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Designing the Green Roofs of the New Horticultural Center

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Abstract:

The addition of two new Green Roofs at the Morris Arboretum provides a canvas to showcase sustainable and functional storm water management for the community. By visiting surrounding area Green Roofs, I have designed both a functional and aesthetically pleasing rooftop garden that will mitigate storm water runoff and showcase both native and water-wise plants that can be successfully grown in the Philadelphia area.

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INTRODUCTION

In 2009, the Morris Arboretum of the University of Pennsylvania broke ground on the construction of a LEED certified horticulture center in the Bloomfield Farm section of the Arboretum. LEED stands for Leadership in Energy and Environmental Design and is an accreditation given by the US Green Building Council to construction projects that successfully integrate a variety of environmentally conscious and energy saving resources.

Among a variety of environmentally-conscious elements designed by Andropogon Associates, Ltd, landscape architects of Philadelphia, the creation and installation of two separate “green” roof structures (also referred to as “eco” or “bio” roofs) were added into the design. These roofs, while an important component of the Arboretum’s LEED accreditation, are also part of the national trend in the United States to adopt green roof technology from European countries where it has been perfected over the past few decades.

My 2009-2010 internship project was the horticultural design and planting of both of these roofs.

HISTORY

Over the course of human history, the concept of the "green" roof is nothing new. Technically speaking, the famed hanging gardens of Babylon were our very modern idea of a green roof; planted terraces of each successive level formed the rooftops of the rooms below[1]. Indeed, ancient civilizations seemed to understand the environmental benefits of green roofs: evidence of grass planted roofs in countries such as Scandinavia, Canada, and Iceland insulated inhabitants from freezing temperatures and even now the indigenous peoples of Tanzania "cover their huts with soil as a shield against the searing heat"[23]. In Europe, wine and beer storage cellars were built into layers of earth to balance temperature fluxes to keep spoilage at a minimum[4]. These acts of architecture were deliberate and intended to use the benefits of planted roofs for human advantage.

Roof greening for human enjoyment and advantage was used again in the 19th century when architects reacted to the massive overcrowding and unhygienic conditions of the city. The structural "breakthrough" of a flat roof "triggered the idea to build roof gardens and terraces en masse to fulfill the [city dweller's] demand for 'light, air, and sun'"[5]. These rooftop gardens were planted with fervor at first, but did not last. To a developer, a flat roof is attractive to build over the then-used sloped roof because it was cheaper. The additional costs of a rooftop garden negated these savings, leading to the modern flat industrial roof with nothing on top but HVAC equipment[6]. As such, roof greening was never embraced in the United States and although the US "was a leader in the implementation of roof greening at the beginning of the 20th century, Europe took the lead in developing green roofs by the end"[7].

In Germany in 1900, a series of roofs were built with wood roofing over laid with tar-board. As a fire prevention measure, these roofs were covered in a thin layer of gravel and sand. Over the lifespan of the roof, vegetation spontaneously colonized the gravel and sand layer. This spontaneous growth on the roofing material attracted the attention of German academics, including Reinhard Bornkamm, the pioneer of modern green roof design[8]. Their study eventually led to the formation of the Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau, or the FLL. Formed in 1975, the FLL was a collaboration of horticulturalists, landscape architects, landscape contractors, and researchers from the German speaking countries who met to "discuss the technical aspects of roof greening"[9].

The birth of the FLL coincided with the rise of the environmental movement in Europe, especially in Germany where the German Green Party was installed in parliament[10]. The battle cry of the German enviro-movement – "Back to Nature" – led to an increase of natural areas, roofs included. This greening of open rooftop space was noticed and German municipalities began to suffer less from storm water overflows and flooding[11] . In 1982, the FLL issued the first of its roof green guidelines and now over forty municipalities all over Germany (as well as other cities such as Toronto[12]) mandate green roof construction[13].

RESEARCH

The first step in my project was to conduct local research on green roof structures. This data included plant lists (both successes and failures), materials used, time frames for planting and blooming, as well as anecdotal evidence from those who had gone through the process before. My data were collected though a series of onsite visits, interviews, and emails and I was at times accompanied by my supervisor, Louise Clarke, as well as the Director of Horticulture and Curator, Tony Aiello.

Though my research I met with or spoke with a number of local green roof horticulturalists and landscape architects. These included John Nysted, the lead Andropogon architect in charge of the horticulture center design, Jeff Jabco who maintains the green roofs at Swarthmore College, Charlie Miller who runs Roofscapes Inc, Vic Piatt who maintains the Scree Garden at Mt. Cuba (The scree garden is an analogous habitat to the green roof and Mt. Cuba has been working on a native planting on a rock outcrop that has been filled with actual green roof substrate – see "Plants of Mt. Cuba"), and Julie Snell the Philadelphia Green Project Manager of the Pennsylvania Horticultural Society who is responsible for tours of the PECO roof in downtown Philadelphia.

