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Elevated Gardening

The basics of growing green roofs

By Marie-Anne Boivin, M.Sc. agr.

Green roofs have a long history, dating back to the Hanging Gardens of Babylon built circa 600 BC. They have become a staple in Europe, particularly in France, Germany, and Switzerland, where state and municipal governments encourage green roof implementation with legislative and financial incentives.

In the 1980s, the development of a lighter growing medium to support plant growth in a thin layer of soil led to their increasing popularity in Europe. Today, millions of square feet of green roof area are installed annually. The major push behind this growth has been water management and retention—relieving stormwater pressure on sewage systems and water treatment facilities.

Photos courtesy Soprema

In North America, interest in green roofs has grown following the introduction of European technology in the mid 1990s. As governments recognize green roof benefits through incentives and legislation to mandate their construction on commercial, industrial, institutional, and residential properties, interest in the technology is gaining momentum. For example, the City of Toronto offers $1 per 0.9 m^2 (1 sf) for green roof installation. (See "Green Roof Incentives from Coast to Coast").

Corporations and individuals are also pursuing green roof installations for environmental and economic benefits. The Canada Green Building Council's (CaGBC's) Leadership in Energy and Environmental Design (LEED Canada) certification program and international organizations such as the Toronto-based Green Roofs for Healthy Cities (GRHC) have also been instrumental in initiating installations.

Pictured above, the extensive green roof at the Bedford Oceanography Institute in Dartmouth, N.S., was installed in 2002. The assembly consists of a wide variety of grasses.

What is a green roof?

Roofing manufacturers have developed sophisticated technology, designing green roof systems that can easily and cost-effectively be installed over the existing roof waterproofing membrane in a matter of days. While installation may be quick, the process must be well understood to create a green roof that meets owner expectations.

A green roof is a structure containing engineered soil and plants placed over an existing roof. Most are constructed on low slope roofs (*i.e.* slope of about two per cent), but can be sustained on slopes up to 40 per cent and greater when measures are taken to prevent soil erosion.

A green roof structure consists of four major layers—drainage board, water retention product, root barrier, and growing medium. The layers are available as an integrated system for ease of installation. Green roof components made by different manufacturers offer some compatibility, but a single source supplier provides a warranty covering the entire green roof structure.

Drainage board

The drainage board, made of high-density polyethylene (HDPE) with a factory-laminated geotextile membrane directs unabsorbed rainwater to drains.

Water retention product

Different water retention products, such as containers with cups for holding water or capillary mats, can store and retain extra stormwater to meet plant needs.

Root barrier

The root barrier may be a physical obstruction made of coated, woven, and micro-perforated fabric, or a filter impregnated with chemicals. It blocks plant roots from invading the underlying roof membrane or drainage board, depending on the system. The chemicals used in the root barrier should be approved by Health Canada's Pest Management Regulatory Agency (PMRA) for use with green roofs.[1]

Growing medium

A specially formulated growing medium that is different from common garden soil is spread over the surface to be greened to receive the selected plant material. These mediums contain a highly porous mineral aggregate content (*i.e.* between 55 and 70 per cent) of

Putting Green Roofs to the Test

In 2000, the National Research Council of Canada's Institute for Research in Construction (NRC-IRC) constructed a field roofing facility at its Ottawa campus to evaluate roof temperature, peak runoff volume, and total runoff volume.*

Urban heat island (UHI) reduction

A median divider separated the facility's roof into two areas—a generic extensive green roof with 152 mm (6 in.) of growing medium and grass, and a modified bituminous (mod-bit) reference roof with instrumentation. This allowed the researchers the opportunity for direct comparison.

The green roof significantly reduced the temperature and daily temperature fluctuations experienced by the roof in spring and summer. The membrane on the reference roof reached close to 70 C (158 F), while the membrane under the green roof stayed a cool 25 C (77 F).

Heat flow through the roofing system was significantly moderated. During a two-month period, the green roof reduced 95 per cent of heat gain and 26 per cent of heat loss in comparison to the reference roof, with an overall heat flow reduction of 47 per cent. The average daily energy demand for space conditioning due to heat flow through the roof was reduced by more than 75 per cent by shading, evapotranspiration, and improved insulation values.

