

The Greenwich (Connecticut) Academy's extensive garden roof was completed in 2002. The project, by Skidmore, Owings and Merrill and landscape architecture firm, Brown & Sardina, covers 1626 m² (17,500 sf).

Construction The Specifier

All Photos courtesy American Hydrotech Inc.

Planning & Specifying

a Garden Roof

by Wyndham B. Wood

Known also as green or eco-roofs, garden roofs have been praised for their ability to manage stormwater, mitigate the urban heat island effect, reconnect people with nature, and lower employee absenteeism by giving stressed employees a place to relax. Green roofs have even been credited for helping heal patients in healthcare facilities and providing food for university students.

Given these benefits, it is unsurprising garden roofs are showing up on projects such as the Seattle (Washington) Civic Center, the Gap Headquarters (San Bruno, California), Montreal, Canada's *Complexe Guy Favreau*, and many others.

Though viewed as an emerging trend in North America, green roofs have a long and established history. Considered one of the Seven Wonders of the World, the ancient Babylonians installed elaborate vegetated roofs in the Hanging Gardens' terraced structures, which were built around 500 BC. Early 20th Century installations include three New York City projects—Madison Square Garden (1920s), the Rockefeller Center (1930s), and Frank Lloyd Wright's Guggenheim Museum (1950s).

Times have changed since then, as have green technologies. As gardens continue to stake their claim on our rooftops, many architects/engineers (A/E) scramble to figure out how they should be designed, specified, and built. While current

technology allows for more efficient, lighter-weight garden roofs, it is not always clear when to use which technology, how to compare different systems, and what language should define the benefits of a green roof to an owner.

Single-source systems

Several important factors are to be considered when evaluating garden roofs. First, a green roof system should come from one single source; that is, a single provider offering components engineered to work together. Compiling individual components from different, isolated manufacturers is a potentially risky proposition that takes more time to design and build. Single-source systems should be warranted by one provider, who should also be able to give the A/E technical support from conception through construction. This warrantor should also have an established history of working with experienced contractors who know the systems involved, and have been installing the manufacturers' products for years.

Most single-source providers offer garden systems in two variations to accommodate different needs and roofs.

1. Extensive roof systems are low maintenance, non-recreational with lower soil depths, and are usually planted with hardy, colorful members of the *Sedum* genus. While most green roofs benefit from irrigation during the first year of establishment, extensive gardens do not typically require long-term irrigation systems.
2. Intensive garden roofs have deeper soil beds and accommodate a range of vegetation, including large bushes and trees. These systems require regular maintenance, and can also be used as recreational areas (*i.e.*, walking parks, golf courses, soccer fields).

First things first

A critical component of any garden roof is the waterproofing, which should be durable enough to safeguard the structure over time with minimal maintenance. The ideal choice is a membrane that performs optimally in a water-saturated environment—typically a fluid-applied, rubberized asphalt waterproof membrane. Since these fluids are applied directly to the substrate, they are seamless and, consequently, better able to withstand the garden roof's inherent slow-moving/ponding water.

In horizontal applications, rubberized asphalt membranes are often installed in fabric-reinforced assemblies. These systems can be as thick as 5 mm (0.215 in.), and typically consist of a spun-bonded, polyester reinforcing sheet sandwiched between two thick layers of rubberized asphalt membrane. The combination of fabric reinforcement with a second layer of fluid-applied

membrane creates a 'bulletproof' waterproofing assembly that can withstand large volumes of water over decades.

In addition to being seamless, these membranes require virtually no maintenance—an important consideration because some vegetation does not survive being uprooted. This also lessens the time and money required for long-term preservation.

Alternatively, some green roof systems use modified bitumen (mod-bit) sheet waterproofing, which is installed above the insulation. Though frequently used for blacktopped roofs, some question placing so many seams under a vegetated roof, as it requires constant moisture. Any water seeping through the seams between the mod bit sheets and insulation will find its way down to the substrate, producing leaks whose origins are difficult to pinpoint and expensive to repair.¹

Most green roof systems incorporate a barrier to protect the waterproofing from root penetration. For plants with less aggressive roots, a lighter-duty polyethylene sheet may be installed. Typically, the sheets are overlapped 127 mm (5 in.) to make it difficult for roots to grow down between them. Aggressive roots often require a heavy-duty root barrier treated with a mild repelling agent. These sheets are often granulated rubberized asphalt sheets with heat-welded seams creating a continuous protection layer.

