

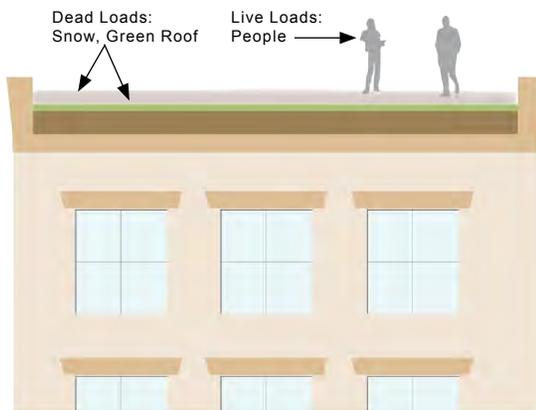
## 4.0 CHALLENGES TO GREEN ROOF CONSTRUCTION

Other considerations in addition to potential costs and benefits can influence building owners' acceptance of green roofs. Challenges associated with installing green roofs on new or existing buildings, if not properly reviewed or addressed, can increase costs and deter owners from installing such roofs.

Potential challenges can include structural considerations, issues associated with installing a green roof on a historic building, knowledge of applicable codes, and issues associated with roof construction and maintenance.

Green roofs occasionally fail to perform at the level for which they were designed. Potential failures include leaks, plant loss, inadequate drainage, soil erosion and slope instability.

This section sets out best practices and lessons learned for each potential risk to help owners, design teams and maintenance staff anticipate and overcome these challenges, and to help smooth the planning, implementation and maintenance of green roofs. It is designed to influence green roof design and encourage acceptance of green roofs, and aims to keep building owners from missing opportunities to benefit their own and their community's financial, environmental and social bottom lines through the installation of green roofs.



Variations from the design weight can lead to structural failure.

### 4.1 SITING AND DESIGN

#### Key findings:

- Variations from a roof's design weight can result in structural failure
- The dead load of a green roof assembly should be determined on a project-specific basis
- Engineers should assess the likelihood that a green roof will have a material impact on other load areas, including seismic loads, snow drifts, and intentional rainwater retention
- Designers should review architectural plans to determine design load capacities, or back-calculate them from an assessment of the existing structure
- Supplemental reinforcement measures may be taken to allow a building to support a green roof, but these can be cost prohibitive

#### 4.1.1 BUILDING STRUCTURAL CONSIDERATIONS

##### Issue: Variation in Dead Load of a Green Roof

The **dead load** of a green roof system is influenced by a number of factors, including **contractor skill**, **medium components**, and **potential water retention**. Variation from the design weight can result in structural failure.

##### Recommendations

The dead load of a green roof assembly should be determined on a project-specific basis, because growth medium composition varies from job to job. ASTM E2397 is the established standard procedure for determining the dead and live loads associated with green roof systems.

The preface in the standard says that the results can only be regarded as a prediction, not as the true weight of the green roof system. Variations in actual green roof dead loads result from normal variations in material thickness and density, from variation in the finished growth medium product, from human error in the distribution and grading of the growth medium, and from variations in plant biomass.

The green roof dead load is independent of other dead loads, such as snow load, included in the guiding building code.

**Issue:** *Other load implications*

The structural design of green roofs concerns more than the dead load of the growth medium and landscaping.

**Recommendations**

Roof landscaping may change snow drift patterns, seismic loads, and ponding from rain accumulation; these changes may be in excess of typical or previous design allowances. Depending on the type of construction, the climate, and the proposed system, engineers should assess the likelihood that the introduction of a green roof will have a material impact on other loading.

**Issue:** *Retrofit of existing structure to accommodate a green roof*

A feasibility study should be conducted on an existing structure to determine the capacity of a building to accept the weight of a green roof. A roof may have enough structural capacity built in to support a green roof of a given depth, or reinforcement may be needed.

