



Standard Guide for Selection, Installation, and Maintenance of Plants for Green Roof Systems¹

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1. Scope

1.1 This guide covers the considerations for the selection, installation, and maintenance of plants for green roof systems.

1.2 This guide is applicable to both extensive and intensive green roof systems.

1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents²

2.1 *ASTM Standards:*

E 631 Terminology of Building Constructions

E 2114 Terminology for Sustainability Relative to the Performance of Buildings

3. Terminology

3.1 *Definitions:*

3.1.1 For terms related to building construction, refer to Terminology **E 631**.

3.1.2 For terms related to sustainability relative to the performance of buildings, refer to Terminology **E 2114**.

4. Summary of Guide

4.1 This guide covers the selection criteria for plants to be used on green roofs. Primary considerations are as follows:

4.1.1 Design intent,

4.1.2 Aesthetics,

4.1.3 Climate; including both macroclimate and microclimate,

4.1.4 Plant characteristics, including the rate of establishment, longevity, and disease and pest resistance, and

4.1.5 Media composition and depth.

4.2 This guide covers the installation of plants for green roofs. Installation methods include:

4.2.1 Precultivation, and

4.2.2 Direct planting on roof (seeds, root cuttings, and plugs).

4.3 Guidance is also provided for the maintenance of plants for green roofs.

5. Significance and Use

5.1 This guide addresses performance characteristics for green roof systems with respect to the planting. A rooftop is an extreme environment with strong and variable wind patterns and little or no protection from the sun's intense heat and ultraviolet radiation. Selection of plant material can be crucial for success of the green roof system.

5.1.1 This guide provides general guidance only. It is important to consult with a professional horticulturist, green roof consultant, or work with similar professionals that are knowledgeable, experienced, and acquainted with green roof technology and plants.

5.2 Determining these performance characteristics of green roof systems provides information to facilitate the assessment of engineering aspects of the facility. Such aspects may include structural design requirements, mechanical engineering and thermal design requirements, and fire and life safety requirements.

5.3 Determining these performance characteristics of green roof systems provides information to facilitate assessment of the performance of one green roof system relative to another.

6. Selection

6.1 In general, green roofs can be categorized into two types, intensive or extensive, depending on the plant material and planned usage for the roof area.

6.1.1 *Intensive green roofs*—Intensive green roofs utilize a wide variety of plant species that may include trees and shrubs and are generally limited to flat roofs. Use of large plants requires deeper media layers, possibly 25 cm (10 in.) or more, which results in more weight and a need for an increased

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

structural load capacity of the building. Intensive green roofs usually have higher requirements for water, labor and other resources than extensive green roofs.

6.1.2 Extensive green roofs—Extensive green roofs use a narrow 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 in a media layer as shallow as 2.5 cm (1.0 in.) and, therefore, they can often be installed on buildings without the cost of major structural alterations. Extensive green roofs generally require less maintenance and are generally less expensive to install than intensive green roofs.

6.2 Criteria for Selecting Species:

6.2.1 Design Intent—The design intent will impact plant selection. Aspects of design intent that may influence plant selection include: accessibility and use of the roof, stormwater management objectives, xeriscaping objectives, and thermal insulation objectives. Considerations for wildlife, such as establishing connections with a wildlife corridor or providing habitat for wildlife of local ecosystems may also impact the plant selection. Considerations for wildlife should be coordinated with a knowledgeable consultant and the regional Extension Service to verify anticipated wildlife in that climate at the rooftop elevation.

6.2.1.1 The design intent and available installation and maintenance budgets are key factors in determining media depths and plant selection.

6.2.2 Aesthetics—Aesthetics often drive green roof design and plant selection. Combinations of evergreens and flowering plants with a long blooming season work well together. However, flowering perennial plants may recede into the ground during winter or long, hot, dry periods in the summer. If they survive roof environmental conditions, they will usually regenerate themselves from the root system, but periods of drought can leave a mass of browned-out, dead looking plants that could be a fire hazard. Similarly, grasses are difficult to keep green throughout the summer. One can allow grasses to grow until June and then cut them back to approximately three inches in height, but this practice requires extensive labor. Plants may look fantastic early in the year, but most cannot withstand summer heat and drought conditions when growing in shallow extensive roof media depths. In order to grow most annuals, perennial flowering herbaceous plants, and grasses, either irrigation must be present or the media must be deeper. If irrigation is not available, then succulent species such as *sedum*, *semperivum*, and *delosperma* are considered good choices because of their ability to withstand extended drought and other adverse environmental conditions often present on a rooftop. Unlike most perennials and grasses, succulents are not considered fire hazards because of the large percentage of water that is stored in their leaves. The aesthetic value of the roof will continually change throughout the growing season and over time. Plant competition and succession will occur as in any landscape. Similarly, identical plant palettes will look and behave differently depending on the local environmental conditions.

