Proper Soil Selection For Garden Roofs: A Primer

By Steve Skinner

Green roofs have become increasingly popular over the past several years due to their ability to provide a wide range of sustainability, energy and ecological benefits while often enhancing the aesthetic qualities and architectural creativity of buildings.

Green roof technology replaces traditional rooftops with an assembly consisting of: 1) a waterproofing membrane; 2) an engineered soil support system that includes insulation and elements for critical moisture retention and drainage within the shallow soil profile; 3) a filter fabric to keep soil particles out of the drainage system; and 4) an engineered growing medium and selected plantings. By replicating natural processes, the garden roof becomes a highly self-sustaining ecosystem that can greatly extend the life of the roof's waterproofing membrane, provide insulation that lowers cooling/heating costs, mitigate storm water runoff, and reduce the "urban heat island effect."

If the *heart* of a green roof is its drainage/water retention elements, as many green roof experts often emphasize, then the *soul* of a green roof is its growing medium. As much as any design consideration, proper soil selection is critical to the long-term success of a garden roof.

Plantings Selection

The growing medium must be designed in concert with all other major design elements of a green roof project. In some cases, for example, the load-bearing capacity of the roof will dictate the design weight and depth of the planting medium and, in turn, the plantings selection. In other cases, where load bearing capacity is less critical, the plantings chosen will be the primary factor in determining the necessary planting medium. Local climate conditions are always a major consideration when deciding what plants to select. Plant materials selected for a garden roof should be based on both adaptability and performance.

For an extensive green roof system, that typically does not include an irrigation system, the plantings must be drought tolerant, able to withstand heat, cold and high winds, as well as possess numerous other distinct qualities based on design intent. Low maintenance landscapes often use sedums, small perennials, and other succulents. For LEED® credits, plants indigenous to the area should be selected.

An extensive green roof system, with shallow soils, no permanent irrigation and subject to the extremes of the rooftop microclimate, can limit the selection of plants. However, there are typically enough varieties available that allow for more to be accomplished than simply a monoculture of sedums. By increasing the diversity of plantings selection, the green roof, besides being more beautiful and interesting, is less susceptible to diseases, pests and climatic variance.

In addition to sedums (ideal for 2-inch to 4-inch soils), a combination that includes grasses, alpines, some small natives, as well as other hardy succulents such as sempervivums are often used in extensive green roof systems. All of these plant types typically grow well in 4-inch to 6-inch soils. They are drought-tolerant plants, requiring little or no irrigation after establishment, with a growing pattern that allows them to spread and cover the roof surface.

Soil Characteristics

Although every necessary detail and consideration regarding the selection of soils for garden roofs would probably require a textbook, or two, the following outlines many of the essentials for an extensive green roof application.

The planting medium must provide a stable structure for the anchorage of the plants' root systems while remaining as lightweight as possible to prevent excess loading of the roof structure. The planting medium must also be water permeable, retain water, resist rot, provide nutrients, and possess many chemical, physical, and biological characteristics necessary for supporting and sustaining vegetation.

Soil specifications for a green roof are determined by a number of factors, including allowable depth and weight, climate and whether the roof will be irrigated. To keep costs down and ensure success it should specify the use of locally available materials and be suited to the specific plants that are to be grown. As no standards currently exist in the United States, specification criteria for the planting medium should comply with performance specifications that meet or exceed German FLL Standards: *Research Association of Landscape Development and Construction; Guidelines for Planning, Performance, and Maintenance of Vegetated Rooftops*. The criteria for growing media specifications for extensive green roofs include:

- Grain Size Distribution
- Density
- Water & Air Management
- pH, Lime & Salt Content
- Organics
- Nutrients
- CEC Capacity

Natural soil should not generally be used on a green roof system due to its weight, the scarcity of high quality soil material, and the tendency for it to compact when removed and transported to a roof. However, as a component of an engineered soil good quality sandy loam can be added in proportions of 10-20 percent of a green roof media. Green roof planting medium should be a precise blend of organic and mineral particles of varying size and composition. This blend must not only be lightweight, but must also possess the seemingly contradictory ability to retain water and yet easily allow excess water to drainwell. Generally, the organic and inorganic particles that make up the green roof planting medium should

occupy at least 50 percent of the soil composition, with the remainder being pore space, which serves as channels to facilitate air and water movement.

That's why *grain size distribution and density* are probably the most important specification criteria. Grain size distribution information provides estimates of a soil's engineering properties such as permeability, water holding capacity strength and stability. *Soil density*, another important criterion for green roof soils, is the mass or weight of soil per volume of area. High soil density can usually means reduced water infiltration rates, poor drainage, increase runoff and limited plant growth.

