

Green Roof Design

Adapted from an AIA Convention Seminar by Cathy Garrett, Kenneth Klein, and Andreas Phelps

January 2007

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SUMMARY

A successful green roof design requires knowledge of sustainability, engineering, and landscape design. The benefits of green roofs—whether a “cool” (nonvegetative) or vegetative—and the tools required to build them are explored.

PERCEPTIONS OF GREEN ROOFS

Unfamiliarity with green roofs can lead to skepticism and misperceptions. Green roofs are often falsely considered to

- Be prone to leaks
- Retain water, which leads to membrane failure
- Be extremely expensive to build and maintain
- Provide no financial advantage to the owner

A well-designed and well-built green roof, however, can prove all of these perceptions wrong.

TYPES OF SUSTAINABLE ROOFS

Sustainable roofs can be either nonvegetative (a cool roof) or vegetative. A vegetative roof incorporates landscape features in the roof system. The two main types of vegetative roofs are intensive roofs and extensive roofs.

Cool Roofs

A cool roof is a nonvegetative yet sustainable roof. Cool roofs are defined as roof membranes that have low heat gain due to high reflectivity and high emissivity. Cool roofs can reduce summer cooling costs by 25 percent to 70 percent. Unfortunately they sometimes slightly increase heating costs in the winter months. The ENERGY STAR® program lists products that reduce energy use; however, be aware that it defines a cool roof solely on the level of reflectance.

On a sunny 90-degree day, a cool roof measures temperatures near 100 to 120 degrees. By comparison, the temperature of vegetative roofs would reach 85 degrees and conventional roofs,

between 140 and 190 degrees, depending on the roof material. By reducing the heat gain to the roof system, the roof membrane has a proven longer relative life.

Vegetative roof systems

Extensive roof systems require minimal ongoing maintenance and typically do not allow occupant access. In an extensive roof system, the roof is covered with a system that is thin in section—which includes sedums, grasses, and mosses—and irrigation is through natural sources. This type of roof system requires only 3 to 8 inches of soil and can be retrofitted to most structures. The average cost is \$4 to \$15 per square foot (2004 prices), and the systems can be adapted to roofs with a zero-percent to 30-percent slope.

Intensive roof systems, as their name suggests, require intensive care. These fully landscaped roofs are usually intended for human access and use. These roofs require deeper soil depth to allow landscape material to develop and irrigation for ongoing maintenance. In many cases they are rooftop gardens created for the building occupant's enjoyment. Often they include shrubs, trees, water features, and irrigation systems. For healthy plants, anywhere between 9 inches and 3 feet of soil is required; soil depths up to around 10 feet have been beneficially used. However, typical current design is in the 9-inch to 3-foot range, which equates a loading of 75 and 350 pounds per square foot for soil and plants, respectively.

BENEFITS OF VEGETATIVE ROOFS

Among the many benefits of a green roof system, six of the most notable are listed below.

Possible LEED points

- Potential of 33 LEED points in the categories of Sustainable Site, Energy and Atmosphere, and Materials and Resources

Reduce urban heat-island effect

- Solar Energy is reradiated as infrared radiation.

Improve air quality

- Smog reduction
- Natural vegetative processes like evapotranspiration, absorption of CO₂, and bind dust particles

Stormwater management

- Vegetative roofs can absorb 15 percent to 90 percent of roof runoff.

Thermal/energy efficiency

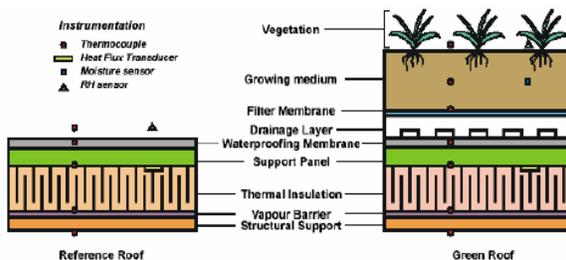
- Added R-value from soil and air layers
- Thermal mass slows down heat transfer through the roof.

Life-cycle assessment

- Longer roof membrane
- Embodied energy and recycled content
- Reduce energy costs 10 percent to 30 percent

REQUIREMENTS AND DESIGN OF PLANTS, SOIL, AND DRAINAGE

The cross-section below details the construction of a successful green roof system. (Note: Thermal insulation may not be required in temperate climates.) The major components of a green roof include those outlined below.



Source: Karen Liu, PhD, from proceedings of the Greening Rooftops for Sustainable Communities conference, Chicago 2003, p. 279.

