Stormwater Best Management Practice

Green Roofs

Minimum Measure: Post Construction Stormwater Management in New Development and Redevelopment
Subcategory: Innovative BMPs for Site Plans

Description

Green roofs are a green infrastructure alternative to conventional roofs that reduce stormwater discharge and provide a wide range of additional environmental and aesthetic benefits. Through integrative design approaches, they offer opportunities to maximize the beneficial use of spaces traditionally unused for stormwater management. In contrast to traditional asphalt shingles or metal roofing, green roofs absorb, store, infiltrate, and evapotranspire stormwater. They also serve as thermal buffers for the building's underneath, cooling the buildings during warm weather and insulating them during cold weather. As greenspaces that are often within highly developed landscapes, green roofs can provide habitat for wildlife such as birds and insects and offer aesthetic amenities to building occupants.

If communities implement green roofs widely, the localized benefits of green roofs can add up in important and measurable ways. By reducing stormwater discharges, green roofs also reduce impacts to local waterways by reducing stream scouring, lowering water temperatures and improving water quality. Widespread implementation can also reduce combined sewer overflows (CSOs) in areas with combined sewer systems, potentially preventing the discharge of millions of gallons of sewage into local waterways. Through better thermal regulation, green roofs may not only reduce urban heat island effects, they may also increase the energy efficiency of buildings. This reduces heating and cooling energy use, thus helping to reduce greenhouse gas (GHG) emissions.

Applicability

Design engineers can apply green roofs to new construction or retrofit them onto existing residential, commercial and industrial buildings. Many cities, such as Chicago and the District of Columbia, actively encourage green roof construction to reduce stormwater discharges and CSOs. Other municipalities encourage green roof development with tax credits, density credits or grants. In addition, green roofs can often provide several points toward a Leadership in Energy and Environmental Design (LEED) certification.

Green roofs provide an opportunity to utilize traditionally unused spaces for stormwater management

Regional Applicability

Green roofs apply in all parts of the country, though designers should carefully consider vegetation type and media thickness based on local climate. In climates with extreme temperatures, the thermal benefits of green roofs can make them more financially justifiable for many facility operators. In drought-prone regions, drought-tolerant vegetation is crucial, and greater media thickness can often improve vegetation resilience.

> The multi-agency report *Design Guidelines and Maintenance Manual for Green Roofs in the Semi-Arid and Arid West* contains additional information regarding implementation of green roofs in arid environments.

Urban Areas

Green roofs are ideal for urban areas because they provide stormwater benefits and other valuable ecological services without consuming additional land. To help offset costs and increase adoption of the

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practice, many highly urban municipalities have incentive programs such as grants or reduced stormwater fees. For example, the District of Columbia's green roof rebate program offers a rebate of $10 to $15 per square foot for voluntary installations. The Water Environment Federation's Stormwater Report contains descriptions of the types of incentives available and links to examples.

Stormwater Retrofit

A stormwater retrofit is a practice that design engineers put into place after development has occurred to improve water quality, protect downstream channels, reduce flooding or meet other specific objectives. Green roofs are a useful tool for retrofitting existing impervious areas associated with building footprints. An important consideration for retrofit applications is the load-bearing capacity of the existing roof. Most existing flat-roofed buildings can accommodate the weight of a green roof without structural modifications, but qualified structural engineers should make this determination.

Siting and Design Considerations

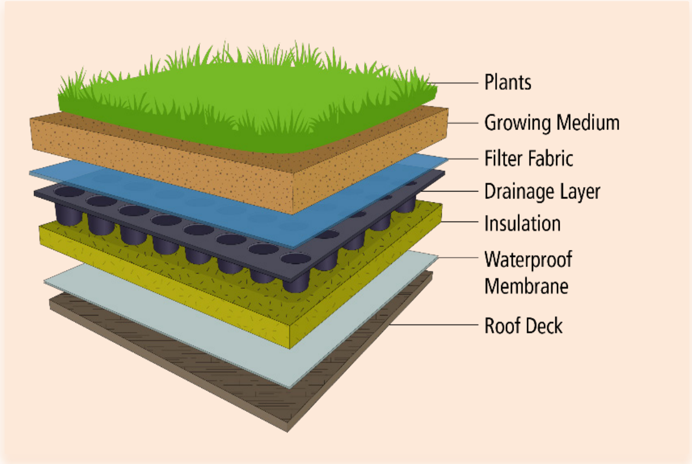
Siting Considerations

Construction staff can install green roofs during initial construction or place them on buildings as part of a retrofit. The following factors determine the amount of stormwater a green roof retains: the surface area of the green roof, the depth and type of growing medium, the slope, and the type of plants. Green roofs are appropriate for industrial and commercial facilities and multi-family residential buildings such as condominiums or apartment complexes. Green roofs can also prove useful for small residential buildings. In all cases, green roofs should be easily accessible and property owners should understand the maintenance requirements necessary to keep the roof functional.

