Toronto Green Roof Construction Standard

Supplementary Guidelines

TORONTO

Livegreen Toronto

Acknowledgements

Toronto Building greatly appreciates the contribution of the City of Toronto Green Roof Technical Advisory Group in the preparation of the City of Toronto Green Roof Construction Standard and the Supplementary Guidelines.

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The Toronto Green Roof Construction Standard (TGRCS) is the first municipal standard in North America to establish the minimum requirements for the design and construction of green roofs. The TGRCS establishes the City's requirements while also meeting the Ontario Building Code (OBC) requirements.

Green Roofs deliver a number of benefits, outlined in the City's green roof strategy, "Making Green Roofs Happen" including stormwater management, energy efficiency, urban air quality and managing the urban heat island effect of urbanization. The TGRCS has been developed to facilitate design flexibility so that each green roof may be designed to maximize its effect in each project.

I am pleased to provide these Supplementary Guidelines to the TGRCS. The Guidelines have been produced to provide designers and others with better understanding of the TGRCS. This is a companion document to the Toronto Green Roof Bylaw and is intended to assist by providing best practices, explanatory material (including the related Ontario Building Code provisions) and other green roof resources.

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Introduction

The purpose of the Toronto Green Roof Construction Standard (Toronto Municipal Code Chapter 492, Article IV) is to provide requirements for the design of a green roof that will meet the City's minimum requirements for green roof construction while also meeting the Ontario Building Code (OBC) requirements. The Standard does not replace or alter any existing Code requirements, or define a singular code compliant green roof design.

Public consultations as part of the bylaw development identified features of the draft standard that were more appropriate as recommendations or considerations in green roof design, rather than prescriptive requirements of a construction standard. The guidelines identify some of these "best practices". The document also identifies provisions of the Ontario Building Code that would apply to the design of green roofs, as well as "traditional" roofs.

This document is not a "how to manual" on green roof design and construction. It is recommended that the team involved in choosing a green roof provider should undertake the appropriate research. This research should include reviewing the complexity and size of green roofs successfully installed by the provider. The team should ask for references and where possible, visit previous projects completed by the provider. Compare the green roof to what was planned and ask the provider about maintenance plans. Understand that green roof systems vary in complexity and purpose.

The supplementary guidelines should not be relied upon as a substitute for construction, design, engineering, and/or policy advice. The City of Toronto does not assume responsibility for errors or oversights resulting from the information contained herein. While care has been taken to ensure accuracy, readers must refer to the actual wording of the documents referenced in these guidelines.

Relation to the Ontario Building Code

Section 8 of Toronto Municipal Code Chapter 492 outlines the relationship between the Toronto Green Roof Construction Standard and the Ontario Building Code (OBC).The Toronto Green Roof Construction Standard is considered an acceptable solution for the design and construction of a Green Roof in addition to the acceptable solutions contained in parts 3 to 12, Division B, of the OBC. Designs shall meet the OBC objectives to demonstrate compliance with the OBC; however a design that complies with the provisions of Toronto Municipal Code, § 492-9 shall be deemed to comply with such objectives.

The reader should appreciate that the successful application of the measures described in the By-law and the Supplementary Guidelines requires a clear understanding of the principles governing the OBC requirements for each measure and proper implementation of certain concepts may require professional design.

In late 2009, Ontario Regulation 503/09 amended the 2006 Ontario Building Code (Ontario Regulation 350/06). The amendment added the following clause to Sentence 1.4.1.3.(1) of Division A, thereby identifying the Toronto Green Roof Bylaw as an applicable law under the Ontario Building Code:

(c.1) by-laws made under section 108 of the City of Toronto Act, 2006, but only with respect to the issuance of a permit for the construction of a green roof if the construction of the roof is prohibited unless a permit is obtained,

Source: http://www.e-laws.gov.on.ca/html/source/regs/english/2009/elaws_src_regs_r09503_e.htm

1 DEFINITIONS AND GREEN ROOF COMPONENTS

Green Roof

City of Toronto By-law No.583-2009 § 492-1 Definitions
GREEN ROOF — means an extension of an above Grade roof, built on top of a human-made structure, that allows vegetation to grow in a growing medium and which is designed, constructed and maintained in accordance with the Toronto Green Roof Construction Standard.

Green Roof Assembly

City of Toronto By-law No.583-2009 § 492-9 A.
Green Roof Assembly A Green Roof assembly shall, as a minimum, consist of a root repellent system, a drainage system, a filtering layer, a growing medium and plants, and shall be installed on a waterproof membrane of an applicable Roof.

There are a variety of ways to achieve the mandatory requirements. The following defines the typical components in a green roof system. Some of the components described below exceed the minimum requirements of the green roof assembly stated above.

Typical Components

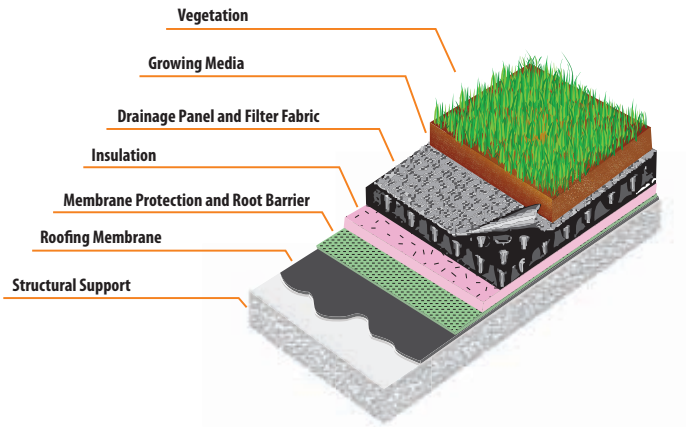


Figure 1. Example of a Green Roof Assembly

Designing high performance green roofs requires an understanding of the following layers and their interaction.

Vegetation
This layer is the living component of the green roof system. This term is commonly used to describe the cover provided by plant material.

The correct selection of the plant species installed can determine the success or failure of the green roof. The selection criteria should consider climate conditions, and the maintenance requirements of the plants.

Growing Media (Engineered Soil)
This is the rooting layer for the plants and is comprised of air, water, aggregate material, and organic material. See Section 5.1 for more information regarding Growing Media.

Moisture Retention Mat
This layer serves the purpose of retaining water to provide moisture for the growing media and the plants. This layer is commonly made of recycled polypropylene fibers stitched to a thermoplastic fabric sheet, such as polyethylene, and it is installed loose-laid. This layer may also serve as a root protection layer. See Section 4.3 for performance requirements of moisture retention mats.

Drainage Panel and Filter Fabric
The function of the drainage layer is to expel surplus water from the roof during rain periods, and, in some cases, serve as a water reservoir for the green roof during dry periods. It can be made from free draining

materials, such as gravel, or from rigid thermoplastic materials such as polystyrene or polyethylene impressed with "cups" to temporarily store the water.

The filter fabric is a geotextile which provides protection against the accumulation of fine soil in the drainage paths, ensuring the long term efficiency of the drainage layer.

Root Barrier
Root barriers are intended to protect the waterproofing materials from root penetration into membrane seams, and the harmful effect of soil microbes acting on the waterproof membrane. The root barrier layer is commonly made of thermoplastic sheets such as PVC, TPO or polyethylene. As an alternate, chemical products or metallic foils such as aluminum, which inhibit growth, can be used in combination with synthetic fiber material or geotextiles.

Waterproofing Membrane
The waterproofing membrane and the components below, are those shared by green roofs and conventional roofs. The membrane is the system that resists hydrostatic pressure and provides protection against water ingress. See Section 4.1 for details of the waterproofing.

Protection Board
May be required as fire separation and protection between the selected membrane and insulation products.

The various layers described above are often combined into one or more products. For example, a waterproof membrane may act as a root barrier and plants, growing media and drainage layers may be combined in a pre-vegetated mat.

OBC Authorized Materials

Given the recent introduction of many green roofing systems components which are not strictly recognized in the OBC. Ontario's objective based code provides the mechanism for dealing with these materials. It is recommended that designers review green roof systems with Toronto Building staff early in the design process to identify any issues related to material selection.