6.2.3 Climate—Climate has a major impact on plant selection. Typically, the microclimate of the roof will be different than the microclimate in the same location at grade. Microclimates on a rooftop can dramatically affect plant health and appearance and contribute to the failure of a green roof system.

6.2.3.1 In particular, average high and low temperatures, extreme hot and cold temperatures, wind, and the amount and distribution of rainfall throughout the year will determine what species can survive in a specific area. Drought tolerance is important because high levels of solar radiation and low media moisture are usually the norm, especially in shallow extensive systems. Climatic conditions, especially the amount and distribution of rainfall and temperature extremes, will eliminate the use of certain species or will dictate the need for irrigation.

6.2.3.2 Microclimate specific to the location must also be considered. Surrounding structures may shade a portion of the roof, thus altering the evapo-transpiration rate of the plants. Drying winds will be stronger the greater the elevation of the building and a roof built with different levels can cause changes in wind and sun patterns, leaving some areas hot and dry and other areas relatively cool and moist. Roof slope and orientation will influence the intensity of the sun, as south-facing slopes will be drier and warmer than north-facing slopes. Slope also affects water-holding capacity, as sloped roofs will drain faster due to the laws of gravity. Plants growing near the bottom of a slope will likely be greener because of higher media moisture content relative to the top. This could be a factor in choosing plant species that will be successful. One must also consider the exhaust from air vents for heating and air conditioning units as well as chemical exhaust from industrial buildings.

6.2.4 Plant Characteristics—Other qualities usually considered desirable for green roof plants include rate of establishment, longevity, and disease and pest resistance. Low growing plants that spread rapidly to cover the media reduce potential erosion problems and inhibit weeds. Although, rapid coverage is important, the lifespan of these plants should be considered, as many rapidly spreading plants may be short-lived. The ability of the plant species to be self-sustaining reduces the need for future replanting and maintenance. Species that are long-lived, that reseed themselves, or spread vegetatively should continue to provide full coverage as long as environmental conditions are favorable. In addition, aggressive plants may provide fast coverage, but one must be careful not to introduce invasive species. For the most part, species such as *sedum* will not become invasive in a temperate climate because it will not be able to compete with the local native species. *sedum* does best on shallow, dry, media where most other species cannot survive. Even if it does escape it is not likely to become established.

6.2.4.1 It is nearly impossible to develop one plant list that is suited for all areas of North America because of the vast array of climates present. It is important to consult with a professional horticulturist, green roof consultant, or work with similar professionals that are knowledgeable, experienced, and acquainted with green roof technology and plants.

6.2.5 Media—Medium composition and depth both have major impacts on plant selection for green roof systems. Most

green roof medium is comprised of a balance of lightweight, well-drained materials as well as other components that have good water and nutrient holding capacity. The ideal growing medium has the ability to sustain plant life with little input or breakdown over time. Expanded shale, clay, slate, lava, and pumice are porous and lightweight, but do not have much water holding capacity. This is particularly a problem when these components are present at the upper surface of the medium layer, as they may not retain enough moisture to allow good seed germination and establishment. Clay, sand, topsoil, and organic matter have good physical properties for growing plants, but are very heavy, especially at peak water holding capacity.

6.2.5.1 Medium depth also influences the plants that can be grown. Shallower medium depths will not only dry out faster, but they are more subject to fluctuations in temperature. A shallow depth will likely make root systems more susceptible to cold damage as roots are generally not as cold tolerant as the tops of plants. In colder climates, it is especially important to identify the lowest temperature that the area experiences during winter. In addition, a deeper medium is necessary for woody species, grasses, and many annual or perennial flowering plants. In some cases, plant growth is stunted in a shallow medium due to restrictions in the root zone. However, a deeper medium also promotes growth of undesirable weeds.

7. Installation

7.1 *Methods*—Several methods exist for propagating and installing plant material in green roof systems. Vegetation may be planted directly on the roof as plugs or seed, or precultivated in the field at ground level as blankets or modular trays and then transported onto the roof. Care must be taken to avoid damaging the waterproofing membrane during installation.

7.1.1 *Precultivation*—Germinating seed or rooting cuttings is easily accomplished at ground level where it is easier to provide intense cultural practices and monitor results. Once transferred to the roof, precultivated vegetation can provide immediate plant surface coverage.