Design Considerations

A building should be able to support the loading of green roof materials under fully saturated conditions and snow loads, if applicable. This load typically ranges from 10 to 40 pounds per square foot but is design-specific (GSA, 2011; MAPC, 2010).

Green roof materials, or layers, vary according to specific types and applications but typically include (from top to bottom) a vegetation layer, an engineered planting medium, a filter mat, a drainage layer and a moisture barrier. Vegetation should be suited for local climatic conditions and can range from sedums, grasses and wildflowers on extensive roofs to shrubs and small trees on intensive roofs. Construction staff can build green roofs layer by layer or purchase them as a complete system. Some vendors offer modular trays containing the green roof components.



Green roof cross section showing typical material layers.
Based on USEPA's diagram of The Common Green Roof Layers

Design Variations

Green roofs include extensive, semi-intensive or intensive design variations (GSA, 2011; MDE, 2009; Tolderlund, 2010). The design selection depends on the loading capacity of the roof, the project budget, local climate and design goals such as the desired volume of stormwater retention. Generally, extensive green roofs have 6 inches or less of growing medium, whereas intensive green roofs have more than 6 inches of substrate. Semi-intensive green roofs are a hybrid between intensive and extensive green roofs, where at least 25 percent of the roof square footage is deeper than or shallower than the 6-inch threshold. Extensive green roofs provide many of the environmental benefits of intensive green roofs but are very low-maintenance and do not typically allow for public access. Engineers generally design semi-intensive and intensive green roofs for the public or building tenants to use as parks or relaxation areas. However, these green roofs require greater capital and maintenance investments than extensive green roofs. Intensive green roofs are particularly attractive for developers, property owners and municipalities in areas where land prices command a premium and property owners want to provide park-like amenities.

Limitations

In most climates, green roofs should include drought-tolerant plant species. In semiarid and arid climates, it can be a challenge to keep plants alive in a green roof shallower than 4 inches (Tolderlund, 2010). Therefore, developers typically prefer semi-intensive or intensive green roof systems in these climates. In arid regions, supplemental irrigation is sometimes a necessity.

Structurally, the roof slope and the load-bearing capacity of the building may limit green roof design. Roof slope should not be too steep, as steeper slopes can promote overland flow, uneven drainage or rapid drying of uphill portions. Although sources often cite 30 degrees as a maximum slope, design engineers should exercise caution when considering any slopes that are not flat. In new construction, engineers should design buildings to manage the increased weight associated with a saturated green roof. When designing green roofs for existing structures, engineers should take the load restrictions of the building into account.

Green roofs can also entail greater capital costs than conventional alternatives. In recognition of this possible barrier to adoption, a number of large cities have some type of incentive program to reduce upfront costs.

Maintenance Considerations

Immediately after construction, property owners need to regularly monitor green roofs to ensure that vegetation is healthy. During the first season, owners may need to water green roofs periodically if precipitation is insufficient. After the first season, property owners may only need to inspect and lightly fertilize extensive green roofs approximately once per year. Property owners need to maintain intensive green roofs like any other landscaped area. Maintenance may involve gardening and irrigation in addition to general roof maintenance.

Green roofs are less prone to leaking than conventional roofs. In most cases, detecting and fixing a leak under a green roof is no more difficult than doing the same for a conventional roof. Still, a qualified professional should use proper construction techniques and conduct leak testing before planting occurs. Many green roof guidance documents—including this General Services Administration report—provide helpful descriptions of leak detection methods, including flood tests and low-voltage leak detection.

