional requirements might involve special provisions for the inspection of a membrane before and after the subsequent green roof layers are installed.

Vapor restriction
Since a green roof reduces the temperature gradients throughout the roof system, condensation is less likely to occur beneath the membrane. Situations requiring an additional vapor restricting sheet should be determined on an individual basis.

Irrigation
Irrigation requirements are specific to the climate and type of plants being used. For green roofs, plants not requiring irrigation are usually selected. The level of sophistication of the irrigation system (when required) is dictated by the client.
Like all elements in construction, green roofs are as diverse as the people designing them, and are customized according to intended use, climatic conditions, building structure and financial limitations.

Challenges
For the specifier, the challenge is to obtain consistent, verifiable information on the application requirements of a green roof system or its components. Most of the green roof companies in North America work in conjunction with established roofing companies and can reliably assist with design specifications for a given site. Some of them offer designs that have been used in Europe for many years while others have improved on these concepts or developed new technologies.

These skilled professionals, including architects and roofing contractors, offer a wide range of services—unfortunately, without access to a certification process. Clients are often hesitant to hire a specialist who is not certified in their area of expertise, and certification cannot be fully appreciated without established standards.

“There is a need to establish a minimum level of expertise for green roof design and implementation,” says Steven W. Peck, founder and executive director of Green Roofs for Healthy Cities (GRHC). “We are developing a voluntary training and certification system for green roof professionals as a means of disseminating consistent, specialized knowledge.” Once standards and codes are established, specifiers and their clients will be less apprehensive about including green roofs in their projects.

Green roof paradox

As the production of green roof components increases and improves, and the more they get specified, the more the cost of green roofs and rooftop gardens goes down, resulting in quantity discounts and increased overall savings for the client. Incentives and rebates exist nationwide for cool roofs, yet only a few municipalities have applied those incentives to green roofs.

Portland, Oregon, Chicago, Illinois, and a handful of other cities encourage their installation. A few states, such as Oregon, include green roofs in their environmental and energy savings programs, but it is not enough to encourage the establishment of nationwide standards and consistent codes. Green roofs provide greater energy savings than cools roofs but few areas in the United States provide installation incentives.
The paradox surrounding green roof standards is the lack of official guidelines keeps some specifiers from recommending green roofs for their projects, but without a substantial number of projects, there is little need to establish those standards.
Thankfully, with or without standards, green roofs continue to be specified in North America in greater numbers. These developments will assist specifiers in making educated, informed decisions and recommendations. The sooner this emerging technology is adopted on a wide scale, the sooner its benefits will be realized.

Notes

[1] Osmondson, Theodore. Roof Gardens: History, Design and Construction. New York: W.W. Norton & Company Inc., 1999.
[2] City of Portland Ecoroof Program: Ecoroof Questions and Answers, www.cleanrivers-pdx.org/pdf/eco_questions.pdf, June 18, 2003.
[3] DOE-2 calculates the hourly energy use and energy cost of a commercial or residential building given information about the building’s climate, construction, operation, utility rate schedule and heating, ventilating, and air-conditioning (HVAC) equipment.

Additional Information

Authors

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ASTM International
Eco-roof
Performance green roof
Roofscape
Rooftop garden

Abstract
As green roof designs and technologies become increasingly specified in the United States, the need arises to clearly define these systems and their components. Specifications, recommendations, and intended applications vary greatly—sometimes contradicting one another—so industry groups have begun taking action toward establishing standards for green roofs.

Visit the following for more information

Green Roofs for Healthy Cities
www.greenroofs.ca

Green Roofs.com
www.greenroofs.com

U.S. Green Building Council (USGBC)
www.usgbc.org

American Institute of Architects (AIA)
www.aia.org

American Society of Landscape Architects (ASLA)
www.asla.org

PHOTO INFORMATION

Photo 1
Chiropractic center in Pennsylvania.
Photo courtesy Roofscapes Inc.

Photo 2
GreenGrid™ modular rooftop garden.
Photo courtesy Weston Solutions Inc.

Figure 1
Performance Green Roof Construction Cross Section
Image courtesy Shade Consulting LLC

Figure 2
Rooftop Garden Construction Cross Section
Shade Consulting LLC)

Figure 3
Roof Systems Comparison of Building Energy Usage
Shade Consulting LLC)