COMPOST USERS FORUM

Paul Mankiewicz of the Gaia Institute (inset photo leading a tour) collaborated with the Simon Stock School in the Bronx to install a green roof (left), both as an educational opportunity and to evaluate various plant species and a planting media sourced from local recycled materials.

Rethinking The Green Roof

Future benefits include grey water recycling, tiered building design and optimizing substrate composition as green roofs continue to advance in popularity.

Jeannette Compton

GREEN ROOFS are ever more present in the collective public consciousness, especially among those involved in green industries and composting. With such cities as Chicago, Portland (Oregon) and Toronto implementing initiatives, green roofs are receiving media attention, and government promotion. Perhaps it is a green roof's ability to provide both ecological and economic returns simultaneously that has helped to propel them.

Green roofs can hold storm water, preventing its entry into sewage systems, where it can reduce treatment efficiency, overload treatment plants and cause raw sewage discharges. Once this water is absorbed into the green roof substrate, it is used by plants on the roof for evapotranspiration, cooling the roof and the building below it. Beyond the hydrological functions of a green roof, the substrate and plants shade and protect the roofing membrane, prolonging its life by preventing extreme temperatures and temperature fluctuations. A green roof can create open space where it is at such a premium.

In North America, studies on green roofs have increased dramatically over the past decade, characterizing and quantifying green roof functions and benefits. Much of the research examines specific roofs and a variety of factors such as storm water capacity, runoff, media composition, and ideal plant species. Storm water retention rates can vary depending on rainfall patterns, media depth, and season.

In general, smaller storms can be contained completely, while larger storms exceed the media's water holding capacity and produce runoff. Yet this volume is reduced and the peak flows are delayed in comparison to a traditional roof, alleviating the burden on storm water treatment facilities and infrastructure. Runoff quality has also been examined, with mixed results. Some believe that green roofs have no impact on runoff content while others worry that nutrients within the substrate may be leached out, citing high organic content as a potential factor.

Another means of impacting water holding capacity is the substrate design. The ability to support plant growth and retain high volumes of water must be contained within a lightweight engineered soil. Testing to optimize and strike a balance between all of these factors has yielded a variety of proprietary media and other products. The combination of these lightweight shallow soils and drought-tolerant plants has become the most prevalent green roof system seen today. Due to variable rainfalls and periods of drought in conjunction with shallow substrate, plants on green roofs must be incredibly hardy.

A Test Roof In The Bronx

Much of the testing of green roofs has been centered on characterizing the basic parameters of shallow, free draining, engineered substrate planted with drought tolerant succulents. This reflects a common approach found in Europe, and has been the standard in North America as well. Yet, little work has begun on expanding this basic approach. The means by which green roofs are designed, namely loading capacity and maintenance concerns, cause prioritizing in direct contradiction of the benefits green roofs are expected to provide. The drought tolerance of preferred plant species in turn reduces their ability to evapotranspirate large volumes of water to cool the building. And the growth limiting environment that eliminates most species thus reduces the roof's ability to strive towards biodiversity and aesthetics. Beyond designing roofs to improve their functioning, green roofs can begin to espouse more ecologically minded design, such as incorporating products from the waste stream in their production, sourcing local materials, and incorporating native plants.

Many of these issues influenced the design of a green roof at the St. Simon Stock School in the Bronx, New York. With collaboration between the school and Paul Mankiewicz of the Gaia Institute, and funding from the Bronx Borough Office of Overall Economic Advancement, the roof was installed in June 2005. Many aspects of this roof were unique. One obvious characteristic would be its placement on a school, providing myriad educational opportunities beyond the ecological and economic ones attributed to all green roofs. But the design of the green roof itself was unique, with unusual substrate, plant selection, and research conducted.

Dr. Mankiewicz developed a green roof soil based on reusing waste stream products 20 years ago, long before green roofs began to gain popularity. Beginning with shredded recycled polystyrene modified to improve water holding capacity and cation exchange capacity, this was mixed with clay and compost to create a incredibly light weight growing media. The soil not only met the requirements of a green roof media, but also removed polystyrene and organic matter from the waste stream and placed it in an ideal use. The inability of polystyrene to break down in landfills makes it an ideal candidate for a green roof, as some green roofs have lasted over 30 years. The production of the media can be completed within an urban area, reducing transportation costs and eliminating high embodied-energy products such as expanded shale, often found in green roof substrates. The roof at St. Simon Stock proved to be the first installed testing of this media. The substrate is used with top layers of straw matting and compost, mimicking the horizons common to *in situ* soils.

