



Green Roofs: Increase the Energy Performance of Your Building

An Online Continuing Education Course for Engineers

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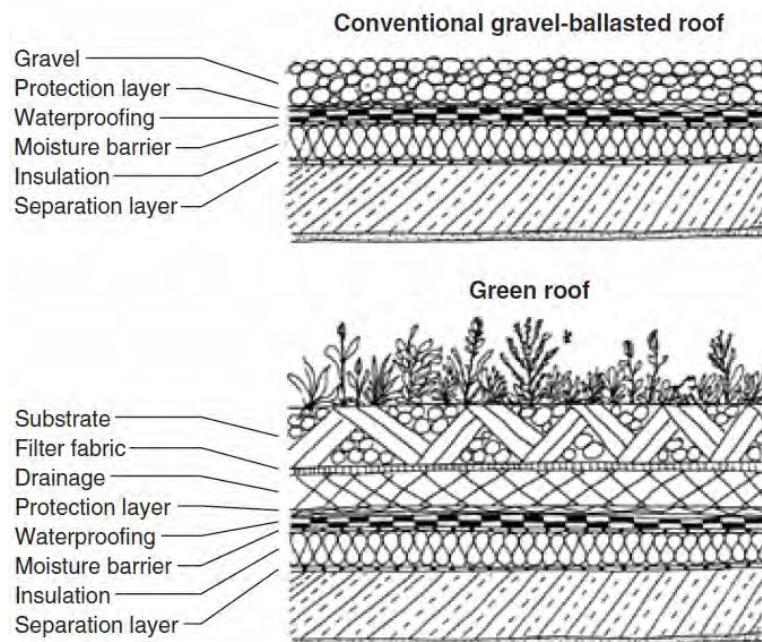
Green Roofs: Increase the Energy Performance of Your Building

Introduction

A green roof is a continuous layer of vegetation and soil that covers a roof's surface. The main components are waterproofing, soil, and the plants themselves. Green roofs are an important conservation technology because they increase the energy performance of buildings, improve indoor as well as outdoor air quality, and enhance the health of urban watersheds. There are two distinct types of contemporary green roofs: extensive and intensive.

An extensive green roof consists of a shallow soil profile with low-growing, horizontally spreading plants. These plants are primarily succulents that are adapted to the alpine (high elevation) conditions that predominate on a rooftop, where there is often little water and soil but significant exposure to sunlight and wind.

Intensive green roofs are more complex systems that require greater maintenance. They are constructed with deep soil profiles (more than 12 inches of soil depth) and feature greater plant diversity, including shrubs and trees. Intensive green roofs are considerably less cost-effective than extensive green roofs are, however.



The drawings show the general buildup of a gravel-ballasted roof and that of a green roof, in cross section. The buildup is very similar in both, but the performance of a green roof is superior to that of gravel-ballasted roofs on many levels. (Source: A. Dürr, *Roof Greening; An Ecological Balance*, 1995; reprinted with permission)

Extensive green roofs usually require less structural support than intensive ones, and they are considered to be more environmentally effective. Therefore, this course focuses on the design and installation of extensive green roofs. Therefore, this course focuses on the design and installation of extensive green roofs.

All green roofs are natural systems that effectively cool the temperature of ambient air at roof level. The vegetation layer shades the roofing membrane, thus significantly reducing heat gain

through the roof. The vegetation cover itself adds green space to areas that otherwise would remain impervious and uninhabitable to birds, butterflies, and other small wildlife.

Green roofs are important to consider in designing a sustainable facility, especially in urban areas, because roofs make up such a large percentage of the impervious surfaces in cities. Thus, they contribute to two key problems: the “urban heat island” effect and urban stormwater runoff. Both problems affect the consumption of energy and water and the demand on energy and water systems.

Pavement (roadways, sidewalks, parking lots), and buildings are the predominant surface covers in urban areas. These hard surfaces absorb solar radiation and transmit heat back into the atmosphere, and they prevent rainwater from filtering down through subsoil. Green roofs technology makes use of the natural processes and functions of vegetation to minimize the adverse effects of these impervious surfaces, especially where green space is limited and there are few trees to absorb water.

Green roofs contribute to energy management and water conservation in both direct and indirect ways. They provide shade, which reduces solar heat gain through the roof by almost 100 percent and mitigates the urban heat island effect. Also, a green roof’s soil and vegetation layer absorbs and filters rain, preventing it from becoming polluted runoff from the roof’s surface. And the photosynthesis process in vegetation has been shown to help reduce greenhouse gas emissions. Green roofs absorb, filter, and temporarily store precipitation. This water storage and filtration feature helps to mitigate the impacts of urban stormwater runoff. Volume, peak runoff rates, and associated non-point-source pollution—primarily sediments and nutrients such as nitrogen and phosphorus—are of great concern to the health of watersheds, aquatic life, and air quality, especially in urban centers.



