PRINCIPLES FOR SELECTING THE PROPER COMPONENTS FOR A GREEN ROOF GROWING MEDIA

Charles R. Friedrich, RLA, ASLA

Carolina Stalite Company

Abstract

When selecting a growing media for a green roof system it should be recognized that maintenance of the system is very different than what is performed at ground level. Media designed for placement above structures may have a weight requirement, and lightweight mixtures are recommended for planting where it is desirable to reduce the media weight. Until recently in North America, many designers requiring a lightweight media suitable for green roof systems had specified a typical nursery potting mix consisting of a blend of peat moss or pine bark with some sand, vermiculite or perlite. Learning from mistakes of the past and following the lead of the German FLL green roof methods the industry has looked to provide a more mineral based media to sustain green roof plantings. Reducing the organic content and adding Stalite-PermaTill expanded lightweight aggregate can reduce the saturated weight of the media without losing volume due to decomposition.

My college soil science professor always reprimanded the class for referring to soil as “dirt”. He would always say: “dirt is something that is tracked in onto the carpet”. It also is commonly referred to as something politicians use to gain an edge on their opponents. In the green roof industry, “dirt” is something that the general contractor sneaks up onto the roof instead of the specified growing media. Most green roof professionals like the term growing media or medium, substrate, or planting media. Before getting involved in the green roof business, I experimented with what I called “engineered soils”, but actually, for green roof media, there is often no soil added at all. There are a few definitions of what soil is, as a media for green roof systems I created my own definition: “the particulate matter or substrate that anchors the plant roots to sustain the plant growth”. That is exactly what roof “soil” is supposed to do, but it does get complicated. For simplicity’s sake let’s call just call it the “media”.

During the past several decades the performance of green roof system media has been evaluated in Europe and it was determined that the most crucial physical property the media should have is good drainage. This is made more challenging with the desire for green roof systems to retain additional water to not only reduce irrigation needs but also reduce and cleanse runoff in urban areas. To address these performance issues, there are six properties that media should possess:

1. Good drainage and aeration
2. Water holding capacity (without getting waterlogged or heavy)
3. Nutrient holding capacity (cation exchange capacity - CEC)
4. Permanent (resists decomposition)
5. Lightweight but sturdy (to resist shrinkage and wind displacement)
6. Stable (in order support the plants)

Natural topsoil that is excavated from the ground should never be recommended for green roofs unless screened, sterilized and graded to meet the criteria for green roofs. Before designing the media we must determine the type of green roof system it will be applied to. The industry has adopted the terms for two types of green roof systems from the German FFL Green Roof Guidelines, *extensive* and *intensive*. There can be some variations, however the main distinction between the two is the maintenance required to sustain the system.

a. Intensive green roof system:
   Intensive green roofs utilize a wide variety of plant species that may also include trees and shrubs. Use of large plants requires deeper growing media layers, possibly 10 inches (25 cm) or more, which results in more weight and a need for an increased structural load capacity of the building. Intensive green roofs are often accessible to the general public and can create a park-like atmosphere. Higher input requirements for water, labor and other resources are standard. (1)

b. Extensive green roof system:
   In contrast, extensive green roofs use a narrower range of species limited to herbs, grasses, mosses, and drought tolerant succulents such as *Sedum* – a succulent plant known for its tolerance for extreme conditions. These types of plants can potentially be sustained without automatic irrigation in a media layer as shallow as 1.0 inch (2.5 cm) and, therefore, they can often be installed on buildings without the cost of major structural alterations. Extensive green roofs are generally not accessible to the public and have lower input requirements for resources. They require less maintenance and are generally less expensive to install. Mosses, succulents such as *Sedum*, and low-growing grasses are common selections for extensive systems. (1)

The media utilized for extensive systems and for intensive can be different and in some cases should be different. Extensive systems, usually but not always have a shallow media layer, normally 3 to 4 inches. The air content at maximum water capacity of 35% or more should be greater than 10%. The water permeability should be greater than 0.0001 cm/sec. (2) When possible, (except with weight restrictions) the deeper the better. Plants always perform better with deep roots. By allowing the surface to dry, green roof media encourages the roots to grow down away from the extremes of the surface environment. I have grown sedums on the ground in Carolina red clay and they have done fine, but on the other hand, picture a roof as a large frying pan, it is a harsh microclimate. When designing an intensive green roof you can grow many plants on top that also grow well on the ground but they must be able to thrive in the same microclimate. The air content for intensive systems at maximum water capacity of 45% or more should be greater than 15%. The water permeability should be greater than 0.001 cm/sec. (3) Some shallow extensive systems, especially in Germany, have sedums planted in crushed roof tile or coarse lightweight aggregate with a thin topdressing of compost. Usually with no irrigation, these green plants thrive once established. However, in North America, our climatic changes are extreme, therefore supplemental irrigation may be needed. Coarse extensive media is almost always reserved for succulents. Intensive media has more of a soil like appearance but still must drain and have physical characteristics applicable to green roofs. Intensive media is a blend of two or more components with particle sizes graded to provide the bulk density necessary to grow a wide variety of plants. Media designed for intensive systems can also be used for extensive, the climate, plant material and depth usually determines the blend. See Figure. 1. The depth necessary to sustain plant growth depends on species and maintenance practices. A rule of thumb guideline is shown in Figure 2.