OBC General Requirements

Building Code Act 9.-(1)	"The chief building official may allow the use of materials, systems, and building designs that are not authorized in the building code if"…they "will achieve the level of performance required by the building code."
Division A 1.2.11. (1)	"Compliance with Division B should be achieved by complying with the applicable solutions in Division B, or by using alternate solutions that will achieve the level of performance required by the applicable acceptable solutions in respect of the objectives and functional statements attributed to the applicable acceptable solutions in Supplementary Standard SA-1."
Division B 11.3.1.1	Where an existing building system is materially altered or repaired, the performance level…should be at least equal to the performance level…prior to the material alteration or repair.
Division C Part 3	Qualifications are required for designers. Specific requirements are established for persons completing design required by the OBC.

Best Practices

The Factory Mutual (FM) Data sheet 1-35, Green Roof Systems, 2.2.16, and the FLL Guideline for the Planning, Execution and Upkeep of Green Roof Sites (FLL) recommend performance requirements for the selection and installation of the green roof components listed in the Typical Components Section above. The FLL recommends that the components of a green roof system:

Provide effective protection to the waterproof layer against static, dynamic and thermal stresses, as well as mechanical and chemical damage during installation and throughout the useful life of the roof, and promote healthy growth of the planted vegetation.

The FLL recommends that whether selecting a complete system, or specifying components from different sources, green roofs manufacturers and designers ensure that all of the materials used in a green roof system are evaluated to ensure:

- Chemical compatibility between the different components in the system,
- Appropriate resistance to changes caused by chemical and biological action of micro-organisms and other chemical components existing in the vegetation and soil substrate or dissolved in the water.

2 STRUCTURAL

Green roofs can add loads to a roof structure which are significant in comparison to typical roof design loads. The weight, stability and moisture retention characteristics of the system (particularly the growing medium and water retention mats) need to be determined. The following

presents OBC sections which address gravity load requirements and recommendations on how to respond to these requirements in green roof design, and green roof structural issues not addressed by the OBC:

2.1 Gravity Loads

Green roof gravity loads should be calculated in accordance with OBC Division B, Part 4.1 Structural Loads and Procedures. If building structural members are to be sized based on tables within Part 9 of the OBC, care should be taken to ensure that the loads imposed by the green roof are within the limits required for use of the tables. Best practice is to carry out the load analysis and design per Part 4 of the OBC.

OBC Structural requirements – Loads

Loads	
Division B 4.1.1.3.(1)	"buildings and their structural members…should be designed to have sufficient structural capacity and structural integrity to safely and effectively resist all loads, effects of loads and influences that may reasonably be expected…"
Division B 4.1.4.1.(b) and (e)	Dead loads to be considered in the structural design include "the weight of all materials of construction incorporated into the building to be supported permanently by the member", and "the vertical load due to earth, plants and trees.
Division B 4.1.3.2.(7)	"Load factor" applied to achieve the desired factors of structural safety for "soil, superimposed earth, plants and trees shall be increased to 1.5, except that when the soil depth exceeds 1.2m, the factor may be reduced…".
Division B 5.1.4.1.(1)	"Building materials, components and assemblies…should be designed and constructed to…resist or accommodate… (b) all structural loads…"
Division B 9.4.1.1	Structural members should be designed to Part 9 requirements or "CWC Engineering Guide for Wood Frame Construction" or Part 4.
Division B 9.4.3.1	(2) "Dead loads need not be considered in computing deflections…". Maximum roof deflection as per Table 9.4.3.1 is 1/360 where ceiling is plaster or gypsum board.
Division B 9.26.11	"Built-up roofs" identifies minimum requirements for built-up roofing membrane construction. Requires minimum No. 15 felts and minimum 3 mopped down layers of roofing felt.
Division B 9.23.4.5	Provides additional structural requirements for "heavy roofing materials" such as roofing tile. Joist, rafter, beam and lintel spans in tables are to be reduced to account for the additional loads.
Division B 9.23.15.7	Refers to tables that specify the thickness of roof sheathing where and where not used as "a walking deck".
Division B 11.4.3.2	Where the performance level of an existing building is reduced…(a) remedial measures should be taken to support the proposed loads".

City of Toronto By-law No.583-2009 § 492-9 B.

B. Gravity Loads
(1) The Applicant shall calculate Green Roof gravity loads following the protocol provided by the ASTM standard: "ASTM E2397.05 – Standard Practice for Determination of Dead Loads and Live Loads Associated with Green Roof Systems".
(2) The density of the growing media shall be determined (a) in accordance with "ASTM E2399.05 – Standard Test Method for Maximum Media Density for Dead Load Analysis of Green Roof Systems"; or alternatively (b) the designer may use an un-factored, saturated density of the growing media of 2,000 Kg/m3.
(3) The Applicant shall include design loads definition as part of the "Green Roof Declaration" form which shall be required as part of an application for Building Permit.

Best Practices

Section 13 of the FLL guidelines, provides reference design loads for the materials most frequently used as drainage layer, vegetation support course and vegetation in green roof systems. The values are given assuming the material is saturated.

When evaluating the design load the designer should anticipate and consider all load impacts of green roofs such as:

- additional snow loading due to drifting around plantings;

- the weight of the vegetation at its maximum growth;
- loading from maintenance equipment.

2.2 Slope Stability

OBC requirements

Slopes	
Division B 9.26.3	Minimum slopes for roof coverings are specified in Table 9.26.3.1. Minimum 2% for modified bitumen, 2% to 4% for built-up roofing. Maximum slopes for roof coverings are also specified in Table 9.26.3.1

City of Toronto By-law No.583-2009 § 492-9 C.
All roofs with slopes in excess of 10º (17%) that support Green Roof assemblies shall incorporate anti-shear measures.

Best Practices

Minimum Slope:
Given that a green roof conceals and restricts drying of the roof membrane, it is recommended that roof slopes to drains under a green roof be greater than the code minimums. Best practices suggest a minimum of 4% slope to drains.

FM Global Property Loss Prevention Data Sheet 1-35 Section 2.2.10.1 recommends a minimum slope of 2% for roof systems supported by structural concrete decks and 3% for all other structural support systems.

Maximum Slopes:
The growing medium of a green roof can become unstable as roof slopes increase. FM Global Property Loss Prevention Data Sheet 1-35 Section 2.2.10.2 limits roof slopes (supporting green roofs) to 11º (20%) for systems not including anti-shear measures (to prevent green roof materials from sliding on or off the roof). Above this slope, anti-shear layers, or anchorage and erosion control systems, should be installed. These measures are to be designed to protect both the structural integrity of the green roof system, and the vegetation layer. The anti-shear measures should be designed to avoid damage to the membrane, or other layers in the green roof system, caused by the stress induced by the slope in the system. FM recommends that green roofs not be installed on roofs above a slope of 22º (40%).

FLL recommends the following anti-shear measures for steep roof slopes:

- For slopes between 11º and 15 º, the shear loads can be overtaken by reinforced eaves combined with waterproofed shear barriers. Anti-erosion measures such as geotextile fabrics should be also included in the design.
- Between 20 º and 30 º, additional anti-shear measures should be installed such as special woven matts, and geotextiles, or anti-shear plates and profiles. When using geotextiles, special care should be given to their tensile strength and fastening details to ensure they can support the required loads. To prevent vegetation from sliding, the vegetation substrate should be selected in a way that its structural soundness is not affected by water (i.e. limiting the amount of fine materials which can be washed out). Fast plant root growth should be promoted to guarantee bonding of the system, and avoid erosion.
- Above 30 º (56%), the vegetation may present performance problems due to lack of root resistance to shear, and it is recommended to limit the vegetation type to light weight pre-cultivated mats.

Special care should be given to the design of the drainage system to avoid water accumulation and the consequent loads at the lower level of the green roof system in high slope systems.

2.3 Parapet Height and/or Overflow Scupper Locations

The OBC provides direction on how to design for water accumulation from rainfall.

OBC Requirements

Division B part 4 4.1.6.4	Provides requirements for the calculation of rain loads on the roof.
Division B Part 4 (4)	"Where scuppers are provided and where the position, shape and deflection of the loaded surface make an accumulation of rainwater possible, the loads due to rain should be lesser of either the one-day rainfall determined in conformance with Subsection 1.1.2 or a depth of rainwater equal to 30 mm above the level of the scuppers, applied over the horizontal projection of the surface and tributary areas"
Division B Part 7 (General)	Provides requirements for design and installation of storm water drains.

Division B 7.4.10.4.(1)	The hydraulic load is the maximum 15 minute rainfall (25mm for the City of Toronto) multiplied by the area of the surface drained and one half the largest adjoining vertical surface.