With such an innovative substrate, it stands to reason that the plants used might be unexpected as well. Plant selection was based not only on drought and sun tolerance, but also native status, ability to attract birds and insects, and educational value to the school. Currently in its second year, the roof has vines growing up its fences, ferns in shadier portions, and columbines blooming. While this system is free draining, the upper layers of compost and mulch retain moisture and the depth of six inches increases the length between rainfalls needed to sustain the plants. Future possibilities include irrigating the roof with grey water from the school's bathrooms to simultaneously encourage plant growth, cooling through evapotranspiration (ET), and a reduction in the school's contributions to the city sewer system. Testing on how to further improve these functions was also conducted on test plots within the roof.

Quantifying Plant And Roof Functions

While the overall design of the green roof was innovative in comparison to existing green roof practices, test plots on the roof explored further possibilities. Deviating from a free draining system, small bins were buried in the roof to test the characteristics of a green roof that retains storm water to the full capacity of the soil. The native plants selected to use in this trial met different criteria than most green roof plantings, possessing both drought and flooding tolerance, salt tolerance, and an ability to evapotranspirate high volumes of water when it is available. Testing of these bins examined water retention and loss through the plants, water holding capacity, plant growth, and a comparison of the new soil to a more common engineered green roof soil. Preliminary findings suggest much potential in movement towards this type of green roof design.

In a randomized plot design, the new soil was used in half of the bins, and the other half were filled with an expanded shale/compost/perlite blend. Half of these bins were planted with a salt marsh grass, *Spartina,* and the other half with a goldenrod, *Solidago,* such that the plants were evenly distributed between the different soils. Installed in June 2005, the plants established during a period of adequate rainfall. After this period, measured volumes of water were applied to each bin to test both the water holding capacity of the bin and the rate at which the plants could utilize water for ET. The results suggest that a nondraining system could retain a two year return frequency storm, most of which would drain through a thinner green roof substrate. Due to the ability of the plants to tolerate standing water and utilize this water at faster rates than *Sedum spp.,* this system was able to utilize all standing water within four days.

Native plants used in the trial possessed drought, flooding and salt tolerance, and an ability to evapotranspirate high volumes of water when it is available.

ET rates lowered as water availability decreased, but still remained higher than published data on more standard green roofs with thinner substrates and *Sedum spp.,* despite these systems being irrigated more frequently. The plants' tolerance of standing water allows a "reservoir" of water to be stored within the soil rather than drain into sewer systems, decreasing the need for frequent rain events to sustain the plants. In addition, the increased rates of ET during periods of flooding allows for quick recovery from rain events, indicating that such a system could tolerate high volumes of rainfall in succession. Aside from the optimized function of the green roof's ability to retain storm water and cool the roof through ET, a nondraining system eliminates concerns over leachate quality, allowing for increased organic matter content within the substrate. While this system is in preliminary testing, it indicates that alternatives to the current design of green roofs may provide greater economic returns as well as ecological functioning.

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Weight loading on green roofs is always of concern, and often becomes a limiting factor in the design of roofs requiring low volumes of substrate and thus limiting plant selection. Consequently, green roof substrates are designed to be as lightweight as possible while supporting plant life. Table 1 shows densities of the two substrates tested, in both dry and saturated conditions. While extensive green roofs often look to attain loading rates in the range of 10 to 20 pounds per square foot, the rates in Table 1 indicate two important factors. Water increases the loading of a soil dramatically, showing how substrate composition alone is not indicative of loading rates. Beyond the variability by water levels, the polystyrene-based substrate is considerably lighter, with similar densities at saturation to an expanded shale based substrate without water. By reducing the loading of the substrate, more water can be held on a green roof to support plant growth.

Future Research Possibilities

This test roof serves as only one possibility of the ways in which green roof performance can be improved. While there exist many applications for green roofs, and variation in design parameters ought to dictate how these roofs are designed, an overall shift in focus from design limitations to design possibilities would benefit the entire process. In cases of retrofits or no-maintenance needs where the volume of soil, plant species and water loading restrain the possibilities of design, shallower soils and highly drought tolerant plants will still provide benefits to a building owner, and in many ways improve upon a black tar roof. However, when greater flexibility exists, the potential to expand upon existing green roof design to improve function and benefits certainly exists.

Further research on how to optimize for this is necessary in plant selection, substrate composition, and performance in comparison to weather data. Expanding what green roofs are capable of and incorporating them into building design also has great potential.

Green roofs can become better integrated within the entire building design, to optimize how they supply benefits to the building. This may be achieved in grey water recycling, tiered building design, or any number of ideas yet to be proposed. Green roofs have already advanced in their popularity and abilities, and their only limit is the imagination of those who design them. ■

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