CONTENT BY VOLUME

INTENSIVE

- lightweight aggregate 35%-60%
- coarse sand (USGA) 25%-50%
- organic (compost) 5%-20%

EXTENSIVE

- lightweight aggregate 60%-100%
- organic 0%-25%
- coarse sand 0%-35%

Figure 1: Component Content By Volume

Green Roof Media Depths

Plants	Minimum Media Depth
Sedums	1" to 3" +
Groundcovers and Grasses	8" to 10"+
Shrubs	18" to24"+
Large Shrubs, Small Trees	24" to 3' +
Trees	3' +

Figure 2: Minimum Depth of Media for Plants

TYPICAL WEIGHTS OF MATERIALS

Material	lbs/ft3 Dry	lbs/ft3 Wet
water		62.428
vermiculite	5.75	24.5
perlite	6.5	32.4
sphagnum peat	9.6	70
ground bark	17	55
compost	32	82
expanded clay	40	54
pumice	40	47
Extensive media	42	65
expanded shale	44	58
Stalite-PermaTill	48	57
lava rock	50	60
Intensive media	62	80
loam	80	120
sand	90	130
granite	170	170

*Weights are not based on averages & may vary with product

Figure 3: Typical Material Weights

Components Of Green Roof Growing Media

Uses for horticultural products and recycled products are surfacing. Even with all the choices, which will perform the best on a green roof can only be determined from long-term evaluation. Figure 3 gives some typical weight comparisons for materials used for horticultural applications.

Organics

There has been much debate over the quantity of organics that makes up the media. In most cases the climate of the roof location should determine the amount of organics used. In arid climates decomposition may be slower or replenishing organics after decomposition may be practiced to maintain the water retention properties of the media. In humid regions over a short period of time, organics will decompose creating two specific problems. First, if the percent of organic matter is too high, the volume of mix decreases due to decomposition, requiring replacement due to the displacement of the media. Second, as the organics break down, the fines filter out down to the separation fabric. Once settled on the filter fabric, the organic fines decompose further creating a slime, which may impede the drainage causing the water to build up in the media. This may create plant health problems and possibly increase the structural load. No more than 10% to 20% of the media should be organic in humid regions. Depending on local availability the type of the organics can vary including peat, rotted sawdust or bark, and composted organics.

Composted organics is a preferred source for the organic component in green roof system media because of its high nutrient and microbial count, and it is politically correct because of its recycling value. However care must be taken when selecting the source of compost; proper stability/maturity, particle size, and feed stock source are some concerns. Unfinished or unstable compost consumes nitrogen and oxygen; this can cause nitrogen deficiency and be detrimental to plant growth, even causing plant death. Excess soluble salts can be phytotoxic to plants. Manure composts tend to be higher in soluble salts than yard waste composts. Compost with soluble salts levels over 10 millimho/cm at 25 degrees C should be watered (leached) and retested before use. (4) This is because over time fertilizers will be applied to the media that may add to the levels. Caution must be exercised when using composted landscape wastes as it could possibly contain some residual herbicides that can inhibit plant growth. If during the composting process the thermophilic phase temperature is not sustained between 113 and 167 degrees F, the chances of weed seed contamination is high. Certain composts may be derived from feedstocks that may include biosolids from municipal sewage treatment facilities. These sources may contain very fine particulates, heavy metals and pathogens. All composts should be tested using the US Composting Council’s Test Methods for the Examination of Composting and Compost manual and any health and safety related parameters (state or federal) should be assured. Depending on the wastewater treatment facility biosolids may have a limited acceptance for horticultural use; especially green roofs including vegetable and fruit production. The fine particles tended to filter down through the mixture and cake up. Green roof media is designed to drain well and the affluent from the roof may be discharged into a creek or other body of water during which the heavy metals (copper, nickel, cadmium, lead, mercury, and zinc) that may be contained in the biosolids could leach out.