Managing the water

The goal of conventional roof systems is to drain water off as quickly as possible. Green roofs, however, need to maintain water within and underneath the growing medium to nourish the plants. As such, excess moisture is channelled to drains only after 'feeding' the vegetation. The process is often referred to as water (or moisture) management, and is the area where technological innovation has made its biggest impact on green roofing. Most single-source garden roof systems use two components to manage water—drainage/retention composites and engineered soils. Both play key roles in managing moisture to keep a green roof green.

Garden roofs have a 50-plus year history in Europe (Germany, in particular), appearing on factories as often as they do on high-end office buildings. They incorporate water management composites that retain moisture for plants and channel excess to drains. One of several important technological advances has been the elimination of the heavy pea gravel drainage layer commonly used in older roofs. This dramatically decreases a system's weight, often by 50 percent. This load decrease may also lessen the time and expense required to build a structure slated to have a garden roof.

A Green Roof Primer

Sometimes, the hardest part is figuring out how and where to begin. Below is a quick-reference guideline to help you in the early stages of a garden roof project:

Design intent

What is the purpose of this garden roof? Will it be pedestrian accessible? When this is the case, the system needs to be intensive, requiring regular maintenance and a structure capable of supporting additional weight.

Waterproofing

As buried applications are difficult to repair or replace, one should specify a waterproofing membrane with a proven performance record in garden roof applications. The membrane should last the life of the building, be fully bonded to the substrate (no seams through which water can seep), and installed by experienced subcontractors. Perhaps most importantly, the entire system—from waterproofing membrane to growing medium—should be warranted through a single source for at least 20 years.

Structural capacity

Although a garden roof system's weight has been reduced by 50 percent (due to lightweight water drainage/retention components), it is still heavy and the structure needs to be designed for additional loading.

Water drainage/retention composite

This is critical to sustain plant life over time. The drainage/retention element should reproduce the natural ground's subsoil's basic elements, drain excess water to prevent fungus growth/root rot, retain water for plants, and provide adequate aeration for the rootzone.

Wind loading

As with its conventional counterparts, a garden roof must be able to withstand wind loading. While ASTM International is currently developing standards addressing this issue specifically for garden roofs (See *Green Roofs and Emerging ASTM Standards*, page 72), a host of other standards provide wind-loading guidelines. These include:

- *FLL Guidelines*

- FM Global: FM Loss Prevention Data Sheet 1-28, *Wind Loads to Roof Systems and Roof Deck Securement*, and FM Technical Advisory Bulletin 1-29, *Loose-Laid Ballasted Roof Coverings*

- American National Standards Institute (ANSI) and American Society of Civil Engineers (ASCE), such as ASCE 7-95, *Minimum Design Loads for Buildings and Other Structures*.

An experienced garden roof manufacturer should also offer wind-loading guidelines.

Fire resistance

Fire resistance guidelines are also available from Underwriters Laboratories (UL) Inc. 790, *Tests for Fire Resistance of Roof-Covering Materials*, the International Conference of Building Officials (ICBO) and FLL. Again, experienced garden roof manufacturers should recommend guidelines and certifications.

Slope

Typical garden roof systems are designed for a maximum slope of 51:300 mm (2:12 in.). Extensive systems can handle steeper slopes, although battens and restraints are required for loose-laid components. Also, steeper garden roofs require soil erosion control measures.

Detailing

Vegetation-free (VF) zones should be installed at all roof flashings, drains, and joints for increased fire resistance and protection against wind loading. VF zones are hardscape areas—typically gravel or architectural pavers—installed in a strip measuring 457-mm (18-in.) wide. Standard protected membrane roof drains with extension collar and clamping ring can be used in shallower, extensive assemblies, while inspection chambers are recommended for drains in deeper, intensive gardens.

Maintenance

While extensive systems require minimal maintenance (some as little as one annual weeding/watering), intensive systems require regular maintenance including mowing, weeding, watering, and fertilizing. ♡

Some U.S. systems based on German technology incorporate these lightweight water management composites. Resembling an egg carton, one material made of recycled polyethylene retains water in its cups, from which plant roots drink. Weep holes located on the plains between the cups drain excess water and aerate the roots.

The water held in the cups of these retention/drainage composites creates a moist, beneficial subsoil environment for the plants. The presence of moisture beneath the soil allows for a daily ebb and flow of water vapor rising from the cups into the soil. During the day when the soil heats up and plants transpire water through their leaves, more water from the composite's cups evaporates upward. When the soil cools at night, the same water vapor condenses to become capillary soil water available to the vegetation.

