## Chapter 13 – Vegetated Roofs

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13.1 Overview of Practice

The following example presents design guidance for Vegetated Roof applications serving runoff quality and quantity needs on VDOT facilities buildings. A vegetated roof cover is a veneer of vegetation that is grown on and completely covers an otherwise conventional roof, thus more closely matching surface vegetation than that of the impervious roof. (PADEP, January 2005)

The vegetated roof veneer may range between two and six inches in thickness, and may be comprised of multiple layers including waterproofing membranes, synthetic insulation, engineered and non-engineered soil media. With proper installation and selection of materials, even thin vegetated covers are capable of providing significant rainfall retention, runoff reduction, and water quality improvement.

![Vegetated Roof Schematic](Roofscapes, Inc.)

Figure 13.1. Vegetated Roof Schematic (Roofscapes, Inc.)
13.2 General Application Considerations

- Vegetated roofs may be applied as part of new construction or in retrofit applications.

- Vegetated assemblies on roofs with pitches steeper than 2V:12H must be supplemented with additional structural measures to protect against sliding.

- The roof structure of the building for which a vegetated roof practice is planned must be evaluated for compatibility with the anticipated maximum dead and live loads. Typical dead loads for wet vegetated covers range from 8 to 36 pounds per square foot. Live loading values can vary considerably and are a function of rainfall retention. Actual design weights should be established using a standardized laboratory procedure.

- The application of a vegetated roof system, in all application scenarios, requires a premium waterproofing system.

- The chosen vegetation must create a vigorous, drought-tolerant cover. The most successful and commonly used ground covers for un-irrigated roof installations are varieties of Sedum and Delosperma. Vegetated roof designs deeper than four to six inches are able to incorporate a wider array of vegetation, including Dianthus, Phlox, Antennaria, and Carex.

- Roof access must be provided to ensure proper maintenance and replanting of vegetative cover as necessary.

13.3 Design Guidelines

- Vegetated roof installations intended to serve as water quality BMPs must not be fertilized. Generally, non-irrigated assemblies are strongly preferred, even though they preclude the use of certain, otherwise acceptable, plant species.

- Internal building drainage, including provisions to cover and protect deck drains or scuppers (small openings to permit the drainage of water from a floor or rooftop), must anticipate the need to manage large rainfall events without inundating the vegetated cover.

- When the selected waterproofing membrane is not root-fast, a supplemental root-barrier must be installed.

- National Roofing Contractors Association (NRCA) and American Society for the Testing of Materials (ASTM) standards should be employed when choosing and testing the roof’s waterproofing membrane.

- Roof flashing should extend 6 inches higher than the top of the growth media surface and be protected by counter-flashings.

- Care must be taken during installation of the vegetated cover to ensure that the waterproofing membrane is not damaged.

- The vegetated layer should provide an internal drainage capacity capable of accommodating the two-year return frequency event without generating surface runoff.

- Deck drains and scuppers serving to discharge water from the roof area should be equipped with access chambers. These enclosures should include removable lids to allow ready access for inspection.

- A vegetated roof’s engineered soil media should contain no clay particles and should contain no more than 15% organic matter.

- The engineered media employed in vegetated roof applications should have a maximum moisture capacity ranging between 30 and 40 percent.

- If insulation is included in the roof covering system, it may be located above or below the primary waterproofing membrane.

- The International Code Council (ICC) and all other applicable standards should be considered for ballasted roofs.

13.4 Types of Vegetated Roofs

Vegetated roof systems that exceed 10 inches in depth are considered intensive roof covers. Intensive assemblies are intended primarily to achieve aesthetic and architectural objectives, with only secondary consideration of stormwater management function. These deep intensive systems may be called “roof gardens.” Extensive roof covers, by contrast, are usually 6 inches or less in depth and have a well-defined stormwater management objective as their primary function. The focus in this example is on the design of an extensive vegetated roof BMP.

Vegetated roof BMPs generally fall into three design categories:
- Single media with synthetic underdrain layer
- Dual media
- Dual media with synthetic retention/detention layer

13.4.1 Single Media Assemblies

Single media assemblies are most often used in pitched roof applications, and for thin and lightweight applications. The plants are selected from very drought-tolerant species, and the engineered media is of very high permeability. The profile of a single media vegetated roof assembly is typically as follows:

- Waterproofing membrane
- Root barrier (optional, depending upon the root resistance properties of the waterproofing membrane)
- Semi-rigid plastic geotextile drain or mat
- Separation geotextile
- Engineered growth media
- Foliage layer

Single media vegetated roof assemblies installed on pitched roofs may require the use of slope bars, rigid slope stabilization panels, cribbing, reinforcing mesh, or other provisions to prevent sliding and instability.

Single media assemblies used on flat roofs typically require a network of perforated internal drainage conduits to effectively convey percolated rainfall to deck drains and scuppers.