Peat moss is derived from sphagnum, which grows in bogs and is harvested. The harvesting of sphagnum peat has been the topic of many concerned environmentalists. Sedge peat or native peat consists mostly of partially decomposed sedges and grasses from bogs. Both types of peat have a pH between 3.3 and 3.5. Peat with a pH above 5.0 is rare. Peat has a very high water holding capacity and is difficult to dry, however when it is dry it is very difficult to wet. Most economical peat today has a very fine particle size. Peat is a good source of organic matter but it is low in nutrients and microbial population.

Milled softwood bark from products such as pine, fir, hemlock and cypress are used by the nursery industry throughout North America. Since softwood bark is low in cellulose and high in lignins it does not decompose rapidly, thus is a good source for the organic amendment in green roof media. Hardwood bark, sawdust or wood shavings should never be used in a green roof media unless fully composted. Because hardwood is high in cellulose and low in lignins they decompose quickly and will rob the plants of nitrogen. Unlike the peat products, the cation exchange capacity of bark improves with age. Bark should be milled to particle sizes less than ½ inch. Ground barks have low nutrient levels and a low pH. (5) I prefer to blend ground pine bark with compost to create a desirable organic component to a green roof growing media. Figure 2 shows some general comparisons between organic amendments.

Stalite-PermaTill Rotary Kiln Lightweight Aggregate

As the main component of the media, the aggregates are the non-organic fragments that make up part of the mix. The aggregate in the media is what supports the plants and provides the pore space for air, water, and the exchange of gases. Because such a small amount of organics is recommended for green roof growing media the aggregate portion must serve additional functions for sustainability such as CEC, buffering, bulk density, drainage and when required, bio-remediation of contaminants. The size and type of aggregate will define how the media will function. "Since green roof media are highly aerated and contain relatively few fine particles (as compared to field soils), there is little if any capillary rise as there would be in a field soil. This makes sub irrigation of a green roof very inefficient." (6) Stalite-PermaTill manufactured lightweight aggregates are provided in many gradations, even gap graded if desired. The addition of aggregate fines or sand to the blend will help with water retention and some possible capillary action. In many parts of North America and Europe some type of lightweight aggregate can be obtained. Crushed roofing tile has been used successfully in Germany as media in extensive systems for sedum. Roofing tile is fired differently than brick and cannot be interchanged with the same results. By-products such as blast furnace slag, bottom ash, and diatomite filter waste are not recommended.

Expanded Shale, Clay, and Slate (ESCS) is aggregates prepared by expanding, pelletizing, or sintering products such as clay, shale or slate is manufactured for the lightweight concrete industry. The most desirable lightweight aggregate is Stalite-PermaTill Expanded Slate because of its availability, consistency and physical properties that meet the requirements of most green roof media specifications. In field soils, nutrients are held for the plant by cation exchange and the capacity to hold cations is given as (CEC). Cations are positively charged ions like H^+, Ca^{++}, Mg^{++}, and K^+ which are attracted to negatively charged soil particles.(7) Stalite aggregates replace clay in the soil and possibly most of the organics in the media, raising the importance of the role of the CEC to reduce leaching of nutrients from the media. While most natural clay based topsoil has adequate CEC, a green roof media mostly made up of coarse particles would have almost none. The CEC of the finer particles of Stalite average around 21.6 me/100g, providing an adequate substitute for natural clay soils for green roofs.

Stalite PermaTill is a rotary kiln produced vesicular amorphous silicate particulate material. It is a highly porous, low-density material and depending on the product, specific gravities range from 1.47 to 1.85 , and a dry/loose unit weight of approximately 50 to 54 pounds per cubic foot, (800 to 865 kg per cubic meter) As it exits the kiln the material is sterile, inert, and ceramic. Some crushing may be performed to facilitate final screening in a screening system. Stalite PermaTill has a pH of about 8.5.