Stormwater runoff

At NRC's field roof facility, an overall runoff reduction of 54 per cent from the green roof was recorded from April to September. In addition to reducing the total volume of runoff, the green roof delayed runoff to an off-peak time and slowed runoff flow rate.

* See Bas Baskaran and Karen Liu's "Thermal Performance of Green Roofs Through Field Evaluation," NRC-IRC (June 2003).

materials such as crushed brick, expanded shale, or volcanic rock to prevent compaction while providing a high air-filled porosity for good plant anchorage. Growing media also contain organic matter such as compost and peat moss.

Irrigation is an option, depending on the type of plants selected for the green roof and whether they are supplied as seeds, cuttings, plugs, pre-grown mats, or plants in containers. Green roof manufacturers can suggest plants best suited to the local environment and building location. Selection depends on the type of green roof and whether an irrigation system will be installed.

A significantly wider variety of plants can be used in intensive and semi-intensive green roofs than in extensive ones (discussed later), when provision is made for irrigation and regular maintenance. Many building owners and landscape architects favour native plant species in rooftop gardens, because they are usually well adapted to the local climate. As many native plants require a high moisture level, selection of drought-resistant species is a key consideration.

For buildings lower than six storeys, the recent introduction of special blowing equipment delivers the growing medium from ground level to the roof, quickly and effectively. For higher buildings under construction, green roof components and soil can be placed by a crane.

Shades of green

The type of green roof selected is based on cost, esthetics, function, maintenance commitment level, and roof slope. However, the roof load capacity is often the primary determining factor, particularly for existing buildings (as discussed later in this article). Extensive, intensive, and semi-intensive green roofs are designed to match desired garden effect, maintenance level commitment, and budget.

Extensive

Extensive green roofs are characterized by low maintenance requirements with plant material selected for self-sustaining capabilities, such as succulent grown covers, drought-resistant perennials, and grasses. Many sedum species are well adapted for extensive green roofs in all Canadian regions, as are species of chive, some iris, creeping thyme, and fescues. Extensive roofs are primarily chosen for their environmental and energy-savings benefits, and are usually inaccessible to building occupants.

Although low-maintenance, extensive green roofs cannot be entirely neglected. The plant materials need to be watered during the first growing season until established and in long periods of drought. Four times a year, the roof should be inspected to evaluate plant health and remove invasive weeds or tree seedlings.

Nevertheless, the degree of maintenance required is significantly less than that of a backyard perennial garden. For case study examples of extensive roof systems in Canada, see "Green Roof Efforts Intensify in Cambridge," and "The Total Package: A Roof Garden with Form and Function."

Intensive

Intensive green roofs look more like traditional gardens with a wider variety of plant materials (including shrubs and trees, depending on the desired garden effect and budget). These gardens are designed to be enjoyed by building tenants and may include walkways, benches, lighting, and ponds. A structural engineer should calculate the roof load capacity based on the components specified in the green roof

Green Roof Efforts Intensify in Cambridge

Photos courtesy Roof Greening Systems

Cambridge (Ont.) Civic Centre's extensive green roof provides esthetic appeal, wildlife habitat, and stormwater management.

An extensive green roof, designed and planned by the City of Cambridge, Ont., and the Fleisher Rideout Partnership, a Toronto-based landscape architecture firm, was installed by Roof Greening Systems on the fourth floor of the new Cambridge Civic Centre in July 2007. It can be enjoyed via a walkout and viewing platform.

The city's goal was to exemplify what the future holds for urban centres.

"Green roofs esthetically make our urban environment look better, and provide wildlife habitat and stormwater management among other benefits," says Susan M. Reise, a landscape design architect with the municipality. "The green roof will also contribute to the city's effort to obtain a gold certification in the Leadership in Energy and Environmental Design (LEED) program for the building."