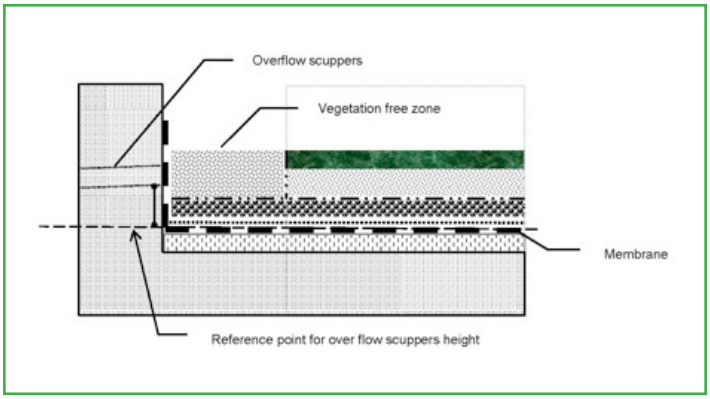
Given a green roof's enhanced ability to store rainfall, and the ready availability of debris to block roof drains, additional care must be taken to ensure that adequate drainage is provided for the system.

City of Toronto By-law No.583-2009 § 492-9 C.

(1) Parapets and scuppers shall be specified in the design, as required, to limit retained rain water loads to within structural limits in the event of obstructed internal drains.

(2) Analysis shall be done in conformance with OBC Division B 4.1.6.4.(4)

(3) The referenced point for the overflow scuppers height must be clearly indicated to avoid the possibility of confusing the overflow scupper height as being measured above the finished green surface or other layer above the waterproofing resulting in higher water load than accounted for by the design as indicated in the sketch below.



2.4 Wind Uplift

OBC Requirements

Wind loads	
Division B 4.1.7.1.(4)	Wind loads are to be calculated using a reference velocity pressure for "a probability of being exceeded in any one year of 1-in-50".
Division B Part 5 5.1.4.1	Building materials, components and assemblies that separate dissimilar environments or are exposed to the exterior shall be designed and constructed to provide sufficient capacity and integrity to resist or accommodate wind up-lift imposed…..

City of Toronto By-law No.583-2009 § 492-9 E.

E. Wind Uplift
The Applicant shall provide a report, stamped by an engineer, providing wind uplift pressures being designed for (including a description of how the pressures were determined), and describing how the design addresses these pressures.

Best Practices

Division B - Part 4 of the OBC requires that the design resist blow-off by the wind. There are practices in the industry, such as loose-laid, protected membrane roofing systems, which are accepted despite limited design information regarding their quantified wind resistance. Green roofs, however, pose a distinct risk of wind uplift.

FM

The FM Global Property Loss Prevention Data Sheet 1-35 Section 2.2.14 recommends a minimum parapet height above the growth media and vegetation free border zones as follows:

Building Height	Parapet height (above growth media)	Vegetation free/ border zone
≤46 m	150 mm	0.5 m
>46	750 mm	≥0.9 m

FLL

FLL provides a list of specific recommendations related to securement with the intention of providing a system that can withstand a load of1.5 times the positive or negative pressure, as prescribed by DIN 1055 standard, Part 4. Similarly, a prescriptive securement process is defined in the FM Global Property Loss Prevention Data Sheet, 1-35, Green Roof Systems, 2.2.3.3 Wind Uplift, Roof Ballast and Safety Factor. The following summarizes the FM recommendations:

- Use a mechanically attached or fully adhered roof membrane system based on appropriate wind uplift design pressures.

- Use of growth media as ballast against wind uplift for the roofing membrane and other waterproofing elements only where a uniform depth of 200 mm or more is provided; a minimum safety factor of 1.7 (or as defined by the green roof designer) should be used for wind uplift calculations.
- Use a minimum of 76 mm of stone ballast in the ballasted areas in the non- vegetated borders, unless greater depths are recommended either by the manufacturer or installer.
- Growth media may be used as a secondary ballast material to ballast the loose-laid roofing components above the waterproofing membrane (i.e., drainage panel, retention mat, root barrier, and insulation board), but not the membrane itself. Use wind uplift design pressures and a minimum safety factor of 0.85 (or as defined by the designer) for wind uplift calculations where growth media is used to ballast.
- Where vegetated, pre-cultivated mats are installed, anchor them until the mat's root growth has achieved sufficient attachment into the growth media to adequately resist wind action (at least one full growing season). Vegetated mats should be properly anchored or ballasted against wind forces based on a safety factor of 1.0 (or as indicated by the designer).
- FM document also recommends the inclusion of a Non-Vegetated Border Zones in the areas affected by larger wind pressure (edges and corners). These areas should be free of vegetation and covered by stone ballast or concrete pavers, and have a minimum dimension of 2.6 m. It also limits the installation of green roofs in geographical areas where the wind speed (3 seconds gust) does not exceed 45 m/s, applicable to all building heights as per FM document Data Sheet 1-35 Section 2.2.2.

Wind Design Standard for Vegetative Roofing Systems (under development)

The Wind Design Standard for Vegetative Roofing Systems, being developed by Green Roofs for Healthy Cities and the Single Ply Roofing Institute provides a methodology for designing green roofs resistant to wind uplift. It provides minimum design and installation requirements for all type of green roof systems. The City's Green Roof Technical Advisory Group will be reviewing this standard for applicability to Toronto.

3 SAFETY

3.1 Fire Safety

OBC Requireme

OFC 2.4.2.1	"Combustible materials should not be stored on a roof or adjacent to any building so as to create a fire hazard to the building or its occupants."
Division B 3.1.15.1 and 3.1.15.2	Every roof covering should have a classification determined in accordance with CAN/ULC-S107-M, "Fire Tests of Roof Coverings".
Division B 11.3.3.2	Where existing…roof assemblies are substantially removed in an existing building and new interior walls, ceilings or floor assemblies are installed, structural and fire resistance elements should be constructed in compliance with the requirements of the other Parts.

Green roof coverings (including plant material) may not comply with the "Fire Test of Roof Coverings" standard, particularly if vegetation is dormant. At this point in time, there is no widely accepted testing method developed for Green Roofs.

City of Toronto By-law No.583-2009 § 492-9 F.

F. Fire Safety

Where roof penetrations, intersecting walls, parapets, upturns or mechanical equipment are clad with combustible materials the design shall include a vegetation-free border zone abutting such features and the vegetation-free border shall be equal to the vegetation height at maturity but in no case be less than 0.5 m.

Best Practices

There is no approved fire testing methodology for Green Roofs, thus it is not possible to classify green roofs in terms of fire resistance. Factors that should be considered include:

- Avoiding vegetation that presents excessive fire risk;
- Keeping the vegetation away from walls, parapets, mechanical equipment;
- Providing non-combustible cladding at areas exposed to the green roof;
- Providing fire breaks to limit vegetation areas;
- Appropriate location of natural gas line supply;
- A consideration of the potential impact of burning

vegetation on paths of egress, and
- Requirements for fire fighting (portable extinguishers and adequate water supply and/or fire hoses.

The "FM Global Property Loss Prevention Data Sheet 1-35: Green Roof Systems" provides specific recommendations to limit risks related to fire. It considers a green roof as non- combustible with regard to interior fire exposure if it is installed over a concrete deck. The FLL guideline accepts the guidelines dictated by the Association of Urban Construction and Housing in Germany (ARGEBAU) which considers the green roof system to have enough fire resistance if the green roof assembly meets the following criteria:

- The soil substrate has a minimum depth of 30 mm
- The vegetation planted constitutes a "low fire load"
- There is a distance between the green roof area and any penetration in the roof of at least 50 cm.

The FM document, Data sheet 1-35 2.2.14, also establishes a minimum 50 cm non-vegetated border zones as separation from any penetration in the roof.

In general, design should provide solutions which achieve compliance with OBC Division B and its objectives and functional statements. The FM document (section 2.2.14) recommends avoiding vegetation types with high risk of seasonal dormancy such as grasses and mosses, and limiting the vegetation height to a maximum of 0.9 m.

FM also recommends partitioning the roof area into sections no larger than 1,450 m^2 separated by a vegetation free border zone of 0.9 m.

The maintenance program provided with the green roof design should include annual removal of dead vegetation that does not promptly compost and may present a fire risk.