Assemblies with rigid geotextile drains or mats can be irrigated from beneath, while assemblies with drainage composites will require direct watering.

13.4.2 Dual Media Assemblies

In contrast to single media assemblies, dual media vegetated roof assemblies utilize two types of non-soil media. Fine-grained media with some organic content is placed over a basal layer of coarse lightweight mineral aggregate. Dual media assemblies do not include a geocomposite drain. The objective of a dual media assembly is to improve the drought resistance of the system by attempting to replicate a natural growth environment in which sandy topsoil overlies gravelly subsoil. These assemblies are typically 4 to 6 inches thick and are comprised of the following layers:
13.5 - Drainage Provisions

- Waterproofing membrane
- Protection layer
- Coarse-grained drainage media
- Root-permeable non-woven separation geotextile
- Fine-grained engineered growth media layer
- Foliage layer

Dual media assemblies are less versatile than their single media counterparts, and their implementation is restricted to roof pitches of 1.5:12 or less.

Large dual media assemblies should incorporate a network of perforated internal drainage piping to convey percolated rainfall.

Dual media assemblies are optimally suited to base irrigation methods.

13.4.3 Dual Media with Synthetic Retention / Detention Layer

Dual media assemblies employ plastic panels (geocomposite drain sheets) with cup-like receptacles on their upper surfaces. These sheets are then filled with coarse lightweight mineral aggregate. The cups trap and retain precipitation. The profile of a dual media system implementing a synthetic holding layer is as follows:

- Waterproofing membrane
- Felt fabric
- Retention / detention panel
- Coarse-grained drainage media
- Separation geotextile
- Fine-grained growth media layer
- Foliage layer

The complexity of the dual media synthetic assembly typically results in a total BMP depth of five inches or greater. These assemblies should only be considered for roof pitches less than or equal to 1:12.

Dual media assemblies equipped with synthetic retention / detention layers are best irrigated by surface spraying or mid-level drip.

13.5 Drainage Provisions

Adequate drainage is essential to the proper functioning of a vegetated roof. Failure of the roof drainage system can lead to loss of vegetation as well as penetration of water into surrounding structures. (Osmundson, 1999) Adequate drainage is a product of two key elements of the vegetated roof – the drainage medium and the drainage piping.

The drainage medium must consist of rot-proof material through which water can percolate and eventually enter the roof drains. In the United States, as early as the 1930’s, pebbles and broken rock were being applied in rooftop gardens as a drainage medium.
The most notable shortcoming of the crushed stone drainage medium shown in Figure 13.3 is its weight. Modern proprietary materials have been developed to provide superior drainage function without the excessive weight of aggregate material with comparable void space. Today, crushed stone drainage mediums are considered obsolete.

One popular proprietary drainage device is the Grass-Cel system. When topped with a layer of plastic filter fabric (necessary to prevent clogging by the fines contained in overlying planting media), the Grass Cel system provides a strong, easily handled and cut, lightweight drainage layer. Other varieties of proprietary drainage medium are Enkadrain and Geotech.
Typically, the drainage piping for a vegetated roof assembly will be plastic, cast iron, or brass. A number of different drain types exist.

One type of vegetated roof drain is the round or deck drain. The round drain is characterized by a grated horizontal top surface and perforated side surfaces. They are useful because their design allows flow to enter at the ground surface level as well as through the sides.
Another type of vegetated roof drain is the dome drain. The dome drain is characterized by its raised dome-shaped surface. It is particularly useful because its elevated surface permits water to enter even when the lower perforations become clogged by leaves and other debris.

A type of drain popular in Europe consists of a combination of sloping concrete trough or gutter in the concrete protective slab covered by a “half-section” of perforated plastic pipe covered in filter fabric. Water entering the system flows through the protective slab, into the gutter, eventually reaching the building downspouts.
13.6 - Growth / Planting Media

The filter fabric/blanket chosen to prevent clogging of the drainage medium should meet the following specifications:

- Grab Tensile Strength (ASTM-D4632) 120lbs
- Mullen Burst Strength (ASTM-D3786) 225psi
- Flow Rate (ASTM-D4491) 95 gal/min/ft²
- UV Resistance after 500 hours (ASTM-D4355)
- Heat-set or heat –calendared fabrics are not permitted.


The following is a non-exhaustive list of filter fabric manufacturers:

- Mirafi
- Supac
- Typar
- AMOCO
- EXXON
- TerraTex


Regardless of the type of drain employed, the system should be equipped with debris-collection basins to avoid clogging of the drainage piping by the inherent presence of debris and fine soil matter. (Osmundson, 1999) The pipes to which the drainage system connects are part of the building drainage system. Therefore, design of the vegetated roof drainage system will require an iterative design approach, working closely with the architect and structural engineer.