- *Structural deck*

The substrate for a green roof must meet several general criteria:

- Typically a concrete substrate but can also be a metal deck with the appropriate cover board material to serve as a substrate
- Slope to drain ¼ inch per foot minimum
- Ability to carry load and accept waterproof membrane

Green-roof membrane types

There are two classifications of green roof membranes:

- Field-formed membranes or factory-fabricated sheets
- Loose-laid or fully adhered membranes

Field-formed systems are monolithic but dependent on a technician to apply the material in the field to the required thickness. Factory-fabricated sheets are of a measured thickness and factory-controlled quality but have seams that must be made watertight in the field. Loose-laid membranes are not as dependant on the quality and smoothness of the substrate. Fully adhered membranes isolate the membrane so that any leaks can be located in a specific area, which can allow for a more directed repair approach.

There is much debate as to what is the best classification. The authors have found that no one classification suits all applications and that each design must be assessed. The green-roof membrane meeting the desired classification based on the project requirements should be selected.

Green roof membrane properties

Any waterproofing membrane intended for use in a green roof must meet several important criteria:

- Low water absorption (less than 1 percent)
- Low water vapor transmission (less than .2 perms)
- Field splicing resistance to moisture
- High tensile strength
- Resistance to puncture and construction abuse

Green-roof membrane materials and types

A variety of membranes are currently marketed that meet the membrane properties discussed above. Of the systems listed below, the most commonly used are hot-applied rubberized asphalt membranes, thermoplastic membranes, modified bituminous membranes, and cold-applied liquid membranes.

- Vulcanized elastomers
- Nonvulcanized elastomers
- Thermoplastics
- Hot-applied rubberized asphalt membranes
- Modified bituminous membranes

- Cold-applied liquid membranes
- Built-up bituminous membranes

Insulation

Insulation is used in some instances to increase the thermal efficiency of a green roof. The insulation should meet the following criteria:

- High compressive strength
- Used in many applications to limit the weight added to the structure
- Must be closed cell material so as not to absorb water

Only two products can meet these criteria: extruded polystyrene and foam glass.

Root barrier

- Prevent root growth into the drainage medium and membrane
- Specify inert sheet materials as root barriers

Drainage layer

Drainage aids the growth of vegetation and prevents root rot, which adversely affects the soil chemistry. Some important aspects of drainage should be understood:

- It must allow lateral transfer and should take up limited space to allow for as much soil for plant growth.
- Scoring the underside of the insulation with grooves for drainage provides limited drainage.
- Combination water retention and drainage composites help limit the overall soil depth required for plant growth.
- Use of control flow drains should be avoided because water can back up; therefore, the authors recommend drains that have a surface cleanout for easy identification and access.

The best method to allow for drainage is to use a proprietary drainage composite, consisting of a polyethylene core and geotextile filter fabric. The filter fabric is an important component and must be selected as to its filter characteristics to prevent soil fines from clogging it while, at the same time, not allowing excessive amounts of soil to be displaced.

SOIL

Soil content is crucial to a successful roof landscape. Soil must be readily drained, lightweight, made of suitable organic nutrients, able to absorb

and retain water for slow release after storms, and have a particle size that won't clog drainage layers.

Often landscape designers have determined their own preferred soil mixture. For instance, PGAdesign Landscape Architects prefers 35 percent expanded shale or lava rock, 35 percent coarse sand, 20 percent fir bark, and 10 percent sphagnum peat moss. When using sand, it is important to sieve the sand first to eliminate grains smaller than the openings in the filter fabric. It is important to coordinate with a structural engineer to determine the weight of the soil and never use field topsoil.

PLANTS

A successful vegetative roof should be filled with a variety of plants. In an intensive roof system, plants achieve a balanced natural environment for enjoyment by people and as habitat for birds and insects. Liberal quantities of plants, and associated soil mass, help to reduce energy consumption and manage stormwater flows. In general, soil depth on roof gardens can vary from 9 inches to 5 feet. The preferred depths for specific planting groups are 9 to 12 inches for grass, 24 inches for small to moderate shrubs, 30 inches for small trees, and deeper soil for larger trees.

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RESOURCES

More Best Practices

The following AIA Best Practices provide additional information related to this topic:

16.02.04	Green Practice Advice
16.02.07	Going Green: Where to Find Green Product Info
11.05.01	Green Building Postoccupancy Evaluations: Learning from Experience

For More Information on This Topic

See also “Selecting Environmentally Preferable Products” by Nadav Malin, LEED AP, *The Architect’s Handbook of Professional Practice, 13th edition, Update*



2005, page 81.

See also the 14th edition of the *Handbook*, which can be ordered from the AIA Bookstore by calling 800-242-3837 (option 4) or by email at bookstore@aia.org.



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Keywords

- Building performance
- Sustainability
- Sustainable design knowledge