3.2 Occupancy/Safety

OBC Requirements

Division B 9.8.8.1	Guards are required where there is a difference in elevation of more than 600mm or where the slope of the adjacent surface is more than 1 in 2. Guards are not required where access is provided for maintenance purposes only.
Division B 3.3.1.17	A guard not less than 1070mm high should be provided around each roof to which access is provided for other than maintenance.

City of Toronto By-law No.583-2009 § 492-9 G.
G. Occupancy and Safety The Applicant shall state, in a Green Roof declaration form and the Green Roof application, the use of the roof and whether or not it will be accessible to the public.

Best Practices

If the roof is to be accessible for uses other than maintenance, all OBC requirements associate with the stated occupancy should be met (i.e. exits, guard rail, live load capacity, accessibility, etc.).

For non- accessible green roofs (other than maintenance), if guards are not provided at the roof perimeter consider a 2m vegetation free-zone at the roof perimeter to minimize the use of safety tie-back anchors for workers to safely access the vegetation for maintenance. System should allow for compliance with applicable workplace safety laws.

It is recommended that guards be provided for green roofs used to produce and harvest vegetables, flowers or other crops in accordance with OBC Division B 3.3.1.17

The intended use and occupancy of the roof should be stated in the recommended "Green Roof Declaration" form integrated as part of the building permit process.

4 WATERPROOFING

4.1 Waterproofing

OBC Requirements

Division B 9.26.1.1	"Purpose of Roofing" is to shed rain and prevent water from entering. Includes "platforms that effectively serve as roofs with respect to accumulation or drainage of precipitation."
Division B 9.26.2	"Roofing Materials" identifies applicable standards for waterproofing membranes, shingles and tiles.
Division B 5.6.1.1	A building component or assembly should "(a) minimize ingress of precipitation into the component or assembly, and (b) prevent ingress or precipitation into interior space."
Division B 5.1.4.2.(1)	Materials used should be "resistant to any mechanisms of deterioration that may reasonably be expected".

Division B 5.1.4.2.(3)	"Design and construction of assemblies separating dissimilar environments and assemblies exposed to the exterior should be in accordance with good practice such as described in CSA 478, Guideline on Durability in Buildings." This standard requires buildings, components and assemblies to be designed, operated and maintained to meet or exceed their design service life. The appropriate design service life of each component is to consider difficulty/expense of maintenance, and consequence of failure.
Division B 9.26.4	"Flashing at Intersections" required except where omission does not adversely affect adjacent elements. Minimum thicknesses of acceptable sheet metals are specified.

City of Toronto By-law No.583-2009 § 492-9 H.

H. Waterproofing
(1) The design and construction shall include the installation of a root barrier in all vegetated roofing systems.
(2) Immediately prior to installation of the Green Roof, the Applicant shall cause to be conducted one of the following leakage testing protocols:

(a) Flood Test,

(b) Electric Field vector mapping,

(c) Impedance Test,

(d) Infrared (IR) Thermal Imaging

(e) Low Voltage Testing,

(f) High Voltage Testing,

(g) Moisture Sensors

and a report documenting a successful test, signed by an architect or engineer, shall be provided to the Chief Building Official.

Best Practices

The Canadian Standard Association in CSA S478-95 (R2001), Guidelines on Durability in Buildings, provides guidelines for establishing and achieving the design service life of buildings and their components. For the cladding assemblies, including roof membranes, the recommended service life is a minimum of 20 years.

Maintaining the waterproofing function of a membrane within a green roof system is considerably more critical than a conventional roof system because of the added cost of repair. While the OBC does not impose any specific requirements, it does require designers to fulfill the purpose of a roof, consider the need for resisting water ingress apply to green roofs, and maintain acceptable performance.

There is no limitation on what roofing materials within a green roofing system could be relied upon for preventing water entry. However, increased membrane quality would be judged to be prudent by most professionals in a green roof design. In general, it is recommended that the following be considered:

- Built-up roofing membranes should consist of a minimum of 4 plies. Organic based #15 felts are not recommended; felts should be glass fiber based Type IV as a minimum.
- The substrate on which the green roof is installed should not be shingles or tiles.
- Some metals have been found to suffer problems with corrosion when integrated within a green roof. In particular, aluminum can be vulnerable.
- Sheet applied modified bitumen membranes should be a minimum of 2 plies.
- Liquid applied membranes should be reinforced and be applied with a minimum 2 plies.
- Waterproofing membranes should be adequately protected from damage from other green roof assembly materials, and from assembly installation activities.
- The design should include materials that adequately protect the waterproofing membrane from damage from roots.
- A leak detection system or a dual barrier system to minimize damage due to membrane failure.

Testing Types

Flood testing is a procedure in which a controlled amount of water, usually 10 cm, is temporarily retained (i.e., drains are closed, or sloped areas are dammed) for a period of 24 to 48 hours over a horizontal surface to determine the effectiveness of the waterproofing system. This should not be confused with a "Flowing water test" which is the application of flowing water continuously over the surface of the waterproofing membrane for a minimum of 24 hours without closing the drains or erecting dams.

Electric field vector mapping is the only leak detection method which does not disturb the vegetation on a green roof when retesting after system installation. A conductor wire is looped around the area to be tested, on top of the membrane and connected to an impulse generator, prior to the installation of other components. The roof can be sloped or flat. During testing, an electric current is delivered at short, regular intervals. The current flows across the membrane, to breaches in the membrane, where it can access the grounded structural deck.

Using a receiver connected to two probes, the testing agent can identify the current's flow and accurately locate the breach. The breach is then accessed and repaired. Repaired areas must be retested immediately. This method is not compatible with EPDM membranes.

Capacitance (Impedance) testing utilizes an electric field to determine the relative moisture content on and below the membrane, but may not pinpoint the exact leak. For accuracy during testing, the membrane must be dry and the assembly uniform in thickness and material. Note that certain materials (such as EPDM) can distort the readings and provide less accurate results.

Infared (IR) Thermal Imaging is an interpretive testing method based on the principle that wet and dry building components have differing rates of heat gain and retention. It can cover large areas quickly and cost effectively, above and below the surface of the membratne but may not pinpoint the exact leak. Best results are obtained from the exterior of the building at dusk, or from the interior or exterior on sunny days when the building temperature is higher than the surrounding temperature. Note that this testing method is not useful after a green roof has been installed, since the green roof reduces heat reflection.

4.2 Drainage

OBC Requirements

Division B 9.26.3	Maximum slopes for roof coverings are also specified in Table 9.26.3.1.
Division B Part 7 (General)	Provides requirements for design and installation of storm water drains.
Division B 7.4.10.4.(1)	The hydraulic load is the maximum 15 minute rainfall (25mm for the City of Toronto) multiplied by the area of the surface drained and one half the largest adjoining vertical surface.
Division B 7.4.10. (2)	Control flow roof drains may be installed provided "(b) the roof structure has been designed to carry the load of the accumulated water, (c) one or more scuppers are installed so that the maximum depth of water on the roof cannot exceed 150mm…"

City of Toronto By-law No.583-2009 § 492 I.

I. Drainage
(1) The design hydraulic load shall be evaluated assuming that the green roof system is fully saturated prior to the maximum 15 minute rainfall.

(2) Positive slope to drain shall be provided at the level of the waterproofing membrane.

(3) The system shall permit effective drainage beneath the growth media.

(4) Vegetation-free zones shall be provided around all drains.

Best Practices:

As a general recommendation, roof drains should be protected from vegetation coverage or loose soil or gravel which can obstruct the drain, and they should be designed to allow regular inspection and maintenance. FM Global Property Loss Prevention Data Sheet 1-35, in Section 2.2.14 requires a 0.5 m vegetation free zone around drains and roof outlets to prevent them from obstruction. FLL section 5.5, provides guidelines on requirements and execution of the drainage components of green roofs to allow for maintenance and inspections of the drains.

For the vegetation system drainage, drainage panels, mats or equivalent free draining materials should be employed to permit effective vegetation substrate drainage.

4.3 Water Retention

OBC requirements

There is no provision in the OBC specifically addressing water retention. In general, water retention should be limited as per the structural capacity of the roof defined in section 3 of this document.

City of Toronto By-law No.583-2009 § 492-9 J.

J. Water Retention
(1) Water retention mats or equivalent materials shall be employed as required to promote vegetation growth.

(2) The drainage layer shall be appropriate for storm water retention and must be selected following "ASTM E2398-05 Standard Test Method for Water Capture and Media Retention of Geo-composite Drain Layers for Green Roof Systems".