Both the roof and the green roof system were selected from a single manufacturer to obtain one warranty for the entire roof. It begins with a modified bitumen (mod-bit) base sheet and cap-sheet membranes, which provide a watertight roofing system over which the green roof components are installed. The first component layer is a high-density polyethylene (HDPE) drainage panel with a geotextile felt backing to ensure excess water flows freely to the roof drain. The next layer is a capillary mat for rainwater retention, which also contains a micro-irrigation system. The green roof does not require regular watering, as the chosen grasses, perennials, and succulents are hardy and drought-tolerant.

Over the capillary mat, lie a root barrier and growing medium. The base layer of growing medium has a highly porous mineral aggregate designed for use on irrigated roofs. In those areas with perennials, the growing medium's formulation is modified to supply higher moisture levels required by these plants.

Looks can be deceiving: The green roof at St-Mary's Health Centre in Montreal looks semi-intensive, but is actually extensive.

Images courtesy Soprema

The rivers of rock at St-Mary's Health Centre are esthetically pleasing as well as functional—they keep the plants in place.

design. For safety, a 1.1-m (42-in.) railing or parapet is required around the green roof.

Semi-intensive

Semi-intensive green roofs are a lightweight alternative, designed primarily for visual appeal. These roofs can be accessible to building occupants or created to be seen from a distance. As esthetics drive this design, plant choices usually require irrigation, fertilizers or amendments, and regular maintenance to preserve a manicured landscape. The main objective is to present an attractive roof garden as opposed to an ecological approach for biodiversity enhancement.

The semi-intensive green roof is more appropriate for terraces, patios, and rooftops used as amenity space. The landscaped portions add value to condominiums, offices, or rooms with direct access to the green roof or simply having a view overlooking the green canopy.

Factors in design

When designing a green roof, consideration should be given to a range of aspects.

Roof size

A green roof can cover the entire roof deck or only part of the surface, depending on the building owner's objectives. Part of the roof can be built immediately and expanded as budget allows because of the integrated system approach to installation.

Roof load capacity

For an existing building, the roof load capacity must be evaluated by a structural engineer; design for new construction should accommodate these capacity limitations. An extensive or semi-intensive green roof with 152 mm (6 in.) of growing medium requires a dead load capacity of 11 to 20 kg (25 to 45 lb) per 0.09 m^2 (1 sf), whereas an intensive roof with more than 0.3 to 0.9 m (1 to 3 ft) of growing medium may need 90 kg (200 lb) per 0.09 m^2 (1 sf). These calculations include the entire green roof structure, as well as the weight of water when the growing medium is fully saturated.

A herbaceous perennial can grow from 100 to 900 g (0.25 to 2 lb) within a few years. New lightweight growing medium formulations containing a highly porous mineral aggregate content can be adapted to reduce saturated weight to as low as 8 kg (18 lb) per 0.09 m^2 (1 sf), where a roof has limited load capacity. Availability of this formulation increases the opportunity for installing green roofs on existing buildings.

The load capacity must reflect standards in the *National Building Code of Canada* (*NBC*), which includes the weight of human traffic, as well as regional snow loads. For human traffic, the minimum load capacity is 4.8 kPa (100 psf).

Roof slope

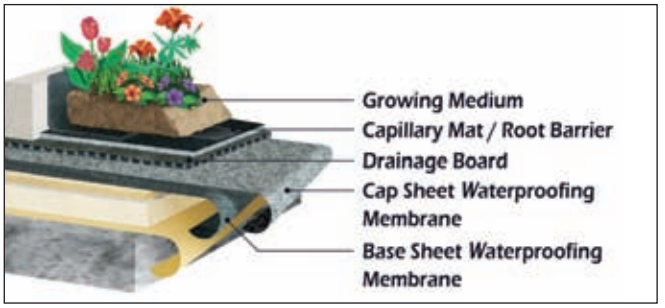
A minimum slope of two per cent to a maximum of 40 per cent is recommended. As the slope increases, horticultural products such as mats and grids (typically used for erosion control in ground-level gardens) may be used to prevent soil erosion toward the bottom of the slope. Slopes greater than 40 per cent require mechanical fixation to stabilize the growing medium and plant materials.

Waterproofing membrane

The roof's existing waterproofing membrane must be assessed for its condition and anticipated life expectancy. Consideration should be given as to whether repairs, re-covering, or replacement will be necessary in the next few years—if required, these steps should be completed before the green roof is installed.