An extensive green roof by Charlie Miller, Roofscapes, Inc., for the Chiropractic Life Expression Wellness Center in Sugar Loaf, Pennsylvania.

During low-intensity periods of rainfall (about one-half inch or less), green roofs have the potential to completely eliminate runoff as the soil layer absorbs the rain. During longer periods of rainfall, or rainstorms of greater intensity (1 to 2 inches or more), green roofs reduce peak flow rates and delay any runoff that might occur later, thus reducing the total volume of water that reaches sewer systems. Watersheds are also protected from non-point-source pollution, such as sediments and nutrient overload.

Green roofs are considered to be a form of low-impact development, and they are becoming more accepted as sustainable planning and design practices. Today, green roofs technology is anchored in the U.S. Green Building Council's Leadership in Energy & Environmental Design (LEED) building rating system because of the ways that green roofs help to minimize the environmental footprint of buildings and mitigate the impacts of urban runoff and urban heat islands.

The following sections provide more detailed information and criteria for engineers to use in considering, evaluating, and implementing green roofs at their facilities. Note, however, that green roof technology is a general technique rather than a specific system that can be universally applied. It is thus important to understand the concept before selecting appropriate design criteria and designing a site-specific green roof. A case study is included to show how these concepts are implemented.

Energy and cost savings are difficult to predict because monitoring data are not yet available in North America. However, many research projects are under way, and several have produced data that verify the cooling effectiveness of green roofs.

Application Domain

The design intent and goals of a green roof need to be defined before the design begins. Installation techniques and material and plant selections can vary and depend on the climate zone in which the roof is installed. In general, green roof applications are appropriate for a variety of government buildings and roof types, including office buildings, housing, and hospitals in warm or cool climates throughout North America. Green roofs are particularly effective when used to increase the energy efficiency of single-story or low-rise buildings, because of the high roof-to-wall ratio. They are also very effective when used for stormwater management on large footprint buildings.

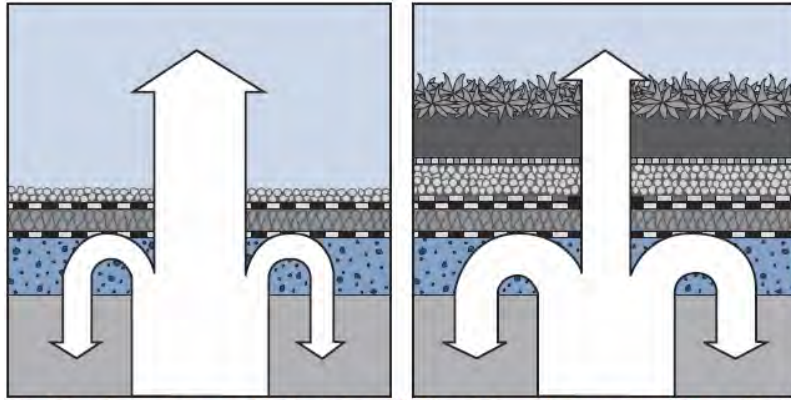
Facilities in areas with strict stormwater regulations, and those that must meet National Pollutant Discharge Elimination System (NPDES) permit requirements and criteria for total maximum daily loads (TMDLs), should consider using green roofs in lieu of conventional systems to control the quality and quantity of stormwater.

Green roofs are appropriate for both new and existing buildings. They can be incorporated into new building designs without much difficulty. Structural load requirements will usually need to be adjusted to accommodate the additional weight, beyond wind and snow loads, as required by building codes.

It is also possible to retrofit existing buildings with green roofs. But this requires a feasibility study to evaluate the structural integrity of the existing building and roof. Gravel-ballasted roofs are often suitable for a green roof retrofit because the gravel layer can be replaced with a green roof layer without adding much weight. It is important to protect existing waterproofing systems

from root penetration, however. Tile and metal roofs are not usually suitable for green roof applications.