Best Practices

One of the major potential benefits of green roofs is its capacity for storm water retention and reduction of run-off from the roof in storm events.

FLL section 6.3, outlines the performance parameters used

for the calculation of the storm-water retention coefficients which can be assigned to different roof assemblies. Table 3 from this FLL section outlines different water retention coefficients for different roof assemblies.

To meet the desired storm water retention, a minimum 100 mm soil course or equivalent water storage strategies such as those outlined below (recommended by the FLL guidelines) should be considered:

- Storage in the vegetation support through the use of substances or materials which retain water, such as prefabricated substrate boards, or
- Water retention mats
- Storage in the vegetation support course and in the drainage course through the use of open pore aggregate (such as porous clay) in graded granular sizes, or
- Storage in the vegetation support course and in the drainage course by allowing water to build up in the drainage layer by using pre-formed drainage boards with retention capacity.

The use of this type of water reservoir system might also decrease the irrigation requirements of the green roof.

Water retention can be achieved by implementing different strategies than increased depth of growing media, however, the depth of the growth media has positive impacts on other green roof benefits, such as biodiversity and plants diversity.

5 VEGETATION PERFORMANCE

Best Practices

For a successful green roof, the design and selection of growing media, irrigation systems, and plantings must be carried out as a system. Engage qualified design professionals, such as an Ontario Landscape Architect, to design the green roof system.

5.1 Growth Media

Best Practices

It is recommended to follow the FLL Standard Section 9 for the definition and maintenance of the growing media. This standard provides guidelines for the composition and performance of different growing mediums. It defines the physical characteristics of the substrate such as the proportion of organic content, granulometric distribution, porosity, dimensions, water retention capacity and material type for each course on the substrate.

It is recommended to provide protection to the growing media after seeding and till the vegetation is established.

Growth media depth above 100mm are encouraged to increase biodiversity.

City of Toronto By-law No.583-2009 § 492-9 K.

K. Vegetation Performance
In order to support plant survivability:
(1) When structurally possible, the growing media shall be at a minimum 100 mm, or
(2) the Applicant shall provide a report confirming that the engineered system as designed provides plant survivability comparable to that of an un-irrigated system with growing media at minimum 100 mm.

5.2 Plant Selection

City of Toronto By-law No.583-2009 § 492-9 L.

L. Plant Selection
(1) Vegetation on a green roof shall not include any noxious weeds as defined in Ontario Regulation 1096 under the Weed Control Act, as may be amended from time to time.
(2) The plant selection and design shall be such that within three years of the planting date the selected plants shall cover no less than 80% of the vegetated roof.
(3) Compliance with the plant coverage required in the preceding sentence can be satisfied by a design that will provide one or more of the following:
(a) that seeds for groundcover plantings shall be sown at a rate not less than 325/m2,
(b) that cuttings shall be distributed not less than 12kg/100m2, and
(c) either that pre-grown plugs shall be installed not less than 11/m2 or a report from the designer that describes how the design fulfills this coverage requirement shall be provided with the application.

Best practices

Given the exposure of the plant medium in a green roof, Alpine species are often the best choice, since they can resist extreme conditions of heat, cold, high winds, extreme sun exposure and long drought periods. Among these alpine species, succulents are the most commonly selected species, because of their capacity for storing water in their leaves and roots, and because of their low substrate depth required for their establishment.

Vegetation should be appropriate for use in the green roof application, which includes, but is not limited to:

a) As defined in ASTM E2400 - 06 Standard Guide for Selection, Installation, and Maintenance of Plants for Green Roof Systems, and
b) Native or adaptive from the Southern Ontario area
c) Appropriate for the Toronto climate and building exposure;
d) Drought resistant to minimize the need for irrigation;
e) Having root systems that are accommodated and resisted by the assembly design;
f) Non-monoculture

Based upon data collected in 2004 and 2005, the Toronto and Region Conservation Authority developed a list of native plants for a green roof environment in Toronto:

http://www.toronto.ca/greenroofs/pdf/plant_suggestions2007.pdf .

Evergreen's Native Plant Database may also be accessed at: http://www.evergreen.ca/nativeplants/

5.3 Irrigation

OBC Requirements

Division B 7.6.2.2	(1) Every potable water system that supplies a fixture or tank that is not subject to pressures above atmospheric shall be protected against back-siphonage by a backflow preventer. (2) Where a potable water supply is connected to a boiler, tank, cooling jacket, lawn sprinkler system or other device where a non-potable fluid may be under pressure that is above atmospheric or the water outlet may be submerged in the non-potable fluid, the water supply shall be protected against backflow by a backflow preventer. (3) Where a hose bibb is installed outside a building, inside a garage, or where there is an identifiable risk of contamination, the potable water system shall be protected against backflow by a backflow preventer.

City of Toronto By-law No.583-2009 § 492-9 M.

M. Irrigation
Adequate measures shall be provided to permit irrigation necessary to initiate and sustain the vegetation during the service life of the green roof.

6. QUALITY ASSURANCE ACTIVITIES

An appropriate quality assurance process should be followed during design construction and operation of the green roof system so it can meet expectations for performance over the building's design service live. The quality assurance activities can establish procedures to ensure that:

- The required quality of design is provided;
- The required quality of materials are used throughout;
- The required quality of workmanship is provided in the construction and maintenance of the green roof components; and
- The roof is operated within the limits for which it was designed.

6.1 Design and Construction

The quality assurance process should outline the specific quality assurance activities that should be completed at each stage of the design and construction of the green roof as per CSA- S470, section 5. Table 1.

6.2 Maintenance Plan

City of Toronto By-law No.583-2009 § 492-3

Maintenance of Green Roofs and Health of Vegetation.

Every Green Roof required to be constructed pursuant to this Chapter shall be maintained in accordance with the maintenance plan required in the Toronto Green Roof Construction Standard.

City of Toronto By-law No.583-2009 § 492-9 N.

N. Maintenance Plan
(1) The Applicant shall develop a maintenance plan for the Green Roof as per CSA-S478-95 "Guideline on Durability in Buildings" which shall define programs of routine maintenance and inspection sufficient to ensure that the Green Roof components perform their required functions for the duration of their design service lives.

(2) The maintenance plan shall address the requirements of the specified growth media and vegetation for vegetation survival.

(3) The maintenance plan shall address re-planting, in the event that re-planting should become necessary, and assure that complete coverage at canopy level is achieved within three growing seasons and maintained for the service life of the Green Roof.

(4) The maintenance plan shall be submitted with the application for a permit for a Green Roof.

Maintenance Plans are focussed primarily on the needs of the green roof during the first two to three years, or ongoing maintenance beyond three (approximately) years. Each type of maintenance plan should address the following matters:

a) Protection measures for vegetated areas from impact of foot traffic (i.e., minimizing potential for damage);
b) The amount, time and control of Irrigation;
c) The amount, type and time of fertilizer application ;
d) Weed Management, including how often, which weeds to remove;
e) Replanting (if required);
f) Periodic inspection of drains, edging, roof penetrations, flashings, non-planted areas. This may also be part of the roofing membrane maintenance program;
g) Troubleshooting, and
h) Assignment of responsibility for removal of, care for, and reinstallation of growing medium and vegetation in the event of a leak.

BIBLIOGRAPHY

"ASTM E2397.05 – Standard Practice for Determination of Dead Loads and Live Loads Associated with Green Roof Systems"

"ASTM E2399.05 – Standard Test Method for Maximum Media Density for Dead Load Analysis of Green Roof Systems".

Factory Mutual (FM) Global Property Loss Prevention Data Sheets. Data Sheet 1-35 Green Roof Systems, 2007

Note: Factory Mutual is an insurance company that has produced a data sheet with general guidelines for green roof systems. www.fmglobal.com

Forchungsgesellschaft Landschaftsentwicklung Landschaftsbau e.V. (FLL). Guidelines for the Planning, Execution, and Upkeep of Green Roof Sites. January 2002.
Note: The German Landscape Research, Development and Construction Society (FLL) Guidelines have served as a reference for the design of green roof systems. The Guideline is available in English, for a cost.
www.f-l-l.de/english.html

"Fire and Wind Design Standard for Vegetative Roofing Systems"- draft version .GRHC

CSA S478-95 (R2001) Guidelines on Durability in Buildings.

Green Roofs for Healthy Cities. (2006). Green Roof Design 101 Introductory Course Participants' Manual, Second Edition. Toronto: GRHC.