Budget

The type of green roof and plants chosen will dictate the depth of



Basic green roof components, installed over the roofing membrane, include a drainage layer, capillary mat, root barrier, growing medium, and a selection of appropriate plants.

Recently introduced blowing equipment delivers soil from ground level to the roof, making the promise of green roofs more accessible.

The Total Package: A Roof Garden with Form and Function

The green roof at the Norman and Robert Hayes Pavilion at St-Mary's Health Centre (Montreal) looks semi-intensive because of the landscape design—esthetics are important, because the garden is visible to people entering the hospital. 'Islands' of sedum and creeping thyme are surrounded by 'rivers' of small rocks with separation lines of grasses such as blue oats. Despite its esthetic consciousness, this green roof is actually extensive because it is inaccessible with low-maintenance plant materials.

This green roof system has a water retention capillary mat over the drainage board, which is capable of holding about 12 L (406 oz) of rainwater per 1 m^2 (10.8 sf) to provide adequate moisture for plants. The mat also contains an irrigation system with drip tapes connected to a water line that automatically opens in drought conditions. A time clock, humidity sensor controller, and pressure regulator on the water line control a slow drip into the capillary mat which acts as a reservoir. This sub-irrigation has the following benefits:

- plants develop drought resistance as the roots grow down to the underground reservoir instead of remaining close to the surface;
- less water is lost through evapotranspiration than with a water sprinkler; and
- seeds brought by the wind have a reduced potential to germinate due to the growing medium's dry surface.

the growing medium, required level of maintenance, and necessity for an irrigation system. These components should be factored into the budget.

The cost of a green roof system can be $12 to $15 per 0.09 m^2 (1 sf) or more, depending on additional factors such as the location and type of building. Elements such as surface area, building height, and types of vegetation (*i.e.* whether seeds, cuttings, plugs, pre-grown mats, annuals, bushes, or trees are used) affect the final installed price of the green roof. Building height dictates the type and cost of the equipment needed to hoist components to the roof. For example, a two-storey building may use a boom truck, whereas a high-rise requires a crane.

Environmental motivations

Environmental consciousness and energy savings play a significant role in why building owners may choose green roofs.

Reducing urban heat island

Urban heat island (UHI) refers to urban air and surface temperatures higher than nearby rural areas. Air temperatures in some urban areas can be up to 5.6 C (10 F) warmer than the surrounding natural land cover.

Studies on the impact of the UHI effect show if only five per cent of buildings in downtown Toronto had green roofs, the temperature would be reduced by 0.5 C (1 F).[2] This temperature reduction results from the daily dew and evaporation cycle—in the process of evapotranspiration, plants use heat energy when evaporating water. Approximately 1 m^2 (10.8 sf) of foliage can evaporate more than 0.5 L (17 oz) of water on a hot day. (See "Putting Green Roofs to the Test.")

Green roofs significantly reduce heat gain in spring and summer, but are less effective in lowering heat loss in fall and winter. In colder months, roof gardens behave similar to typical ground level plants in frozen garden soil. However, as rooftop plants are subjected to severe winter conditions—such as higher wind velocity and lack of snow cover—they are selected based on hardiness.

Extending roof life

The green roof also protects the building's waterproofing membrane. Temperature fluctuations cause thermal expansion and contraction, a leading contributor to premature waterproofing failure over time. Green roofs reduce the difference between day and night temperature fluctuations, substantially adding to the membrane's service life. They also protect the membrane from the damaging effects of ultraviolet (UV) radiation.

Reducing stormwater runoff

Green roofs are increasingly advocated as a component of stormwater management strategy for urban areas. Part of the rainfall is stored in the growing medium, used by plants, and released into the atmosphere through evapotranspiration. Green roofs also delay runoff into sewage systems and reduce potential for combined sewage overflow events that plague many cities with aging infrastructure. With enough garden roofs, stormwater runoff would substantially reduce and be delayed, creating significant savings in wastewater treatment. (See "Putting Green Roofs to the Test.")