13.6 Growth / Planting Media

It is nearly impossible to classify a given soil mixture as optimal for all vegetated roof applications. Detailed performance data for a particular growth media requires long-term, controlled monitoring. In general, however, the growing media should adhere to certain guidelines, described as follows (Source: Osmundson, 1999):

- The optimum planting media consists of 45% sand, 45% soil and 10% humus.
- The presence of silt should be kept to a minimum. Silt possesses the ability to clog the system’s filter fabric.
- Mulching should be avoided, as wash-off is likely during severe rainfall producing events.
- The growth media must provide a permanent means of supplying internal aeration to prevent compaction of the mix.
The selected media must drain completely and efficiently over a 24 hour period.

The media must be suitable for the plant species chosen. It must be able to supply or absorb water and nutrients for the vegetation to use over time.

The media should exhibit very little shrink / swell phenomena, retaining its original volume over time.

### 13.7 Stormwater Peak Rate and Volume Mitigation

While conventional hydrologic methods are used to estimate the runoff from a vegetated roof system, one must consider that the runoff released from the system is not surface runoff, but rather percolated water. The rate and quantity of water released from a vegetated roof assembly during a particular return frequency storm is dependant upon the following physical properties of the assembly.

- Maximum media water retention
- Field capacity
- Plant cover type
- Saturated hydraulic conductivity
- Non-capillary porosity

The assembly’s maximum water retention is a product of the quantity of water that the media can hold against gravity in a drained condition.

In the absence of continuous simulation modeling or detailed laboratory performance data, a reasonable approach to assessing peak mitigation performance of a vegetated roof assembly is to compare its performance to that of a conventional impervious roof.

A general rule of thumb when computing runoff from vegetated roof systems is that for storm events in which the total rainfall depth is no more than three times the maximum media water retention for the assembly, the rate of runoff from the roof will be less than or equal to that of open space. (PADEP, 2005)

The maximum moisture content of a vegetated roof drainage media is 40 percent. In the following tables, the required depth of a vegetated roof drainage media layer located in Henrico County is shown by return frequency storm. Vegetated roof assemblies whose drainage media depth and maximum moisture content achieve the target values shown will exhibit runoff patterns similar to undeveloped, open cover conditions.
Table 13.1. Twenty four Hour Rainfall Depths, Henrico County

For runoff patterns to behave similarly to those of undeveloped open space, the available water retention within the drainage media of a vegetated roof assembly must be greater than or equal to one third of the rainfall depth for the return frequency storm for which peak mitigation is desired. These equivalent depths are presented as follows.

Table 13.2. Required Media Moisture Retention Depth for Roof Assembly to Behave as Open Space (Henrico County)

The physical depth of a vegetated roof assembly drainage media needed to achieve the moisture retention depths presented in Table 13.2 is a function of the maximum moisture content available within the media. Below are the required media depths for drainage medium exhibiting moisture contents of 30 and 40 percent respectively.

Table 13.3a. Required Drainage Media Depth for Roof Assembly to Behave as Open Space (30% moisture content)
### 13.8 Pollutant Removal Performance

While various claims for pollutant removal performance of rooftop gardens have been made, it is not clear at this point that there is a sufficient database to support them. What is clear is that the opportunity of this BMP to intercept overland flow with its associated load of suspended sediment, phosphorous and nitrogen is non-existent. The only true source of pollutants on the rooftop garden will be atmospheric deposition, assuming there is no fertilizer application, as recommended in virtually all guidance documents. We can only surmise there has been little to no investigation of the removal process in the case of atmospheric deposition.

### 13.9 Vendor Websites

The book by Theodore Osmundson (1999) provides an excellent reference on the landscaping details of rooftop gardens, with many photographs of outstanding installations. However, this reference provides little guidance on the engineering aspects of rooftop drainage and structural design so critical to the success of the rooftop garden. Therefore, we believe it is imperative that the drainage engineer contact various vendors regarding engineered roof top systems, together with the architect and structural engineer for the site development well before the design of any roof top garden system. We have provided a partial list of vendors and their website addresses to assist in this process, recognizing that this list is not exhaustive and that there are other proprietary systems. Our list of vendors does not in any way constitute an endorsement of any one product.

- **American Hydrotech, Inc**  
  [www.hydrotechusa.com](http://www.hydrotechusa.com)

- **Building Logics**  
  [www.buildinglogics.com](http://www.buildinglogics.com)

- **Elevated Landscape Technologies Inc. (ELT)**  
  [www.eltgreenroofs.com](http://www.eltgreenroofs.com)

- **Green Grid**  
  [www.greengridroofs.com](http://www.greengridroofs.com)
13.9 - Vendor Websites

Henry Company
www.henry-bes.com/greenroofing.asp

Prairie Technologies
www.prairie-tech.com

Roofscapes, Inc.
www.roofscapes.com

Xero Flor America, LLC
www.xeroflora.com