Green Roofs for Healthy Cities. (2006). Green Roof Infrastructure: Design and Installation 201 Participants' Manual, Second Edition. Toronto: GRHC.
Green Roofs for Healthy Cities. (2007). Green Roof Waterproofing and Drainage 301 Participants' Manual. Toronto: GRHC.

Green Roofs for Healthy Cities. (2008). Green Roof Plants and Growing Media 401 Participants' Manual. Toronto: GRHC.

Note: Green Roofs for Healthy Cities is a not-for-profit industry association dedicated to the development of the green roof and wall industry. In 2009 Green Roofs for Healthy Cities launched their Green Roof Professional program (GRP). Successful completion of the program requires the completion of a multidisciplinary exam on best practices associated with the design, installation and maintenance of green roof systems. For more information contact www.greenroofs.org.

CITY OF TORONTO RESOURCES

a. City of Toronto Green Roof Website

www.toronto.ca/greenroofs

This is the City of Toronto resource website on green roofs, including the full study, "Report on the Environmental Benefits and Costs of Green Roof Technology for the City of Toronto".

b. Selected Reports to Standing Committees and City Council

Bylaw to Require and Govern the Construction of Green Roofs
March 27, 2009
http://www.toronto.ca/legdocs/mmis/2009/pg/bgrd/backgroundfile-20562.pdf

Attachment to March 27, 2009 Report: Report from the Chair, Toronto Green Roof Technical Advisory Group

http://www.toronto.ca/legdocs/mmis/2009/pg/bgrd/backgroundfile-20564.pdf

Status Update on the Green Roof By-law
December 17, 2008
http://www.toronto.ca/legdocs/mmis/2009/pg/bgrd/backgroundfile-17893.pdf

Proposed By-law to Require and Govern the Construction of Green Roofs
November 13, 2008
http://www.toronto.ca/legdocs/mmis/2008/pg/bgrd/backgroundfile-16784.pdf

Requiring and Governing the Construction of Green Roofs in Toronto
June 28, 2007
http://www.toronto.ca/legdocs/mmis/2007/pg/bgrd/backgroundfile-4973.pdf

Guideline for Requesting a Change to the Toronto Green Roof Construction Standard

City of Toronto By-law No.583-2009 § 492-18

A. The Chief Building Official shall periodically review the Toronto Green Roof Construction Standard and, after consultation with the Green Roof Technical Advisory Group, recommend amendments to City Council to reflect the City's experience with Green Roofs and new construction techniques and materials.

Suggestions for improving the Toronto Green Roof Construction Standard may be submitted by the public for consideration in the Chief Building Official's next review. City Council has directed that the Chief Building Official and Chief Planner undertake a review of the Toronto Green Roof By-law by January 31, 2012.

A proposed change to the Toronto Green Roof Construction Standard must identify:

- Provision in the current Toronto Green Roof Construction Standard proposed for revision;
- Wording for proposed change;
- The problem or issue that the proposed change is addressing.

The proposal must also provide ample justification and supporting documentation for the proposed revision. This may include, but is not limited to: Research, testing results and a cost/benefit analysis.

Proposals may be mailed or faxed to:

Chief Building Official
Toronto Building
City of Toronto
12th Floor, East Tower
Toronto, Ontario
M5H 2N2
Fax: (416) 397-4383

Appendix A: How to Calculate the Required Green Roof Coverage

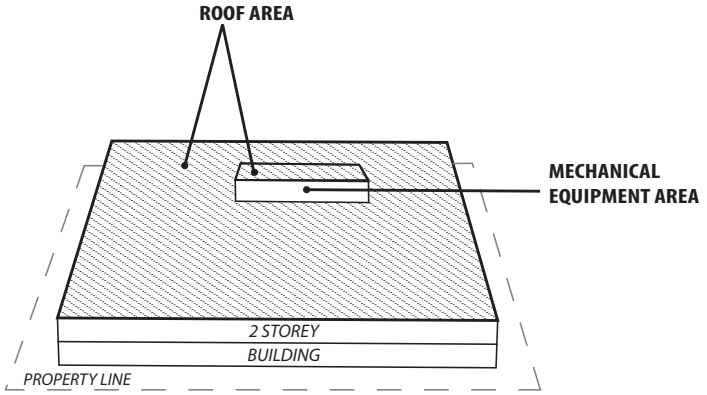
Toronto Municipal Code Chapter 492, requires green roofs on new commercial, institutional and residential development with a minimum Gross Floor Area of 2,000m^2 as of January 31, 2010. Starting January 31, 2011, the Bylaw will require green roofs on new industrial development.

The green roof coverage requirement ranges from 20-60 per cent, depending on the size of the building. In 2011, the coverage requirement for industrial buildings will be the lesser of 10 per cent of Available Roof Space or 2,000 m^2. For detailed information on determining whether a new development may require a green roof refer to the website at: http://www.toronto.ca/greenroofs/

The following illustrations provide examples of how to calculate the green roof requirement for different building types and sizes. The illustrations contained in Appendix A are examples only and are not to scale. Please note that the Coverage of Available Roof Space will vary based on the Gross Floor Area of the building and may be different from the coverage reflected in the following examples. Non-vegetated portions of a green roof and roof penetrations are not indicated on the illustration and are not considered part of the Green Roof Area. Refer directly to the Bylaw for details on the calculation of the required Green Roof Area.

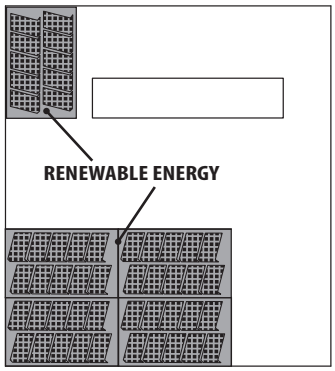
Low-Rise Commercial Building

Green Roof Requirements



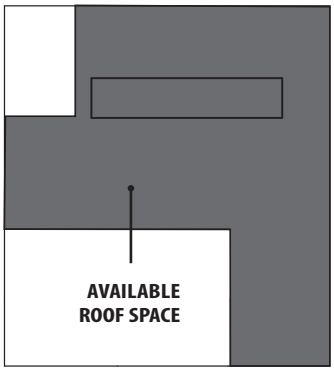
Total Roof Area

Total Roof Area = Roof Area (including Mechanical Equipment Area)



Exclusions from Roof Area

(may include - Renewable Energy)



Available Roof Space

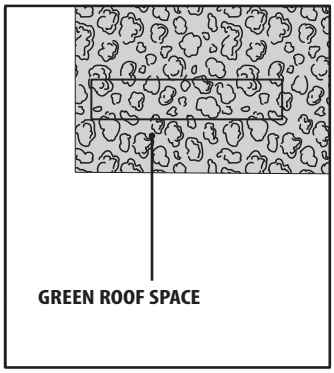
Available Roof Space = Total Roof Area - Exclusions from Roof Area

×

Gross Floor Area (Size of Building)	Coverage of Available Roof Space (Size of Green Roof)
2,000m² - 4,999m²	✔ 20%
5,000m² - 9,999m²	30%
9,000m² - 14,999m²	40%
15,000m² - 19,999m²	50%
20,000m² or greater	60%

Coverage of Available Roof Space

Percentage Calculation Chart
(contained in the Green Roof By-law)

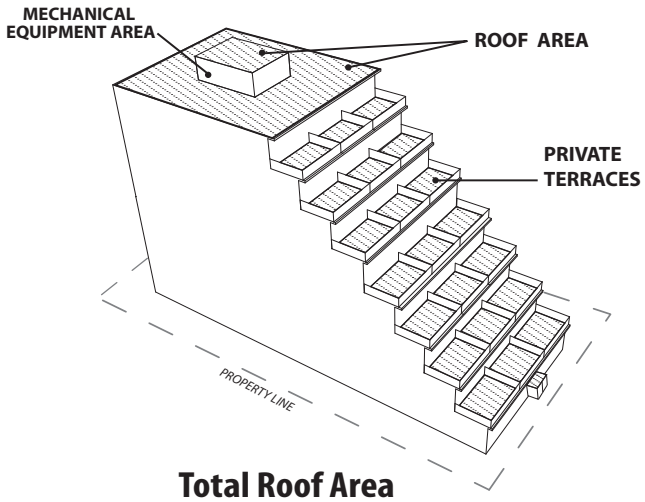


Green Roof Area Required

Green Roof Area Required = Available Roof Space x Coverage of Available Roof Space
(as specified in the Green Roof By-law)