'Cleaning' the air

While the green roof absorbs heat, it decreases the tendency for thermal air movement and filters the air moving across it—1 m^2

(10.8 sf) of grass roof can remove 0.2 kg (0.4 lb) of airborne particles every year.

Economical motivations

The addition of a green roof can enhance property value and building marketability. At a condominium complex, the penthouse suites with green roof terraces tend to sell more quickly and at a higher premium than those with only patios. Commercial space between high-rise buildings with a green roof terrace commands higher rents, but attracts additional customers for restaurant and boutique tenants because of the pleasant surroundings.

Green roofs can also camouflage buildings, providing an esthetic view for tenants of higher, adjacent facilities. A green roof and green walls can blend a box-type concrete block structure into surrounding trees, making the building less noticeable.

No ordinary garden

A green roof cannot be equated to a ground-level garden. Roof gardens have a unique microclimate which requires plant material that can survive and thrive at elevation. These spaces need to be tolerant of heat and direct radiation, drought, wind, and frost never experienced by regular garden plants.

Plant selection is contingent on the regional climate zone, type and depth of growing medium, roof height/slope, influence of surrounding buildings, and availability of irrigation. Shallow root growth and regenerative properties are preferable and succulents are well suited to most rooftop environments.

A landscape architect specializing in green roof design should be consulted. Green roof suppliers can be an additional source of information, as many have specialists who can provide recommendations on plant selection and maintenance. The aforementioned Green Roofs for Healthy Cities is also an invaluable resource—it conducts conferences and seminars and enables contact with professionals who can assist with green roof design and installation.[3] ✍

Notes

[1]To verify if chemicals are approved, visit the Pest Management Regulatory Agency's website at www.pmra-arla.gc.ca.

[2] Studies conducted in Toronto by Environment Canada. For details, visit www.cleanairpartnership.org/cooltoronto/pdf/finalpaper_bass.pdf.

[3] For more information, visit the GRHC website at www.greenroofs.org.

Marie-Anne Boivin, M.Sc. agr., is an agronomist that has been actively promoting the creation of green spaces on top of new and existing buildings as an integrated design strategy for urban sustainable development for more than 10 years. She is co-ordinator of Sopranature development at Soprema where she assists architects, landscape architects, and engineers with green roof and roof garden conception and design. Boivin regularly makes presentations, publishes articles, and presents workshops and programs at colleges and universities on green roof technology. She can be contacted via e-mail at maboivin@soprema.ca.

ASTM and Green Roofs

A list of ASTM International standards for green roof installation is provided below:

- ASTM E 2399-05, *Standard Test Method for Maximum Media Density for Dead Load Analysis of Green Roof Systems*;
- ASTM E 2397-05, *Standard Practice for Determination of Dead Loads and Live Loads Associated with Green Roof Systems*;
- ASTM E 2398-05, *Standard Test Method for Water Capture and Media Retention of Geocomposite Drain Layers for Green Roof Systems*; and
- ASTM E 2396-05, *Standard Test Method for Saturated Water Permeability of Granular Drainage Media [Falling-Head Method] for Green Roof Systems.* ✍

Green Roof Incentives from Coast to Coast

Port Coquitlam, B.C., is the first Canadian municipality to enact green roof legislation with the adoption of a zoning bylaw amendment that requires green roofs for all buildings with an area greater than 5000 m^2 (53,821 sf). Kim Fowler, director of development services, says the amendment is an integral part of the City of Port Coquitlam Sustainability Initiative.

"The primary purpose is to obtain environmental benefits including intercepting and reducing stormwater runoff, improving building thermal performance and energy consumption, and reducing the urban heat island effect," Fowler says. "The first high-density tower being built in the downtown core will have an extensive green roof, and more are planned."

Toronto was among the first cities in Canada to actively promote green roofs. A short-term inaugural program in 2006—the Green Roof Incentive Pilot Program—was developed to support residential, commercial, and institutional construction of various green roof types. Sixteen successful applicants were approved as part of the pilot program and, as a result, approximately 4000 m^2 (43,057 sf) of green roofs are being constructed. The program provides a grant of $10 per 1 m^2 (10.8 sf) of eligible green roof area, up to a maximum of $20,000. ✍