Stalite PermaTill is generally used in green roof systems as the mineral component of the media mix, as a granular drainage material, or as a media alone with no amendments. It is available throughout the Eastern half of the United States. The hydraulic conductivity of Stalite will differ depending on type and gradation. The gradation can vary from ¾ inch (1.9 cm) to a fine sand like material. The media may require a blend of different sizes of Stalite with or without sand and/or an organic component depending on whether the application is for an *Intensive or Extensive* green roof. Variations in the media can be obtained by adjusting the gradation of Stalite to meet the desired porosity or weight requirement. The main adjustment that needs to be addressed is a correction for the weight and volume relationship of lightweight aggregate fines, that is, the minus No. 4 (4.75 mm) sieve size to a similar size of sand. The oven-dry or saturated surface dry/loose unit weight tests (see Test Method C 29/C 29M) can be performed to establish the weight-volume relationship. (9) Care must be taken to specify what C 29/C 29M testing procedure 9.0 is to be used for the fines (rodding 10.1, jigging 11.1, or shoveling 12.1). Using the shoveling procedure to determine loose bulk density may result in the sample weighing less per volume moist than it will when dry because moisture tends to cause bulking of the ESCS fines that creates larger air pockets in the sample. Typically, a loose cubic foot of ESCS fines will weigh approximately from 35 pounds per cubic foot (560 kg/m3) to 65 pounds per cubic foot (1120 kg/m3) depending on the source. Absorption of ESCS varies with the source, but is usually 9% to 35% of the oven-dry loose unit weight. Because of the absorption differences between the types of ESCS, determining the amount of water release from the particles of ESCS may be important when specifying certain plant species. Care must be taken not to have the media absorb too much moisture or pull needed water away from the roots during dry periods. The absorption (ASTM C127) and the particle size distribution (ASTM C136) of ESCS can determine the porosity of the media. Providing good drainage and encouraging deep roots is essential when developing a green roof planting media.

Some of the properties of Stalite PermaTill are:

1. Lightweight 48 to 65 lbs. Per cubic foot, will not float or blow away
2. pH 8.0 to 8.5
3. CEC 21.6 meq/100g
4. Will not decompose or degrade by freezing and thawing
5. Good water holding capacity with lower absorption and higher water release
6. Open cells hold water and closed cells provides the lightweight characteristic.
7. Bulk specific gravity ASTM C127 1.60

Sand

Sand alone, or even with some organic is unable to retain enough nutrients to sustain the plants without scheduled irrigation and fertilization. This is why golf course putting greens must be irrigated and fertilized regularly. Usually sand, if used at all, is only 30% of an extensive blend and no more than 50% of an intensive media. More often Stalite has been graded down to particle sizes to replace the sand in the media. Finer Stalite increases the water holding capacity and CEC of the media. Coarse sand is preferred with no particle larger than 2mm in diameter. Particle size should range be between .25mm to .75mm, fines below. 10 mm should be less than 10% of the mix. To be safe the sand should meet USGA root zone specifications for putting greens. Field or creek sand should be avoided unless sterilized or water separated, otherwise you may have a lovely crop of weeds on your rooftop. Sand should meet the following criteria:

1. Weight wet 110-130 lbs. per cubic foot
2. Must be non-calcareous (not chalky)
3. Should meet USGA particle size requirements for putting green construction
4. Has no or negligible 0-4 meg/100g CEC
5. Should have a total pore space volume between 12 and 25% capillary and 15-30% non-capillary
6. Bulk density 1.25 to 1.60 grams per cubic cm. (used to calculate porosity)

Project Management

As designers we are expected to be competent in the design of plans that the contractor is expected to implement as specified. To design and specify without following proper horticultural practices may be considered by some to be incompetent, especially to a competent landscape contractor. On the other side of the fence, I have been discouraged many times by the compulsion by some landscape contractors to not follow specifications. This action may bite them back professionally and legally. It is especially important to follow specifications for green roof systems; mistakes can be catastrophic because contrary to popular belief, everything that goes up does not necessarily come down. The solution is for the designer to get paid to manage the green roof portion of the project separate from the general contractor. Final green roof work can be a separate bid item away from the general contractors budget. Granted, this sometimes can open up a new can of worms with scheduling, but with this, someone other than the owner can never assume the designer’s control.

Blending

Blending the media components on the construction site is not recommended because the possibility of contamination. Companies experienced with blending media almost always perform these services at their own facility and transport finished product to the site. An experienced operator must perform the blending operation to insure that the ratio of the individual components in the final mix is correct. Mixing equipment may vary from facility to facility. Some use high tech blending equipment with hoppers and belts, while others are talented enough to judge quantities just using loader buckets. A concrete slab is preferred when mixing the materials to avoid contamination. Working with Stalite PermaTill is adventitious during the blending process. When saturated with water Stalite PermaTill actually allows the other components to adhere preventing separation during transport and placement. Make sure the equipment is pressure washed prior to handling media to prevent weed seed contamination.