**Recommendations**

Determine the type of existing construction: steel frame, concrete flat slab, masonry, or light wood, for example. Review the existing structural and architectural plans to determine the design loads. Alternatively, design loads can be back-calculated from an assessment of the existing structure. If the roof does not have sufficient reserve capacity to carry the additional weight, imposed loads may be redistributed at the architect

and engineer's discretion. For example, an existing roof may be designed for public occupancy (100 pounds per square foot). One option would be to restrict access and to reallocate a portion of the design live load to the green roof. Some roofs are finished with substantial architectural build-ups such as concrete pavers or stone. Removing unnecessary finishes may provide sufficient capacity for a green roof of equal weight. The allowable depth of the green roof is determined by the load capacity that can be allocated to it.

Depending on the type of construction, supplemental reinforcement measures might be taken, but these are often cost prohibitive. Examples include adding depth to existing beams or reducing the tributary area by providing additional full-length members parallel to the existing beams. If a member is reinforced to take extra load, the connections and supporting members must also be evaluated for capacity.

Plumbing must also be coordinated with the structure. Core drilling and saw cutting through slabs must be reviewed by an engineer and caution must be taken to avoid cutting beams and reinforcement.

**Issue:** *Roof access*

Roof occupancy will contribute to determining the live load and the safety requirements.

**Recommendations**

Review the type of desired occupancy with the architect. If a formerly unoccupied roof becomes publicly accessible, consider both load and safety measures. A handrail or parapet may be required at the roof perimeter. Structural provisions must be made to accommodate the load and the attachments associated with a handrail or parapet.

**4.1.2 INSTALLATIONS ON HISTORIC BUILDINGS**

Historic buildings create an opportunity for green roofs because of the original, well-engineered quality that many of these structures have. Many pre-World War II buildings were designed and engineered for durability.

*Low-growing, ground cover plantings behind existing parapets of historic buildings so that vegetation is not visible from the public right-of-way.*

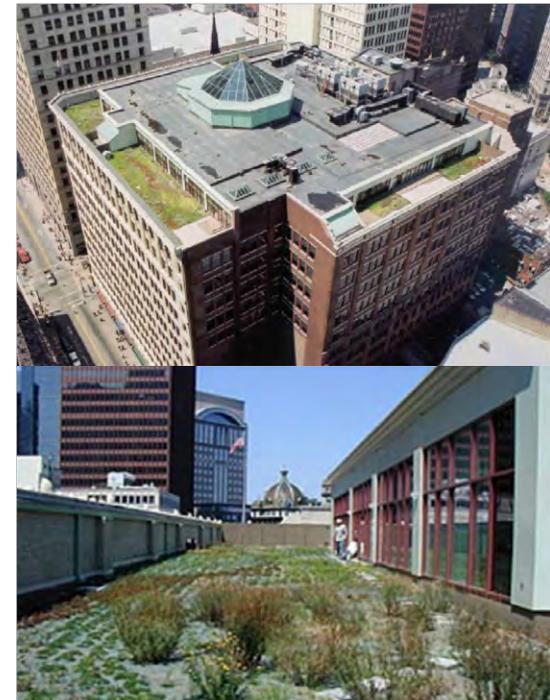


Figure 24: Compatible green roof on a rehabilitated office/retail building



Figure 25: Incompatible green roof on a rehabilitated office/retail building

The GSA and EPA worked together to renovate this historic building using 99% of the original structure and adding an assessable green roof covering the 4th and 5th floors. The green roof insulates the McCormack POCH reducing energy use and costs, provides a pleasant environment for building occupants and provides visible plantings from other floors of the building.



Figure 26: John W. McCormack Post Office and Courthouse (PCOH).

**Issue: Building character**

The character of the building must be retained for historic buildings. Federal buildings must meet the Secretary of the Interior’s Standards for Rehabilitation, which requires any vegetation planted on a green roof to not be visible above the roofline from public thoroughfare, as it would negatively impact the character of the building (Figure 24 and Figure 25).

**Recommendations**

Low-growing, ground cover plantings (e.g., sedum) should be planted behind existing parapets so that vegetation is not visible from the public right-of-way. There are no additional construction permitting requirements for installing a green roof on historic buildings. However, construction permits for historic buildings will be reviewed by the state Historic Preservation Office (in the NCR, this is the Washington DC Historic Preservation Office). The preservation office will review permits to ensure that alterations are “compatible” with historic building character. A flat roof should not conflict a new green roof, as compared with the installation of solar panels, which stick up and alter the building’s outline or façade.