7.1.2 *Direct Planting on a Roof*—Germinating seed or rooting cuttings directly on the roof eliminates the difficulty of transporting and transplanting plants to the roof. However, environmental conditions are usually more extreme on a roof, which is not ideal for seed germination and plant establishment. Wind and direct sunlight can quickly dry out the top portion of the media and kill newly germinated seedlings. Dry media also tends to be susceptible to wind erosion, but may be held in place with netting to reinforce the media during plant establishment. The use of a shade cloth may help to reduce the negative effects of too much direct sun. An irrigation system is often a necessity since seedlings are in danger of drying out when rainfall is inadequate.

7.1.2.1 When planting on the roof, container-grown plants and plugs should be planted with their media surface level with the surface of the roof media. If the media depth in the container is deeper than the media layer on the roof, then loosen the roots at the bottom of the root ball, remove excess media, and plant so the media levels are equal while the roots are distributed laterally in all directions. It is best to avoid trying to install plants with a deeper rootball than the media in

which they are being planted. Tap rooted plants can be placed in mounded areas over structurally sound portions of the roof.

7.1.2.2 *Plugs*—Plugs already have an established root system and canopy and can continue growing after they are transplanted. However, a large number of plants are required to achieve rapid cover because of the limited number of growing points. Time to achieve complete coverage depends on the size, initial spacing, and growth rate of the plugs. Also, plug plants will take time to become anchored in the media. During this establishment phase, birds sometimes remove plugs as they search for food.

7.1.2.3 *Cuttings*—Cuttings of *sedum* root quickly, thus providing numerous growing points, but the cuttings are subject to drying out before rooting takes place if hot, dry conditions exist. Shade cloth and irrigation is necessary unless cuttings are placed in early spring or fall. Cuttings are not an option for most other plant species if one is establishing the plants on the roof. Similar to cuttings, propagation by seed can provide rapid cover, but attention must be paid to cultural conditions.

7.2 *Seasonal Considerations*—The best time of year to plant a green roof is in spring following the last frost or during autumn sometime before the first frost. Planting during the summer can be successful, but irrigation must be supplied and additional attention must be paid to the health of the plants. One day of hot dry sun with temperatures of 90°F could destroy the entire planting. Strict attention to plant health must be paid during the first month. On extensive roofs, close to full coverage should be achieved within one year.

8. Maintenance

8.1 *Irrigation*—Container-grown plants and plugs should be watered immediately following planting and then watered frequently for the first few weeks unless ample rainfall occurs. Then gradually wean them off of irrigation. After establishment during the first year, watering may not be necessary depending on the local environment and the plant species chosen. The amount of water required depends on the plant species. In general, extensive roofs should not require irrigation. However, it may be advisable to have an irrigation system in place just in case the site experiences an extended drought or other unusual weather patterns.

8.1.1 Passive and active irrigation or combinations of both are potential methods of irrigating plants. Passive systems store rainwater in the drainage layer, which moves back up into the media layer via capillary action. Examples of passive systems include fiber mats placed under the growing media that act like a sponge; cups formed into the drainage mat; and contours in the bottom of a modular unit. Active irrigation involves pumping water onto the plants either by subirrigation or, more commonly, overhead irrigation. Numerous options are available for overhead irrigation through a variety of commercially available spray heads. Watering may be performed manually, controlled by time clocks, or computer programs that sense media moisture. In all cases, water must be monitored. An irrigation system should be customized to each specific green roof system based on the intended use of the roof, choice of plant materials, media depth, environmental conditions, and budget. A professional irrigation specialist should perform irrigation system design.

8.1.2 The need for long-term irrigation is dictated by climatic conditions at the site, especially the amount and distribution of rainfall and temperature extremes. These conditions can eliminate the possibility of using certain species.

8.2 *Plant Maintenance*—Green roofs will require regular maintenance, especially for intensive roofs.

8.2.1 Periodic fertilization may be necessary to maintain lush growth. Species such as *sedum* require very little fertilizer and often do better when neglected.

8.2.2 Herbicides, insecticides, fungicides, and fertilizers should be avoided. If they are necessary, they should be used sparingly. These chemicals could potentially hasten degradation of the roof membrane. During the first two growing seasons, undesired plants should be removed so that the desired vegetation can obtain full coverage. Volunteer woody species such as poplar, should be removed from extensive roofs before

the roots compromise the roof materials. Weeds can be controlled by utilizing shallow media layers and by foregoing irrigation. Many weeds cannot survive in shallow medium depths and thus have trouble competing with drought tolerant species such as *sedum* or *sempervivum*.

8.2.2.1 If limited funds are available for long-term maintenance, then drought tolerant succulents such as *sedum* should be grown in a relatively shallow media. Otherwise, weeds may become a serious problem. If the maintenance budget is not a concern, then the choice of plant material and media depths are widely expanded.

9. Keywords

9.1 green roof; plants; sustainable development; sustainability

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