The acidity or alkalinity of the media is important. The pH must be within a range allowing green roof plants to take up nutrients from the media. For long-term plant health, the pH should be relatively stable especially in the eastern US where acid rains can significantly reduce the pH of the media. In parts of the Northeast, rain pH is as low as 4.9. If the base mineral of the roof medium has a relatively high pH, then the acid storm water exiting the roof should be neutralized. Penn State experiments have shown that when rainwater migrates through an expanded clay roof, the pH is moderated close to neutral, pH7. (10) With its pH ranges of 7.0 to 9.0, ESCS is very beneficial for buffering. This is especially good for sedums. Excess acidity may be corrected by the application of lime dust. Excess alkalinity may be corrected by the application of sulfur or other suitable acidifying compounds. The nutrient content of the media is important and the chemicals usually evaluated are nitrogen, phosphate, potassium and some trace elements. However, except to correct pH, I feel to amend the media during the blending process is unreasonable and not economical. First, the media is often placed on the roof several months before the plant material is installed, crane availability and construction schedules often dictate placement. Second, because the media drains so well, pre-blended fertilizer located within the lower profile will be leached out and be wasted before the new roots reach it. Nutrient deficiencies may be corrected by using slow release fertilizers at the time of planting.

Placement

Especially in tight spots, placing the media on the rooftop can be challenging. Conveyors, cranes, lifts, blowing machines, elevators, packaging, and yes, even helicopters have been utilized. Care must be taken because of weight restrictions and safety issues. When stockpiled, protect the media from absorbing excess water and from erosion at all times. Do not store materials unprotected from large rainfall events. Do not deliver or place the media in frozen, wet, or muddy conditions. Material should be at or near optimum compaction moisture content as determined by AASHTO T 99 (ASTM D 698). Do not place materials that are excessively moist. Do not allow excess water to enter site prior to compaction. If water is introduced into the material after stockpiling, allow material to drain or aerate to optimum compaction moisture content. After placement onto the roof, preset the media by thoroughly watering the entire planting area. Fill settled low areas with the media and repeat the compaction and filling process until settlement ceases. When handling materials, operating tools and equipment, protect the media from displacement by laying down planking or plywood as required for protection.

Value Engineering

We must keep an eye on what goes up on the roof. Contractors not familiar with the importance of the growing media may be talked into a substitution that will only satisfy the lawyers. This brings us to an oxymoron… “value engineering” or what I like to call it “de-value engineering”. In my opinion, the single most annoying and difficult part of protecting the design intent of a project occurs after the bidding process. It starts when the general contractor mutters the oxymoron “Value Engineering”. This by far is the dirtiest word in the business. It doesn’t matter who utters the phrase; it always lands in the lap of the green roof designer. Why is this? It is very simple; the budget is blown at the end of the project not in the beginning. The growing media and planting is almost always the last phase on the critical path to completion. A talented designer can work with the project owner and work out design issues to reduce costs without totally jeopardizing the intent of the design. However in the real world, we as designers are usually the last ones to find out that their designs have been diminished in the back office of the construction trailer by the sub-contractor and the general contractor. When the designer finds out what has happened, he or she better be ready to whip out a very convincing rejection letter to squash the attempted sabotage.

As an insider, I can give you some insight on how value engineering is sometimes abused. It usually starts early in the game, during the bidding process, and with no doubt the lowest bidder has already devised a plot to undermine the specifications and pad the low bid. They usually are the ones that were calling venders for material prices the final day before the bid letting or just after when they are told they left something out. As the overruns pile up during construction, the budget starts to get squeezed. One day, when the weekly job meeting begins, the construction superintendent asks for some “value engineering” suggestions for the remaining items on the punch list. Of course our lowest bidder has some wonderful substitutions to suggest. He then pulls it out and shows everyone at the meeting how it can replace the more “expensive” specified product with another at a much lower cost. Now here is the secret that the shafted specified vendor will eventually find out: The low bidding sub-contractor, having already securing the best deal on the substitution product, knows it’s very late in the game, now can mark up the price twice as much than when he bid it under competitive conditions, thus making more money by “de-valuing” the job.

Now that we are savvy of the practice, how do we control it? It is up to us as professionals to challenge every modification made to our designs without our seal of approval. Most of the time, the offended vendor who just unfairly lost out to an unworthy competitor alerts us. The folks who get hurt the most by this practice are the good contractors who bid the projects to specifications, as they never had the opportunity to win the bid fairly. It seems no matter what the project management relationship is between the designer and the general contractor, the budget rules. When this happens late in the project, proper communications between the parties do tend to drift. Sometimes the “approved equal” specification is ignored completely. Budget issues will always include the green roof plan, however, the designer and the licensed installation contractor can go over the line items together and work out the best way to take the “de” out of “value engineering”. Everyone with professional integrity and the proper knowledge to stay current will benefit. The long-term results will benefit everyone.

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