Though a slow process, this moisture transfer is important to a garden roof's long-term viability. Natural soil systems benefit from the active transfer of water to the roots via capillary action, thanks to a continuous pathway through the subsoil to the rootzone. As there is no actual subsoil on a green roof, this water reservoir (and the resulting moisture transfer) becomes that much more important to sustaining the vegetation. In essence, these water management composites act as subsoil irrigation, nourishing the plants from underneath.

Some newer water management composites on the market have a root barrier adhered to the top side of the water drainage/retention composite. While convenient from an installation standpoint—a two-in-one deal, of sorts—the root inhibitor layer's placement above



Before the 'lawn' is ready, one of the most important components of a green roof system is the waterproofing membrane. It must remain watertight and resist the forces exerted upon it by plant roots.



the cups prevents roots from growing down into the reservoirs. Unlike most garden roof systems, which place the root barrier directly above the waterproofing, these newer composites prevent any direct contact between the water and the roots, thereby limiting the composite's function and amount of nourishment provided to the roots.

Dirt is a four-letter word

Due to their unique nature, garden roofs require special growing media—ideally, engineered soil tailored to each specific application. These soils are unique in several ways. Ordinary ground soil (essentially, dirt) is very heavy because of its high clay content. This material compacts on a garden roof and holds excessive moisture, preventing aeration at the rootzone and creating an environment that encourages fungus growth and root rot.

Soil engineered for a garden roof weighs far less than ordinary ground soil, thanks in part to the inclusion of a lightweight mineral such as expanded shale, pumice, or scoria. These components are then blended with the appropriate percentages of sand and organic matter. The overall mixture should demonstrate a balanced pH, drain well and be capable of holding nutrients and moisture. The goal, of course, is to create a balanced environment that ensures the roots have enough moisture without being oversaturated. The right soil mixture, working in concert with the appropriate water management composite, also provides proper root aeration, allowing them to 'breathe' without ever being exposed to

inhospitable, dry air.

Increasingly, reputable garden roof manufacturers are engineering and marketing their own soil blends, designed for extensive and intensive garden roofs in different climates. Due to the specialization required for garden roofs, many manufacturers also employ soil and plant experts to help A/Es planning garden roofs.

Plant selection

A well-designed garden roof sustaining itself over time should adhere to the principles of good ecological design. Appropriate plant selection is an important part of this process. Vegetation should be chosen first and foremost for its ability to thrive in the local climate, withstand the harsh conditions of a roof and mimic the surrounding landscape's structure, function and diversity. Garden roof vegetation should also be sustainable, not having to rely on fertilizers, irrigation, or maintenance.

Plant diversity is important to a garden roof's long-term potential. To get the most out of the seasons, early- and late-flowering species should be planted along with annuals and long-living perennials. Mixing in shallow-rooted wildflowers with deeper, fibrous-rooted grass-like vegetation helps encourage long-term plant viability. Garden roof vegetation needs to resist direct radiation, drought, frost, and strong wind conditions. Again, native plants are often the most favorable choice.

System benefits

Regardless of a garden roof's technical aspects, one has to

Green Roofs and Emerging ASTM Standards

The ASTM International Green Roof Task Group, a division of subcommittee E06.71 on building sustainability, explores standards dealing with green roofs and its medium in relation to density, porosity, and water retention. ASTM WK 575, *Practice for Assessment of Green Roofs*, for example, proposes a procedure for assessing systems through technical requirements and sustainability considerations. While many requirements may be satisfied by related existing standards, some unique issues (*i.e.* fire safety) still need to be addressed.

- ASTM WK 4235, *Standard Guide for Selection, Installation, and Maintenance of Plants for Green Roofs*, identifies flora considerations in extensive/intensive green roof systems.
- ASTM WK 4236, *Standard Practice for Determination of Dead Loads and Live Loads for Green Roof Systems*, provides a procedure for predicting green roof weight. It includes loads associated with non-absorptive plastic sheet components, fabrics, synthetic drainage mats, substrate, granular drainage media, retained water, and transient moisture in the drainage layer. (The procedure excludes loads associated with waterproofing.)
- ASTM WK 4237, *Standard Test Method for Water and Media Retention of Synthetic Drain Boards for Green Roofs*, is applicable to synthetic sheets retaining water/media in cup-like receptacles on their upper surface.
- ASTM WK4238, *Standard Test Method for Maximum Substrate Density for Dead Load Analysis of Green Roofs*, helps estimate maximum dead load for green roof assemblies, and measures the moisture content and hydraulic conductivity. It is suitable for substrates containing less than 30 percent organic material as measured using the loss on ignition procedure A in ASTM F 1647-02, *Standard Test Methods for Organic Matter Content of Putting Green and Sports Turf Root Zone Mixes*. (The maximum substrate density and associated moisture content measured in this procedure apply to drained conditions near the saturation point.)
- ASTM WK 4239, *Standard Test Method for Saturated Hydraulic Conductivity of Granular Drainage Media [Falling-Head Method] for Green Roofs* is intended for coarse-grained materials where 100 percent is retained on the US#8 sieve.