The PECO roof holds the distinction of being the area's largest at over 45,000 square feet[14]. Though intensive in certain planting areas (beds as deep as 15 inches of medium), the majority of the planting area is an extensive green roof. I learned that PECO planted their roof with sedum carpets contracted from sedum-mat grower Sempergreen. Outside research has determined that sedum mats are the most economical form of roof greening[15], so it was decided to purchase a sedum mat to cover the extensive roof at the arboretum. This choice was also selected due to the labor saving aspects of pre-grown mats; when installed the mats provide 75% roof coverage instantly with minimal time and labor commitment.

A number of "Green Roof Guides" are also now available on the market for the consumer who wishes to undertake roof greening as a do-it-yourself project. Both *Green Roof Plants* by Ed Snodgrass and *Planting Green Roofs and Living* Walls by Dunnett and Kingsbury provide green roof plant species lists that have been proven effective. Andropogon also compiled a roof species list which they submitted to us as the intended plantings for their roof design. While there were some dubious selections in the Andropogon list (see Appendix A), I used it as a jumping off point to research plant species and to cross reference others against the green roof texts and personal testimony from those I consulted.

Another component of my research consisted of the LEED standards for certification. Adding green roof design features enable building projects to add a number of LEED points to their total depending on a variety of factors, such as water reduction and storm water management. The LEED points awarded to the Arboretum for inclusion of the garage green roofs included Sustainability Sites credit 6.1 and 6.2 (Storm water Design quantity and quality control) and 7.2 (Heat Island Effect, Roof) and Water Efficiency credits 1.1 and 1.2 (Water Efficient Landscaping). The Arboretum was not eligible for Sustainable Sites credit 5.2 (Site Development, Maximize Open Space) because the Arboretum is not providing public access to the rooftops, and therefore the space is not considered "open" to the public. The project is also not eligible for SS credit 5.1 (Site Development, Protect or Restore Habitat) because the construction is not located in a dense urban area[16] (Appendix B).

DESIGN METHOD

My project consisted of two separate green roof structures to design: the four bay garage which is an extensive green roof (meaning 4 inches of substrate growing medium) and the six bay garage which is an intensive green roof (with 8 inches of substrate growing medium). Both of these garages are part of the LEED certified Horticulture Center in the Bloomfield Farm section of the Arboretum.

With the extensive four bay roof designed via Sempergreen sedum mat, my focus turned towards the deeper intensive roof. The extra substrate dramatically increased the palate of plants to choose from, so I began working on a design that would be both aesthetically pleasing and low maintenance.

The final draft of plantings I designed is based on a color block scheme. The roof is divided into sections progressing through the colors: whites, pinks, reds, oranges and yellows, blues and purples. At the ground level at each of these sections is a groundcover (or combination of groundcovers) that respond to the color (for example, in the white section the sedum groundcover selected is *Sedum album* and *Sedum spurium* 'White Form' both of which bloom with white flowers at slightly different times, prolonging the white groundcover blooms). Flowers of corresponding bloom colors are then planted into the groundcover. The effect of this throughout the roof is one of strict categorization and color flow. I also made sure to select a variety of flowers for each section with varying bloom times, to prolong the color show throughout three seasons.

However, this strict flower placement is only viable in the first season of the roof's life. Though the groundcovers were picked to grow and fill the area around them, but not to stray too far from their original planting site, the taller forbs were selected for their fecundity and willingness to grow and set seed. The idea is that each growing season, the once-contained flowers will germinate and move around the color blocks on the roof. This will create a dynamic change on the roof from year to year as the forb placement will shift each season.

This approach also positively impacts the manpower needed for roof planting upkeep. Because the intent is for the flowers to move of their own accord, there is no need to spend time formally replanting the roof year to year. Also, as the roof acclimates to the environment, certain species planted might not survive. Instead of needing manpower and extra plants to fill gaps that did not overwinter, the hands-off approach of the roof will lead to a homeostatic mix of flowers that are able to survive and reproduce each season[17]. I believe that this approach to the roof design will lead to a low maintenance planting, but will still have enough design elements to look well maintained and cared for, and not simply a meadowland planting.

MATERIALS

As stated earlier, the Arboretum purchased pre-grown sedum mats from Sempergreen to cover the four bay extensive roof. These mats were grown in Virginia and contain a mix of various sedum species established in a mat of coconut fiber[18]. The predominant sedum species include: *S. acre* 'Gold Moss', *S. album* 'Coral Carpet', *S. floriferum* 'Weighenstephaner Gold', *S. hispanicum* 'Purple Form', *S. kamschaticum*, *S.* 'Angelina', *S. spurium* 'Red Carpet', *S. spurium* 'Tricolor' and *S.* 'John Creech'[19].