Washington DC does not separate “certificates of appropriateness” for historic properties.

**4.1.3 CODES AND STANDARDS**

**Issue: What codes and standards are pertinent to green roof installations?**

**Recommendations**

The District of Columbia has adopted the 2006 International Codes (I-Codes) published by the International Code Council (ICC), and the 2005 National Electric Code (NEC) published by the National Fire Protection Association (NFPA), subject to any changes, deletions or additions as set forth in Title 12 of the District of Columbia Municipal Regulations (DCMR).

The following recommended standards reference green roofs, though they are not required by the District:

- ASTM [E2396](#) – Standard Testing Method for Saturated Water Permeability of Granular Drainage Media [Falling-Head Method] for Green Roof Systems
- ASTM [E2397](#) – Standard Practice for Determination of Dead Loads and Live Loads Associated with Green Roof Systems
- ASTM [E2398](#) – Standard Test Method for Water Capture and Media Retention of Geocomposite Drain Layers for Green Roof Systems
- ASTM [E2399](#) – Standard Test Method for Maximum Media Density for Dead Load Analysis\*
- ASTM [E2400](#) – Standard Guide for Selection, Installation, and Maintenance of Plants for Green Roof Systems
- ANSI/SPRI VF-1 External Fire Design Standard for Vegetative Roofs

For stormwater regulations, see *Section 2.1*.

\*Method E2399 includes tests to measure moisture-retention potential and saturated water permeability of media.

## 4.2 INSTALLATION AND CONSTRUCTION

### 4.2.1 CONTRACTOR SELECTION

#### Key findings:

- Inexperienced green roofing contractors can cause budget overruns and improperly installed green roofs.
- An installer's lack of skill can lead to chronic performance problems.
- An experienced contractor should be able to efficiently and accurately coordinate construction schedules with the General Contractor, and install a high quality product within budget and on schedule, with minimal disturbance to other trades and without compromising the Owner's warranty.

#### Issue: Contractor inexperience

Lack of experience by green roofing contractors likely delay the administrative and construction process, likely result in budget overruns, and can result in incorrectly installed green roofs.

One frequently observed problem is that the installation of fabric, drainage, and growth medium layers takes longer than anticipated, and therefore the optimum window for planting is missed (the optimum planting window depends on the specific plants and local climate). When this happens, the green roof contractor must re-mobilize later and install the plants when weather conditions are more favorable. Damage to the green roof or waterproofing during the period between installation and planting can cause disputes among the green roof installer, other trades, and the General Contractor and can result in exclusions in the Owner's warranty.

An installer's lack of skill may not be apparent before or during construction, but can result in chronic performance problems. Improper material installation can result in failure of the green roof. In the worst cases,

the green roof must be removed. If the symptoms of the failure arise after the warranty period, the Owner must absorb the cost of replacement or removal.

#### Recommendations

An experienced contractor should be able to efficiently and accurately coordinate construction schedules with the General Contractor. The following green roof construction best practices are recommended when a contractor is selected to install a green roof.

**Contractor** — an experienced green roof contractor should install a high quality product, within budget and on schedule, with minimal disturbance to other trades, and without compromising the Owner's warranty.

- A knowledgeable and qualified proposal should be provided.
- The performance characteristics of individual green roof components should be known (an inexperienced contractor may submit inappropriate materials, thus delaying the administrative and construction process).
- Communication and coordination with the General Contractor and the Roofing Contractor is essential for minimizing unforeseen challenges, e.g., all trades that require roof access need to finish their work before green roof construction begins.
- A visit to the site before construction should help the Green Roof Contractor understand site-specific construction logistics.
- Construction in urban environments typically requires street closures and police presence.

**Material storage** — the green roof contractor should anticipate probable material storage logistics during the bidding phase and should arrange final material storage logistics with the General Contractor prior to green roof installation.

- On-site material storage can save time and



Green roof contractors using a pneumatic blower to install the growing medium



A "super-sack" of growing medium hoisted above the roof.



A crane delivering "super-sacks" of growing medium to the rooftop

therefore cost, as opposed to retrieving materials from an off-site storage location.