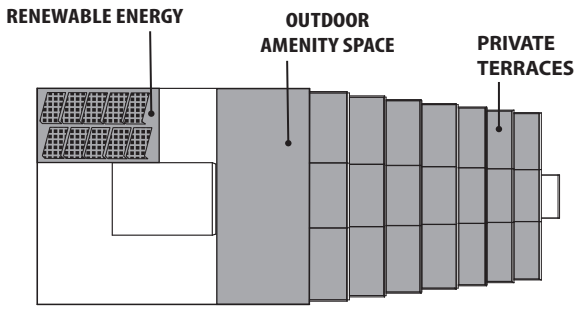
NOTE:

Non-vegetated portions of a green roof and roof penetrations are not considered part of the Green Roof Area



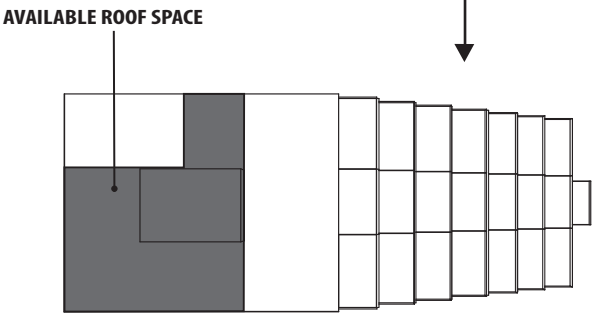
Total Roof Area

Total Roof Area = Roof Area (including Mechanical Equipment Area) + Private Terraces



Exclusions from Roof Area

(may include - Renewable Energy
- Private Terraces
- Outdoor Amenity Space
(Maximum of 2m^2/unit)



Available Roof Space

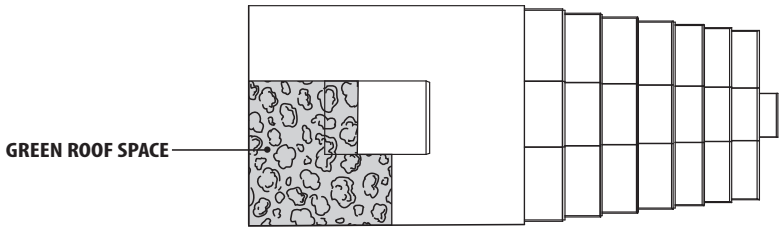
Available Roof Space = Total Roof Area - Exclusions from Roof Area

×

Gross Floor Area (Size of Building)	Coverage of Available Roof Space (Size of Green Roof)
2,000m^2 - 4,999m^2	20%
5,000m^2 - 9,999m^2	30%
9,000m^2 - 14,999m^2	✔ 40%
15,000m^2 - 19,999m^2	50%
20,000m^2 or greater	60%

Coverage of Available Roof Space

Percentage Calculation Chart
(contained in the Green Roof By-law)



Green Roof Area Required

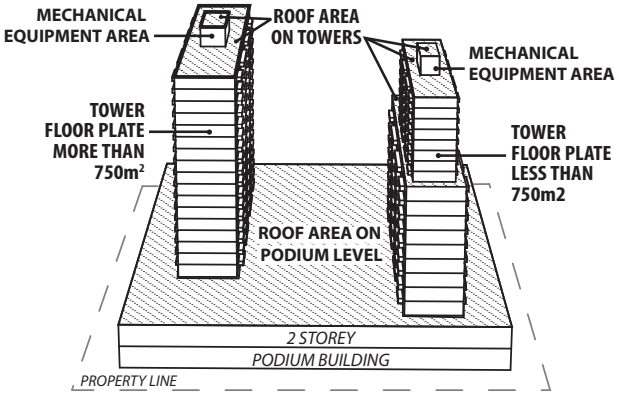
Green Roof Area Required = Available Roof Space x Coverage of Available Roof Space
(as specified in the Green Roof By-law)

NOTE:

Non-vegetated portions of a green roof and roof penetrations are not considered part of the Green Roof Area

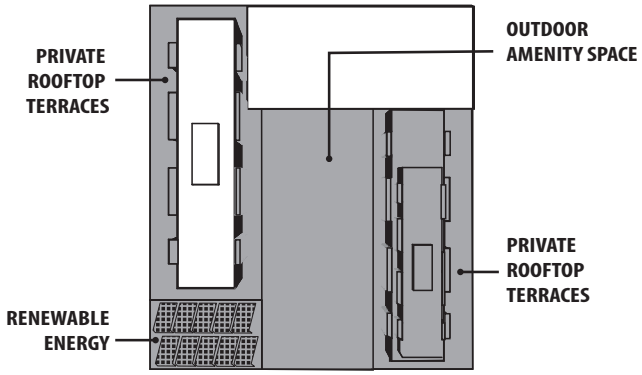
High-Rise Building

Green Roof Requirements



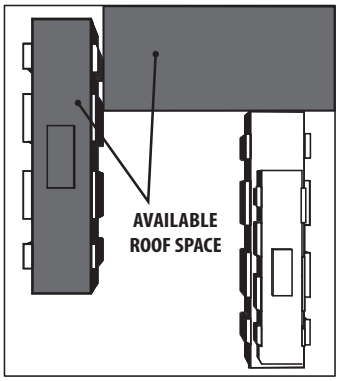
Total Roof Area

Total Roof Area = Roof Area (including Mechanical Equipment Area) + Private Terraces



Exclusions from Roof Area

(may include - Renewable Energy
- Private Rooftop Terraces
- Outdoor Amenity Space (Maximum of 2m²/unit)
- Tower Floor Plate <750m²



Available Roof Space

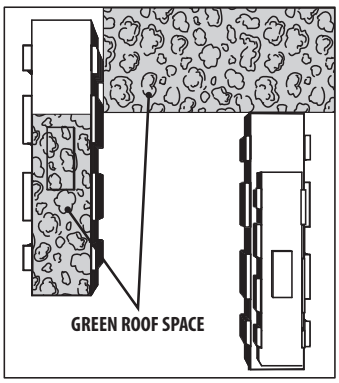
Available Roof Space = Total Roof Area - Exclusions from Roof Area

×

Gross Floor Area (Size of Building)	Coverage of Available Roof Space (Size of Green Roof)
2,000m² - 4,999m²	20%
5,000m² - 9,999m²	30%
9,000m² - 14,999m²	40%
15,000m² - 19,999m²	50%
20,000m² or greater	✔ 60%

Coverage of Available Roof Space

Percentage Calculation Chart
(contained in the Green Roof By-law)



Green Roof Area Required

Green Roof Area Required = Available Roof Space x Coverage of Available Roof Space (as specified in the Green Roof By-law)

NOTE:

Non-vegetated portions of a green roof and roof penetrations are not considered part of the Green Roof Area

Appendix B: Applying for a Building Permit to Construct a Green Roof

Permit Required

As of January 31, 2010 all green roofs constructed in Toronto must comply with the Toronto Green Roof Construction Standard. Building permit applications made prior to this time are exempt. The construction of all green roofs, whether or not they are required under the bylaw, requires a building permit in conformance with Toronto Municipal Code Chapter 492.

Fees

There is no additional building permit fee if a green roof is part of a permit application for a new building, or where it is included as part of constructing an addition to an existing building.

A fee is charged for a building permit to construct a stand alone green roof. The service index under "Re-roofing with structural work, raised roof structure" is used.

Forms

Two forms are available on the Toronto Building website that must be completed as part of the building permit application and inspection process:

http://www.toronto.ca/building/forms.htm

1. Green Roof Declaration Form

This form is required to be completed for submission with all building permit applications for new buildings or building additions with a Gross Floor Area exceeding 2000m2, or where a green roof is proposed to be constructed.

2. Green Roof Inspection Checklist

Upon completion of the installation of the green roof, this site review report is to be submitted by the designer to the inspector, verifying that the green roof installation is in conformance with City of Toronto Bylaw No.583-2009, Section 492-9 "Toronto Green Roof Construction Standard: Mandatory Provisions."