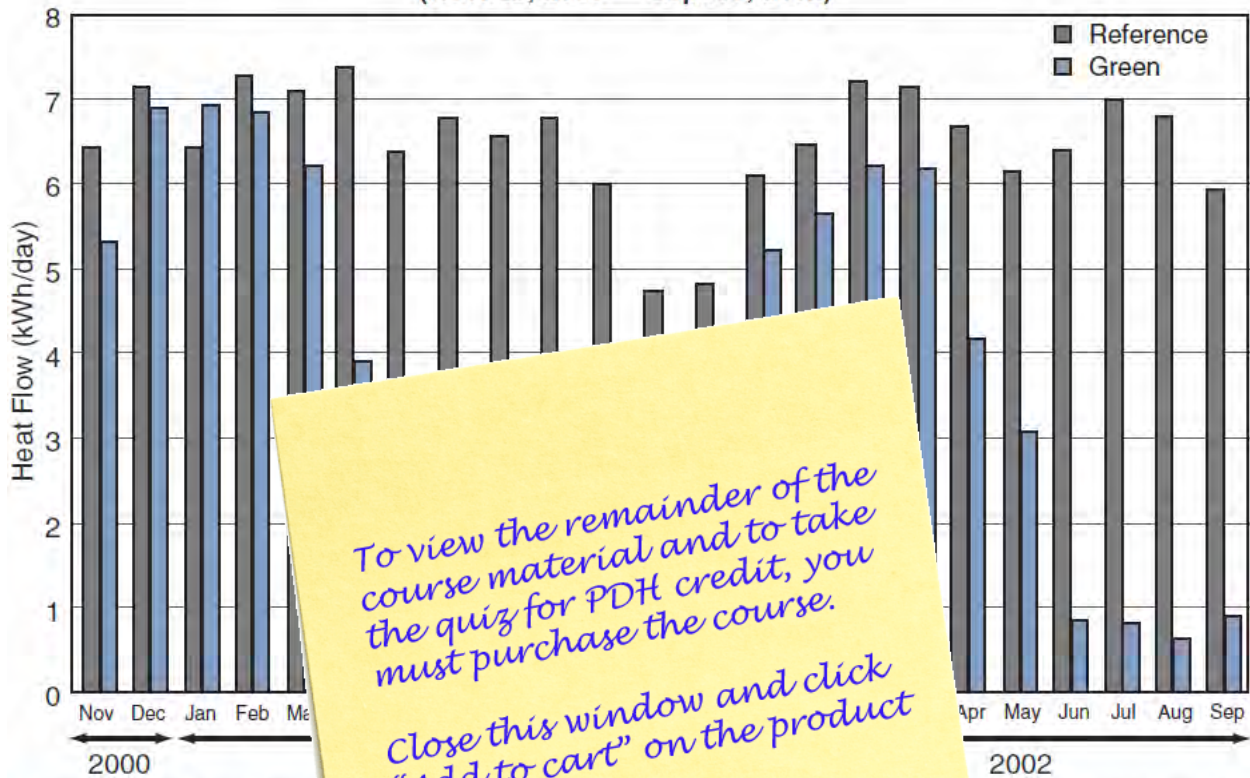
Energy-Saving Mechanism



Heat flow through a gravel-ballasted roof (left) and through a green roof. The added thermal mass of the green roof prevents a large amount of air from escaping through the roof system. (Source: A. Dür, *Roof Greening; An Ecological Balance*, 1995; reprinted with permission)

Green roofs represent a unique, unconventional approach to increasing the energy performance of buildings through shading, insulation, evapotranspiration, and thermal mass. Measurable direct benefits are lower roof surface temperatures and reduced heat transfer through the roof, which reduce peak air-conditioning and energy demand. These energy-saving properties are different in summer and winter.

Average Daily Heat Flow Through Roof Systems
(Nov. 22, 2000 — Sep. 30, 2002)



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Measurements of heat flow of the reference roof in spring

significantly less than that

Summer energy savings. Green roofs reduce the heat gain through the waterproofing membrane, thereby shading the roof surface. From March to November, a change in the plants use the energy in sunlight and water in the soil. Plants or green roofs prevent the surface of the roof from absorbing the sun's heat energy. This has a direct impact on the temperature of the indoor air immediately beneath the roof. The plenum heat gain is reduced, and energy demand for space conditioning is correspondingly reduced.

As plants take up water from soil and transport it through their leaves to the atmosphere (transpiration), water also evaporates from the soil's surface and leaves. The total water loss—evapotranspiration—helps to effectively cool ambient air temperatures at roof level. This has a significant impact on mitigating the urban heat island effect.

Winter energy savings. In winter, plants are dormant, and neither photosynthesis nor evapotranspiration take place. During this season, the thin vegetation layer of an extensive green roof adds thermal mass and provides a barrier that prevents some of the warm air from escaping