- On-site storage is not always feasible on retrofit projects.
- Material must not be stockpiled on the roof in a single area such that structural capacities are surpassed.

**Medium installation** — the contractor should use the medium installation method that is most appropriate for the specific characteristics of the project. Medium installation is the longest stage of green roof construction.

A crane can install the medium at a rate of about 8 cubic yards per hour. The medium is delivered to the site in **super-sacks** of about 2 cubic yards each, which are hoisted individually to the roof. The bagging cost for delivery is up to \$30 per cubic yard.

A pneumatic blower truck can install the medium at a rate of about 12 cubic yards per hour. The medium is delivered in bulk. The cost of renting a truck is typically high and varies from project to project; however, blower trucks are typically more affordable than cranes on larger projects. An experienced blower truck company with a history of green roof installation will typically include installation and grading in the contract price.

#### 4.2.2 HANDLING/KNOWLEDGE OF PLANTS

##### Key findings:

- Landscaping and roofing are the key trades involved in successful green roof installation.

##### **Issue:** *Improper plant handling*

Improper plant handling techniques can lead to plant mortality and unsuccessful establishment of the green roof.

##### **Recommendations**

The green roof contractor should have a working knowledge of plant handling and establishment

techniques. A green roof is a living building component, and the plants must be stored and handled with care to ensure their viability. Landscaping is a key trade for the successful installation of a green roof, and landscape contractors have the knowledge and experience with plant material to ensure that the green roof is properly installed and to ensure that precautionary measures are in place to respond to variable climactic conditions. Recognizing the need for this expertise, many roofing contractors who are serious about integrating green roofs into their business models have developed green roof divisions that focus on plant handling, installation, and maintenance.

##### **Issue:** *Liability and warranty*

In addition to landscaping, the other trade involved that is key for the successful installation of green roofs is roofing. However, liability and warranty issues can arise when the scope of the green roof installation is divided and performed by two separate contractors or trades people (that is, by separate roofers and landscapers). This division of scope can mean that the warranty provisions are not adequately coordinated. A common scenario is for a roofer to install the waterproofing and green roof foundation components, such as foundation fabrics, drainage layers, and separation fabrics. A separate landscape contractor (who may or may not be a sub-contractor to the roofer) then installs the green roof medium and the plants. If a single contractor is not responsible for installing and providing a workmanship warranty for all of the green roof components, liability disputes can arise when the green roof does not perform as specified. Plant viability and replacement might be covered under the installer's workmanship warranty, but it might be excluded by the landscape contractor because they cannot be sure whether plant mortality is caused by a component installed by the roofer.

##### **Recommendations**

A single contractor must be responsible for supplying all the materials and labor associated with the green roof assembly—that is, all components above the waterproofing. The green roof installer should provide



*Irrigating a sloped green roof during the establishment period*

a long-term warranty to the Owner that covers durability of the cover materials, workmanship, and performance of the plant ground cover. The roofing installer should provide a long-term material and labor warranty that covers the underlying waterproofing system. To reduce potential disputes, job specifications should clearly delineate responsibilities for leak location, uncovering of the membrane, and repairs to the waterproofing and to the green roof assembly. One way of insuring comprehensive coverage is for the Owner to request a single-source warranty. However, single-source warranties may not always be advisable, because they can add to cost and limit choice. In addition, care should be exercised that warranties identified as “single-source” are truly inclusive of plant viability and performance.

#### 4.2.3 SAFETY TRAINING AND PERSONNEL

##### **Issue:** *Safety issues*

Safety training and precautions are required by law for all roof types.

##### **Recommendations**

The green roof contractor must comply with all Occupational Safety and Health Administration (OSHA) safety requirements that pertain to green roof installation:

- *Fall protection* — During installation, any worker exposed to a fall distance greater than 6 feet must be protected by a guardrail system, safety net system, or personal fall arrest system. During maintenance, any worker exposed to a fall distance greater than 4 feet must be similarly protected.
- *Protective Equipment* — The construction team must assess the project site to determine any additional protective equipment. A hard hat and steel-toed boots are always required. Other common safety equipment used by green roof installers includes safety glasses, reflective vests, and fall arrest harness or lanyard systems (when parapet heights necessitate them).
- *Exposure to Silica Dust* — If the installation requires

cutting, grinding, or drilling of concrete or masonry, workers may be exposed to silica dust. If this is the case, workers require hazard communication training and a respirator.