All soil systems are composed of four major components: solid particles, microbes and other small plants and animals, water (with various dissolved chemicals), and air. Infiltration of water, nutrients, and air into the soil and subsequent movement to plant roots is critical in a green roof's planting medium selection. The soil's *water and air management*, including saturated water capacity, air content, saturated air content and saturated hydraulic conductivity, help define infiltration and moisture retention characteristics of the planting medium. The soil's capacity to hold water and remain aerated has several critical influences on water management.

Organic Components

The types of plant forms and green roof applications determine the organic content type and percentage in the planting medium. Natural soils typically have between two to five percent organic matter (OM) by mass. Extensive green roof soils typically have between three and six percent OM by mass. The O&M percentage can initially be established slightly higher to aid the young plantings in getting started. Over time, the initial organic matter will be decomposed and replaced in part by organic matter coming off the plants and organic dust settling onto the roof. Eventually the green roof planting medium will likely stabilize at two to three to five percent OM by mass, within the same range as natural soils.

Specifying an organic component with a fairly low carbon-to-nitrogen (C/N) ratio is crucial in green roof soils. Unlike in natural soils, where organic matter has accumulated through continuously decomposing material, the green roof soil's only initial source for organic matter is what's put in the blend. It's important that the organic component used has been decomposed to a state where it can provide nutrients to the plant and not impart toxic compounds that are a byproduct of rapid decomposition.

The organic component contributes to plant growth through its effect on the physical, chemical, and biological properties of the growing medium, including a direct and indirect effect on the availability of nutrients for plant growth. In addition to contributing nutrients for plant growth, the organic matter content in green roof planting mediums acts as a "glue" that promotes soil structure and promotes healthy soil biology. Humus, comprised of partially decayed organic compounds in soil, makes the soil more friable and infiltration is increased. Organic matter sources include composted materials such as straw, sawdust, wood, leaves, grass clippings, agricultural wastes, biosolids and animal carcasses, used separately or in combination.

Proper planting medium selection is critical to the longterm success of a garden roof. A precise blend of organic and inorganic materials tailored to each specific application, a green roof planting medium must not only be lightweight, but must also possess the seemingly contradictory ability to retain water and drain well.

Mineral Components. What most distinguishes the green roof planting medium from natural soil is its primary mineral content, which is often synthetically produced expanded slate, clay or shale. Naturally occurring materials such as pumice, scoria can be used. Secondary types of mineral components commonly used include sand, perlite scoria or pumice fines.

Factors for the mineral component include selecting materials that not only meet the specified grain size distribution, but also satisfy the density issue. Weight is a critical factor. Sand, for example, is relatively inexpensive but its higher weight can be a limiting factor, compared to alternative materials.

Saturated weights for commonly used mineral components range from 75 lbs. per cubic foot to less than 45 lbs. per cubic foot. Often, the weight factor will ultimately require more expensive, less readily available materials.

Soil Chemistry & Nutrients. The soil's chemistry — its reactions and its soluble, mineral, and biochemical transformations — greatly influence green roof longevity and plant performance. Soil pH is one of the most important factors in plant growth. Typically a pH of 6.0 to 7.5 is recommended for garden roof soil. *Carbonate content*, the amount of calcium carbonate present in the soil, is also an important specification because, like pH, it can effect the plants' uptake of vital nutrients and water.

Plants need at least 16 essential nutrients in order to grow. Besides carbon, hydrogen and oxygen, other elements used by plants in large amounts are the macronutrients, including nitrogen, phosphorus, potassium, calcium and magnesium. In addition plants need other micronutrient like sulfur, iron, manganese, copper, boron and zinc. Compost used in the media often meets all the nutrient requirements for a green roof, but in future years it may be necessary to augment the media with fertilizers n order to keep the nutrient levels within the proper ranges.

Conclusion. Increasingly, reputable green roof system manufacturers are developing their own soil blends, engineered for extensive and intensive garden roofs in specific climates. Due to the specialization required for green roofs, manufacturers, marketers and specifiers of engineered soil need to fully understand the importance of all factors that will spell success or failure of a green roof media.

Green roofs are becoming more and more prevalent in the United States as their sustainability, energy savings and ecological benefits are becoming better understood. With this growth comes the need for a healthy knowledge of indigenous plants, regional climates and specifically engineered soils. A well designed garden roof with proper waterproofing, drainage/retention, plant selection and a site-specific planting medium, will provide a long lasting, self-sustaining ecosystem requiring minimal annual maintenance — and, of course, a pleasing view.

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