Sedums were also extensively used in the design of the intensive six bay roof, as well. This is because sedums naturally occur in locations that are similar both in climate and geology to rooftop conditions[20] and new professional opinion based on ongoing research is that the quick establishment time of sedums and other smaller groundcovers might actually help the subsequent growth and development of slower growing woodies and perennials[21].

Sedums are actually structurally adapted for arid climates in relatively nutrient poor soil, making them an ideal genus for roof greening. They have "thick cuticles, small cells, small volume of internal airspace, large vacuoles for water storage, protected stomata, and a minimal root system. Up to 95% of the total volume [of a sedum] can be dedicated to water storage"[22]. Sedums also employ Crassulacean Acid Metabolism (CAM) to retain water in high heat and drought. CAM plants open their stomata during the cooler night hours to take up carbon dioxide and do not risk losing water though transpiration[23][24].

Forb species and grasses were purchased as plugs from local vendors, primarily North Creek and Well-Sweep Herb Farm. Though larger pot sizes were available for most selected species, plugs were selected to plant because of the relative adaptability of their smaller sizes. Larger plants grown in the nursery would already be accustomed to the rich potting medium and regular watering schedule of the nursery. Smaller plugs would not be as fully adapted to the nursery culture and would be more likely to survive the transition to the green roof medium and moisture conditions.

The roof media, Rooflite Intensive and Rooflite Extensive MC, was provided by Skyland USA, LLC and vary in composition between the two separate roof applications. However, both mixtures were primarily composed of HydRocks ™ which are inert particles of ceramic that provide water retention in periods of less moisture and sharp drainage in excess moisture events. According to the design specifications, the medium of the extensive roof is a pH of 6.6 and the pH of the intensive medium is 6.1, making both the roofs an alkaline habitat. This was taken into consideration when selecting plants and making design choices.

Primarily, the media differ in available nutrient loads and organic composition depending on the depth of application. The extensive medium measures at 45.75 lb/ft^3 dry and 72.52 lb/ft^3 when at maximum moisture capacity (it is capable of holding 46.3% of its own weight in water before reaching maximum moisture capacity). It is 5.2% organic matter (provided from certified US Composting Council compost) and its nutrient load is 26.5 mg/L of Phosphorus, 192.4 mg/L of Potassium, 40.6 mg/L of Magnesium, and 6.3 mg/L of Nitrate and Ammonium[25].

Conversely, the intensive Rooflite medium measures at 41.64 lb/ft^3 dry and 74.41 lb/ft^3 when at maximum moisture capacity (it is capable of holding 53.2% of its own weight in water before reaching maximum moisture capacity). It is 9.3% organic matter (provided from certified US Composting Council compost) and its nutrient load is 85.0 mg/L of Phosphorus, 471.0 mg/L of Potassium, 85.1 mg/L of Magnesium, and 5.7 mg/L of Nitrate and Ammonium[26].

FUTURE RECOMMENDATIONS

The green roof at the Morris Arboretum provides a great opportunity for research at the University of Pennsylvania. The design and study of green roofs is still a young field in the United States and (although research has been done in Europe) needs to be evaluated on a climate and zone specific level – even the trials and successes in Portland and Chicago cannot be completely applicable to the Philadelphia area.

I have designed a green roof plant tracking template (Appendix C) that I recommend updating monthly throughout the first few years of the roof. As the plants grow, seed, and progress through generations, there needs to be a system of tracking bloom time, general health, and population numbers from year to year. It is also a way to establish data on plants that may not survive after a few generations.

Another application of the species tracking template is the monitoring of species not planted by the arboretum. There is a high probability that there will be seedlings of various local species that are carried to the roof from fauna or wind manipulation. Although I recommend the removal of invasive or aggressive native plants, it is important to document their presence and the time of their arrival. I also recommend a trial period of 'volunteer' plants that are native and non-aggressive that appear on the roof. Though they are not part of the original design planting, seeds that germinate on the roof might provide data for local plants that would otherwise not be considered for green roof situations.

I have also designed a template for the roof itself that I recommend be filled out yearly (Appendix D). This report would not only encompass the plant species on the roofs, but also the analysis of the growing medium, the tracking of herbicide and fertilizer applications and make note of the structural integrity of the roof itself. Penn State provides analysis of green roof growing medium, and I believe it would be prudent to track the availability of nutrients and organic matter over the first few years of the roof to know if fertilization will be needed in the future.

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