- *Other safety considerations* — Operating equipment such as cranes, derricks, hoists, and industrial trucks must meet the same requirements as with any other roof installation. As with any roof installation, electrical hazards and excessive exposure to heat and cold need to be considered.

Full-time safety coordinators are required on some sites to ensure compliance with safety protocols.



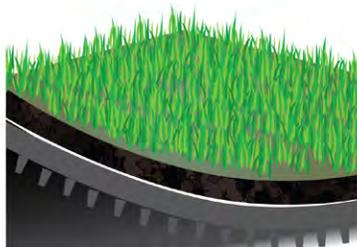
*Use of protective equipment such as hard hats and steel-toed boots during green roof installation*



*Plugs: Pre-grown; flexible; greatest diversity in vegetation*



*Cuttings: Least expensive option; uniform coverage; can be hydroseeded*



*Pre-grown mats or trays: Most expensive option; provides immediate cover; must be fitted quickly and secured until rooted*

#### 4.2.4 PLANT ESTABLISHMENT

**Issue:** *The green roof environment is especially harsh compared with on-grade conditions, and not all plants are able to successfully establish on green roofs.*

##### Recommendations

Sedum varieties are the preferred plants for extensive green roofs. The three common methods of plant establishment are **cuttings**, **plugs**, and **pre-grown mats**. Coverage rates will vary seasonally, but the foliage of a typical healthy green roof will have 80% coverage during the growing season. With regular maintenance, each of the three planting methods should result in 80% coverage after two years, and this is a common requirement of green roof installer workmanship warranties. The initial aesthetic, the variety of plants, and the cost vary with planting method.

**Cuttings** are small, healthy pieces of the plant that are placed on the media surface and become established by developing new roots that grow into the media. The use of cuttings is the least expensive method and provides high coverage rates, though it limits the type of plants that can be grown. Installing **plugs** is labor intensive, but allows a wider variety of plants. Whether cuttings or plugs are used for the initial installation, maintenance includes picking new cuttings from established plants to spread in bare spots. **Pre-grown mats** are comparable to turf sod; cuttings are established on amended green roof media in a nursery setting, grown to maturity and harvested (with the media) immediately prior to delivery.

**Temporary irrigation** during the first growing season is recommended for all projects, but is particularly important for the establishment of plants grown from cuttings and pre-grown mats.

When plants are established from plug/pot form, appropriate sizes should be used. The appropriate plug/pot form size depends on system thickness, planting density and other factors.

#### 4.3 MAINTENANCE AND OPERATION

##### Key findings:

- Wholesale roof failure is the inability of a green roof to perform at the level for which it was designed.
- Wholesale failures include leaks, plant loss, inadequate drainage, soil erosion, and slope instability.

Maintenance of a green roof may prevent failure of the green roof system. The phrase **modes of failure** addresses **wholesale green roof failure**, or the inability of the green roof to perform at the level it was designed for, not general client aesthetic dissatisfaction. Wholesale failures include leaks, plant loss, inadequate drainage conditions, soil erosion due to wind and water, and slope instability. A client should be adequately educated on the type of green roof system and its purpose, and on the type of plants that are used in the green roof. This can also help the client understand the maintenance requirements for the green roof.

##### 4.3.1 LEAKS AND LEAK DETECTION

##### Key findings:

- Leak-detection methods include flood tests and low-voltage electric leak detection.
- Flood tests are the industry standard on conventional roofs, but become more difficult after a green roof is installed.
- Low-voltage leak detection allows precise identification of leak locations, but certain roof constructions do not permit the use of this technique.

##### Issue: Leaks

Leaks are generally caused by poor workmanship. Unless the problems are ubiquitous, a project failure will not result. However, the process of identifying and repairing leaks is relevant to consider.

Figure 27: The common methods of plant establishment on a green roof.