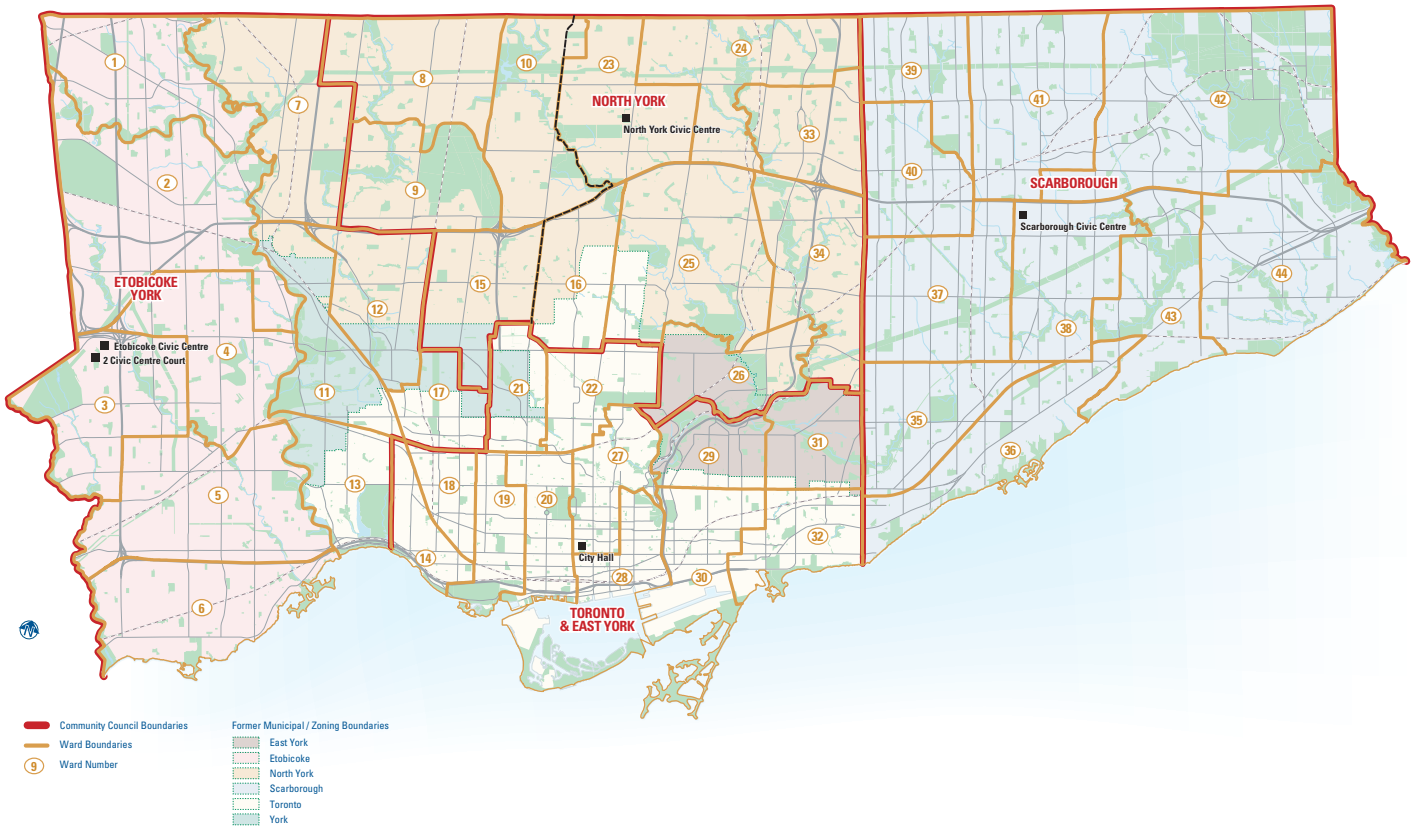
Tools for Designers

Green Roof Designer Checklist

The Green Roof Designer Checklist is a voluntary tool to assist designers in reviewing green roof projects by providing a summary of Ontario Building Code and Green Roof By-law provisions. The form is not required as part of a building permit.

http://www.toronto.ca/building/pdf/Green_Roof_Designer_Checklist.pdf

Toronto Building Customer Service Office Locations

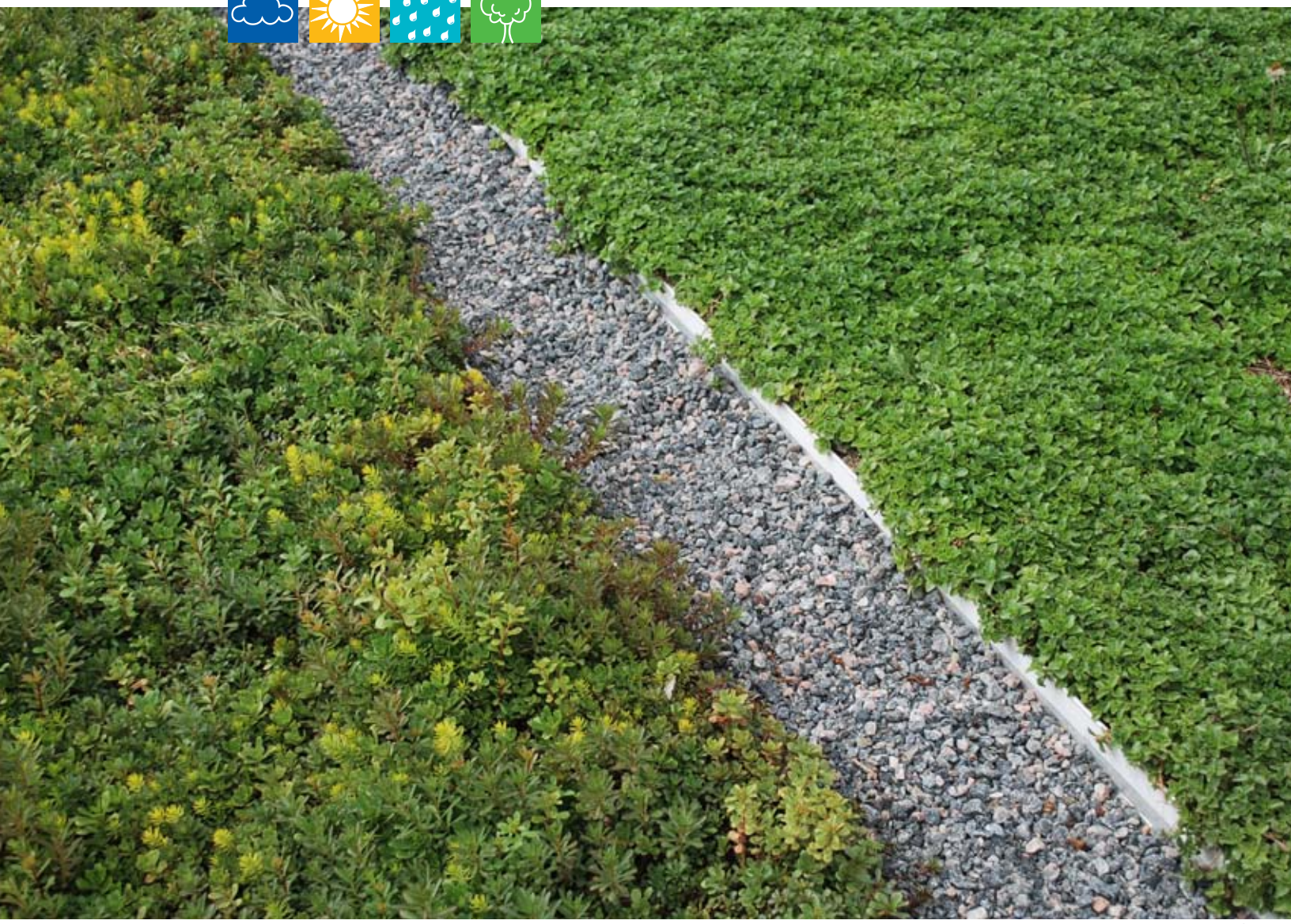


Toronto and East York District
Toronto City Hall
100 Queen Street West
416-392-7539
Wards:
14, 18, 19, 20, 21, 22, 27, 28, 29, 30, 31, 32

North York District
North York Civic Centre
5100 Yonge Street
416-395-7000
Wards:
8, 9, 10, 15, 16, 23, 24, 25, 26, 33, 34

Etobicoke York District
Etobicoke
2 Civic Centre Court
416-394-8002
Wards:
1, 2, 3, 4, 5, 6, 7, 11, 12, 13, 17

Scarborough District
Scarborough Civic Centre
150 Borough Drive
416-396-7526
Wards:
35, 36, 37, 38, 39, 40, 41, 42, 43, 44



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