Those wanting to become involved with ASTM work on green roofs should contact the task group chair, Michael Gibbons, FCSI, CCPR, at michael@architecturalsystems.org. ♥

consider how it benefits an owner and/or his building.

The decision is usually based on cost. Garden roofs are initially more expensive than traditional systems. However, both short- and longer-term owners reap rewards in several important ways. Early in a building's life, the owner profits from increased property values, and in the case of intensive garden roofs, added usable space. Owners can often charge higher rents, particularly when a garden roof is accessible to tenants or visible from interior spaces.

In addition to the above, long-term owners gain from improved building performance, including energy efficiency. The water management system helps insulate the interior from temperature extremes, thereby reducing heating/cooling demand. It also minimizes noise transmission to create a more peaceful and productive environment, and protects the waterproofing membrane from mechanical and ultraviolet (UV) degradation, which may extend the life of the roof beyond 40 years. As a result, the owner saves thousands of dollars in roof replacement expenditures.

Other advantages make garden roofs solid investments, though in less obvious ways. In high-stress environments (*i.e.* corporate headquarters), employees can visit a garden roof to take a break from the daily grind, which may improve their health and decrease employee absenteeism, saving companies thousands of dollars annually.

Given these factors, a green roof's long-term financial impact is highly beneficial, particularly in a building designed for energy efficiency. While the return on investment (ROI) for different buildings varies, one principle is universal—a long-term owner will spend less on building operation and maintenance over time than on a comparable building without a garden roof.

The urban roast

Some of the system's best-publicized garden roof benefits are those with a larger impact on the structure's surrounding environment. Green roofs directly address two major environmental issues: the urban heat island effect and stormwater management.

Heat island effect

The heat island effect is the term used to describe the ambient temperature rise in cities during the summer months. Hotter cities require more power to keep

things cool, and temperature spikes have added annual power costs of approximately \$40 billion across the country. Studies attribute these higher temperatures to the dark, heat-absorbing hard surfaces (*i.e.* asphalt paving and blacktopped roofs) dominating the urban landscape. Computer simulations and other research methods reveal lowering city temperatures by a few degrees could save \$100 million annually.

Increasing the amount of green space in our cities can minimize heat island effects. Evapotranspiration (water loss from the soil both by evaporation and plant transpiration) can cool the surrounding air, which mitigates smog and lessens demand for cooling. Roofs are available, open spaces, which is why garden roofs are heralded as an important solution to the urban heat island problem.

Running off the roof

Adding to the push toward green roofs is another major issue—stormwater management. In some areas, stormwater runoff from roofs contaminated with pollutants is channelled to natural bodies of water where local ecosystems are put at risk. Garden roofs offer a convenient and productive method for exploiting this runoff. A system equipped with a comprehensive water management system—drainage/retention composite plus soil—can retain as much as 90 per cent of the rain falling

upon it. As these roofs get installed on larger stretches of commercial roof acreage, stormwater management expenditures should decrease dramatically.

The future looks green

Sustainable building programs, such as the U.S. Green Building Council's (USGBC's) Leadership in Energy and Environmental Design™ (LEED) certification, help A/Es pursue sustainable design. Garden roofs employing modern water drainage/retention technology can qualify for more than 10 LEED credits, so owners wishing to achieve certification should seriously consider what they choose to put overhead.

While definitions of 'green' and 'sustainable' are still being worked out, industry stakeholders unanimously agree we should be doing more to clean our air and water, improve our quality of life and reintroduce some much-needed balance into our cityscapes.♥

Notes

¹ The extent to which a mod-bit sheet system's seams are vulnerable is the direct result of quality workmanship in the field. When seams are perfectly treated during installation, the building may remain watertight. Any substandard work, however, increases the potential for failure. Since garden roofs are buried applications, this can be a risky venture.

Additional Information

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Abstract

Aside from reconnecting people with nature in the heart of the city, the benefits of having green space atop a building's roof range from stormwater management to fighting the

urban heat island effect. The specification of a garden roof system requires a thorough understanding of wind resistance, waterproofing strategies, and even floral species.