## Recommendations

As in typical, non-green roofs, presence of a leak is typically confirmed from water damage inside the building. There are two main methods to locate leaks: **flood test** and **low-voltage electric leak detection**.<sup>†</sup>

The green roof and waterproofing vendor should be consulted to determine the most appropriate method for locating a leak. During the process of leak detection and repair, the green roof is excavated, the waterproofing is repaired, and the green roof is replaced. Only an agent of the green roof system provider should excavate the green roof; an owner's warranty may be compromised if an unapproved party excavates the green roof. Proper medium handling techniques include:

- Segregating different types of medium (failure to do so may cause impeded drainage conditions)
- Proper plant-handling techniques (to allow successful replanting)
- Proper medium placement and grading techniques (to provide even system thickness and weight)

**Flood tests** are the industry standard in typical roof construction. This test is used on many green roof projects prior to green roof installation, but becomes more difficult after the green roof is installed. An agent of the green roof system provider determines the region of the roof where the leak is likely to originate. The region is isolated and water is directed onto the area. In most instances drains must be plugged during this type of test. If the roof structure will not support the added weight, then the suspect area must be uncovered before flooding. By observing how flooding influences the rate of the leak, the damaged area can often be identified. Leaks are identified and patched; if no leaks are identified, a new region of the roof is investigated and the process repeats. Once all leaks are found and patched, the whole roof should be soaked to verify that leaks no longer exist. The process can be long and can result in significant damage to the green roof. Efforts should be made to properly store and re-plant plants, but in some cases new vegetation will have to

be purchased.

**Low-voltage leak detection** allows precise identification of leak locations. However, certain roof build-ups do not allow the use of low-voltage leak detection. The method requires a grounding plane underneath the waterproofing membrane; examples of appropriate grounding planes are reinforced concrete (except hollow core planks) and metal roof decks. When decks are constructed from electrically non-conductive materials, metal screens or foils can be placed under the waterproofing membrane and connected to a building ground such as steel plumbing. The leak detection technician introduces a low voltage electric charge onto the surface of the membrane. In practice this is done by creating an electrical charge in the wet medium that covers the membrane. The charge travels through moisture in the vegetated cover, through any penetrations in the waterproofing, connects with the grounding layer, and is registered by the technician. Low-voltage leak detection can be performed before and after the green roof is installed, on appropriately designed green roofs. Leaks can be detected with precision, which minimizes damage to the green roof.

## 4.3.2 PLANT LOSS

Plant loss can be caused by a number of factors. Depending on the cause, the appropriate response will vary from maintenance activities to green roof demolition.

**Issue:** *Foot traffic*

## Recommendations

**Foot traffic** should be strictly limited to green roof maintenance activities. If significant building maintenance traffic not related to the green roof is expected, pavers or gravel walkways should be placed in primary paths. Paver plazas should be used if the green roof is intended to be an amenity space, and access to the vegetated area should be restricted. Sedum and other succulents can take low levels of foot traffic, but sustained traffic will kill the plants. Non-

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<sup>†</sup>High-voltage leak surveys are only applicable as a construction quality assurance measure and therefore are not relevant when considering methods to locate active leaks after completion of the vegetated cover.

succulent plants are generally less tolerant of foot traffic than succulents are. On a sedum/succulent roof, damaged areas can usually be re-established using cuttings collected from un-damaged areas. On non-sedum/succulent roofs plant damage usually requires purchasing and installing new plants.

**Issue:** *Impaired drainage conditions*

Impaired drainage can result from unsuitable medium or from improper installation of drainage components. Aside from plant loss, impaired drainage conditions may result in overloading the roof, and in water intruding into the building via door thresholds, skylights, or hatches. Inappropriate medium is the most common cause of green roof failures. Medium with high silt or clay content will frequently lead to plant failures.

**Recommendations**

Green roof media should have moderate to high **permeability** and **porosity**. Guidelines for media selection are available from several sources, including the FLL Guide.

Typical plants used in green roofs are selected to be tolerant of drought conditions and are generally not tolerant of extended periods of saturation. In extreme cases, the medium may have to be removed and replaced with a more suitable green roof medium. An improperly installed drainage component has the potential to impede proper drainage, resulting in extended medium saturation. In this case, the drainage element must be replaced, often requiring disruptions to large areas of the green roof.