Effectiveness

Green roofs can effectively reduce peak flows associated with storm events, reduce the total volume of stormwater discharge, and reduce the export of some pollutants often associated with traditional roofs. In a literature review of studies across climate and design types, Akther et al. (2018) found that green roofs had stormwater retention rates of at least 80 percent for small storm events but highly variable stormwater retention rates for larger storm events. In a review of green roof hydrology, Li and Babcock (2014) found that green roofs can reduce total stormwater volume and peak flow rates by around 30 to 90 percent and capture greater portions during smaller rain events prior to media saturation. Through exploratory modeling of the combined sewer system of New York City, Rosenzweig et al. (2006) also showed that a 50 percent adoption of green roofs across the sewershed would reduce total stormwater volume by up to 10 percent.

The ability of green roofs to address pollutant loading to downstream waters is mixed. As precipitation tends to be low in nutrients, green roofs often need fertilization to support healthy vegetation. When property owners fertilize green roofs excessively or outside of the growing season, green roofs may release nutrients, including nitrogen and phosphorus. Proper fertilization, combined with the ability of green roofs to reduce the total volume of stormwater, mitigates these effects. Still, in a study comparing the water quality of green roof and conventional roof discharges, EPA concluded that, if possible, property owners should direct green roof discharges to another green infrastructure practice for nutrient management and not discharge directly to a receiving water (U.S. EPA, 2009). However, green roofs have a clearer advantage over conventional roofs when it comes to toxic pollutants, as conventional roofs often produce discharges containing heavy metals and polycyclic aromatic hydrocarbons (Van Metre & Mahler, 2003).

Cost Considerations

Green roofs generally cost more to install than conventional roofs. However, they can be cost-competitive over their full life cycle when considering factors such as stormwater benefits, increased life span, increased energy efficiency and improved real estate value.

The life span of a green roof is generally similar to, if not better than, a conventional roof. For example, an extensive green roof can last around 25 years, which may be twice the life span of a conventional roof (Kosareo & Ries, 2007). This increased life span can often justify the high installation cost.

The size and type of a green roof influences its installation cost, with larger installations costing less per square foot than smaller installations, and extensive systems costing less than deeper, intensive systems. Compared to conventional roof installation costs of around $10 to $20 per square foot (Niu et al., 2010), green roof material costs are fairly low—with materials costing between $1 and $3 per square foot—but green roofs are labor-intensive to install and require a crane to lift materials to the roof, which can cost between $4,000 and $5,000 per day. Sources often cite the total cost of a green roof as $15 to $35 per square foot, with cost per square foot decreasing as size increases (GSA, 2011; RSMeans, 2019), though costs can be as high as $60 per square foot (Tolderlund, 2010). Maintenance costs for green roofs vary over time, and costs are initially higher to establish the vegetation. After the first 5 years, maintenance costs are typically between $0.10 to $1.00 per square foot per year (MPCA, 2020).

To capture the true cost of green roofs, including monetizable benefits, several studies have performed life cycle costing or net present value (NPV) assessments comparing the cost of traditional roof installations to green roof installations. Although the range of benefits varies between studies, most authors found net economic benefits for green roofs, especially for green roofs on larger buildings. A life cycle assessment by Blackhurst et al. (2010) found that green roofs may not be as cost-effective on individual small, residential single family homes, but multi-family and commercial building green roofs are competitive when considering social benefits like reductions in the urban heat island effect, GHG emissions and stormwater treatment. Using NPV and incorporating air quality, energy savings and stormwater reduction benefits, Niu et al. (2010) found the NPV of green roofs to be 30 to 40 percent less than conventional roofs over a 40-year lifetime. Additionally, GSA (2011) developed cost-benefit models for green roof implementation on commercial and institutional buildings ranging in size from 5,000 to 50,000 square feet. Using national averages as well as cost figures specific to the District of Columbia, GSA (2011) found that accounting for reductions in stormwater, energy use and GHG emissions was generally enough to balance out installation costs, and green roofs offer a significant cost advantage when considering real estate and community-based benefits.

Additional Resources

- What is Green Infrastructure?
- What is EPA Doing to Support Green Infrastructure?
- Green Infrastructure Modeling Tools
- Green Infrastructure Design and Implementation
- Green Infrastructure Funding Opportunities
- Tools, Strategies and Lessons Learned from EPA Green Infrastructure Technical Assistance Projects
- Managing Flood Risk with Green Infrastructure

Additional Information

Additional information on related practices and the Phase II MS4 program can be found at EPA's National Menu of Best Management Practices (BMPs) for Stormwater website

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