**Issue:** *Over-watering and over-fertilizing*

Over-watering and over-fertilizing typically occur when the cause of plant loss is not apparent. The symptoms of over-watering are very similar to the symptoms of under-watering, and the same is true for over-fertilization, therefore, they are easy to misdiagnose.

**Recommendations**

Over-watering can be corrected by cutting off supplemental water. Over-fertilizing can be ameliorated in some cases by adding other amendments to balance nutrient ratios available to plants. It does take time for nutrient levels to stabilize, and additional maintenance may be required during this time. Laboratory testing of growth medium samples should be conducted before beginning a nutrient amendment course.

**Issue:** *Improper plant selection*

Appropriate plant selection is the most critical factor in successful plant establishment. Sedum and other succulents are the most pervasive plants used in green roofs, and are the only appropriate plants for thin extensive profiles in most cases. Increased medium thickness and supplemental irrigation do allow a greater variety of plants to be used, but cannot fully counteract the unique and extreme conditions experienced on a green roof. Where inappropriate plant selections prevail the plants must be replaced wholesale.

**Recommendations**

Designers should consult the green roof system provider to determine appropriate plants or confirm that plant selections will be eligible for the system provider's warranty.

**4.3.3 WIND SCOUR AND UPLIFT**

Wind scour can be a serious problem in coastal environments, in open areas with few obstructions, and in urban areas where adjacent structures cause turbulence. Typical wind stabilization measures are located at the roof perimeter; examples include high parapets and ballast (e.g., stone, architectural pavers, and turf pavers). The goal of these measures is to break up the wind at the perimeter, and to provide a heavy perimeter margin that will be less vulnerable to scour.

**Issue:** *Wind scour*

Wind scour can result in loss of growth medium, and, in

extreme cases, in green roof delamination. The primary area of concern with wind scour is at the roof perimeter.

#### **Recommendations**

Wind scour in the field of the green roof is of less concern because of the scour-resisting characteristics of the plants themselves. The foliage of the plants creates a rough surface, which in turn creates low-level turbulence that disrupts the wind streamlines. Plant roots form a widespread network of anchors that stabilize the growth medium and integrate the layers of the green roof together.

There is no established green roof wind design standard; current methods in use include ASCE 7, FM, and SPRI methodologies, but these do not account for the anchoring capability of plant roots or other conditions specific to green roofs.

#### **ISSUE:** *Wind uplift*

#### **Recommendations**

Wind uplift is not an important threat to most green roofs, because the materials are air permeable and cannot support significant pressure differentials. In addition, surfaces roughened by plant foliage or coarse stone will result in low uplift potential. Concern for green roof damage related to uplift may be warranted where 1) an internal layer is not air permeable, or 2) smooth hard surfaces are incorporated, such as architectural pavers. Layers that are not permeable to air may include thermal insulation installed in a PMR (protected membrane roof) configuration, or membrane root-barriers.

#### **4.3.4 ROOT PENETRATON AND BIODEGRADATION**

Two types of failure attributable to biological factors are root penetration and biodegradation of medium

#### **Issue:** *Root penetration*

Plants with aggressive roots will, over time, damage the water-proofing layer of green roofs. Waterproofing manufactured from asphalt is at the highest risk.

Chemical root-inhibiting products are not recommended on green roofs because they leach over long periods of time and could cause water pollution issues. Failure to use root-resistant waterproofing without providing a root-barrier can cause catastrophic damage, and therefore can subsequently lead to demolition of the green roof and the underlying waterproofing.

#### **Recommendations**

Thermoplastic membranes offer the most reliable type of root barrier. All waterproofing membranes used in conjunction with green roofs should be tested for root-resistance. Tests are available to gauge the vulnerability of waterproofing membranes to root damage.

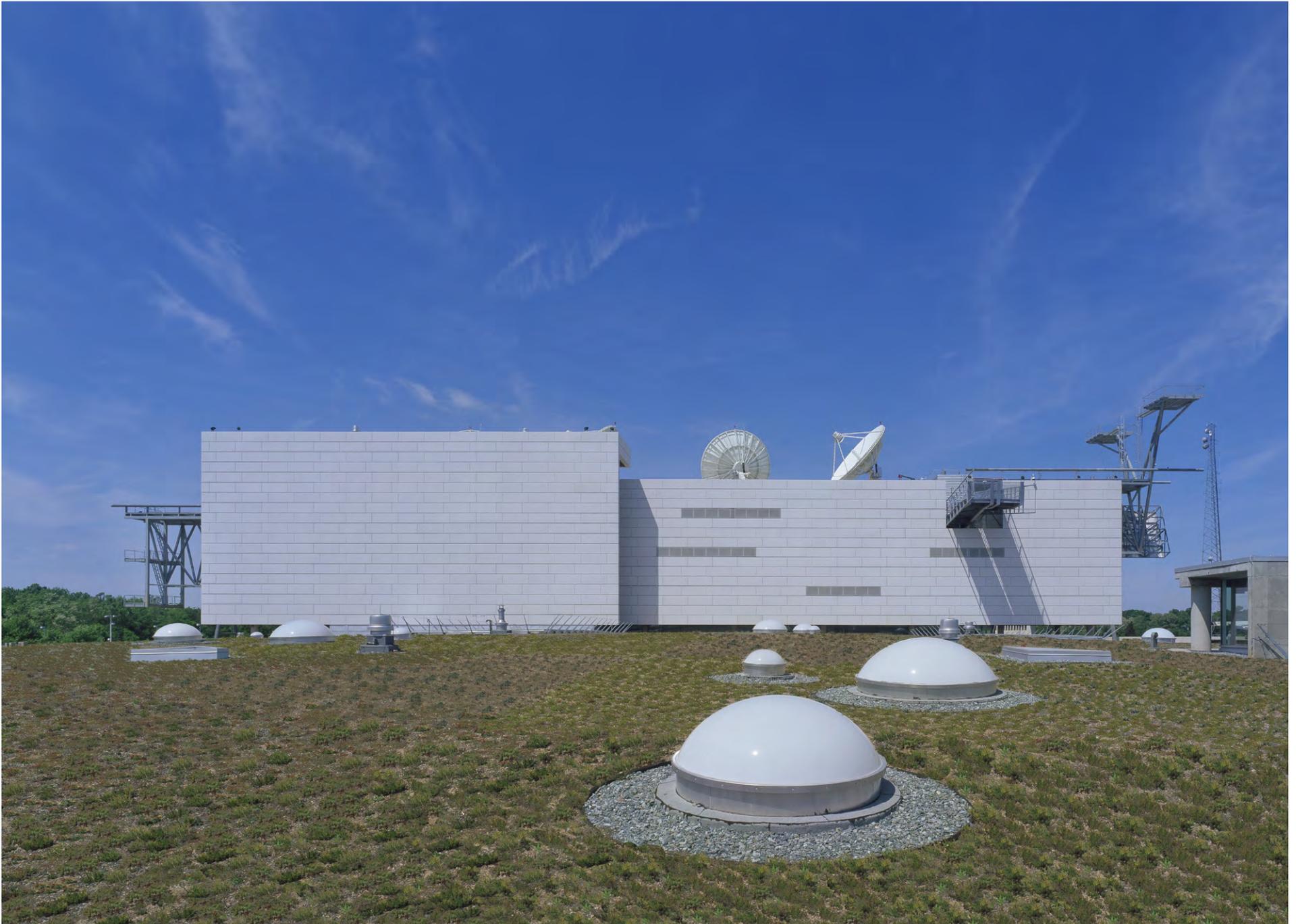
#### **Issue:** *Biodegradation of media*

Biodegradation of plant fibers and other organic constituents in medium that contains high levels of organic matter can lead to a collapse of the soil structure, to reduced drainage capacity, and to anoxic conditions that inhibit plant growth. Failed medium can rarely be improved by amendment, and failure usually results in removal and replacement of the material.

#### **Recommendations**

Medium properties should follow conventional recommendations for green roofs. In temperate climatic zones like the NCR region, growing medium should have low organic matter content.





**GSA National Capital Region - NOAA Satellite Operations Facility (NSOF), Suitland, Maryland**  
A 146,000 square foot extensive green roof installed on the new LEED Gold certified operations center (2006).