Centre for Urban Greenery & Ecology
CUGE Standards

GUIDELINES ON
FILTER, DRAINAGE AND ROOT PENETRATION BARRIER LAYERS FOR ROOFTOP GREENERY

CS E04:2010

Guidelines on Skyrise Greenery

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GUIDELINES ON
FILTER, DRAINAGE AND ROOT PENETRATION BARRIER LAYERS FOR ROOFTOP GREENERY

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Filter, Drainage and Root Penetration Barrier Layers for Rooftop Greenery
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The CUGE Standards will be reviewed every three years. Concurrently, CUGE also gathers new information continually through its on-going research.

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Filter Layer for Rooftop Greenery

SECTION 1 SCOPE

1.1 INTRODUCTION

This specification sets out the basic requirements for the construction of the filter layer, drainage layer and root penetration barrier layer of rooftop greenery.

Rooftop greenery is designed and installed on the rooftop spaces of new buildings and existing structures, and is very much a part of a building's surface.

The substrate (soil-alternative) volume, being atop a building's rooftop, will have to be contained. This can be achieved through the use of the filter layer to contain the substrate layer.

Excess water in rooftop greenery, atop a building, needs to be effectively drained away. The installation of the drainage layer is to fulfil this function.

The roots of vegetation on rooftop greenery have to be contained to avoid any possibility of the vegetation root compromising the performance of the building surface and structure. The appropriate installation of the root penetration barrier layer can help to achieve this.

1.2 OBJECTIVE

This specification is intended as a guide for the construction of the filter layer, drainage layer and root penetration barrier layer of rooftop greenery.

It is intended to act as a reference point for quality assurance of the filter layer, drainage layer and root penetration barrier layer of rooftop greenery.

The design and construction of rooftop greenery shall comply with the relevant codes of practice and standards of the relevant authorities.

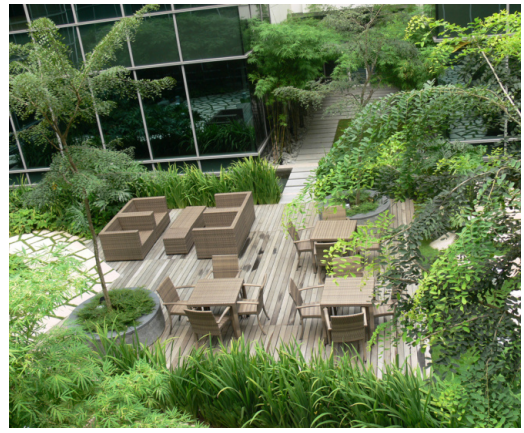
1.3 DEFINITIONS

Green roof

Extensive green roofs are in general not designed for active recreational use. They are developed mainly for aesthetic and ecological benefits. Distinguished for being low in installation cost, lightweight (50-150 kg/m^2) and with shallow mineral substrates, minimal maintenance is expected. Inspection should be performed, at the minimum, once or twice a year. Plants selected are usually of low maintenance and are self-generative. Extensive systems can also be placed on pitched roofs of up to an inclination of 30 degrees. They are common in European countries, especially Germany.

Roof garden

Intensive green roofs, or roof gardens, are developed to be accessible. They are often used for recreation and other social activities. Hence they are associated with added weight, higher capital cost, more intensive planting and higher maintenance requirements. The plant selection ranges from ornamental lawn, shrubs, bushes to trees. As they are designed for usage, regular maintenance such as mowing, fertilising, watering and weeding is required.



1.4 PERFORMANCE REQUIREMENT

Filter Layer

The main function of the filter layer is to contain and retain the substrate layer, preventing loss of aggregates and substrate volume. Significant loss of substrate volume can adversely affect plant growth and establishment, especially on green roofs whereby the substrate layer is thin.

The filter layer should prevent the clogging of the drainage layer (which is beneath the substrate layer) by fines and plant debris, while allowing air and water to pass through.

The filter layer should have the appropriate chemical and physical properties to function appropriately under the unique site and microclimatic conditions of rooftop greenery. The filter layer should not inhibit vegetation growth and root establishment.

Drainage Layer

The drainage layer should function appropriately on rooftop space, such that excess water can be effectively drained and, where intended and necessary, water can be appropriately stored and retained for irrigating the vegetation, especially for green roofs (extensive rooftop greenery).

As the microclimate at the rooftop space can be extreme (intense sunlight and stronger winds with increasing altitudes), the selection, installation and maintenance of the substrate layer should address these concerns.

The drainage layer should function appropriately on the rooftop greenery space, such that the plants can establish without inhibition.

Root Penetration Barrier Layer

The main function of the root penetration barrier layer is to separate the roots of the vegetation from coming into physical contact with the building surface and structure – thus preventing the growth of the vegetation root from compromising the integrity of the roof surface and structure and adversely affecting the building's intended performance.

The root penetration barrier layer should function appropriately on the rooftop greenery space, such that the plants can establish without inhibition.

The root penetration barrier layer should have the appropriate chemical and physical properties to function appropriately under the unique site and microclimatic conditions of rooftop greenery.

SECTION 2 FILTER LAYER

2.1 INTRODUCTION

2.1.1 Geo-textiles or geo-fabrics are commonly used in roof gardens and green roofs as a screen or filter layer to contain and prevent migration of solid grains and particles from the substrate volume. The main function of the geo-textile is to form the border of the substrate layer and contain the solid grains and particles of the substrate.

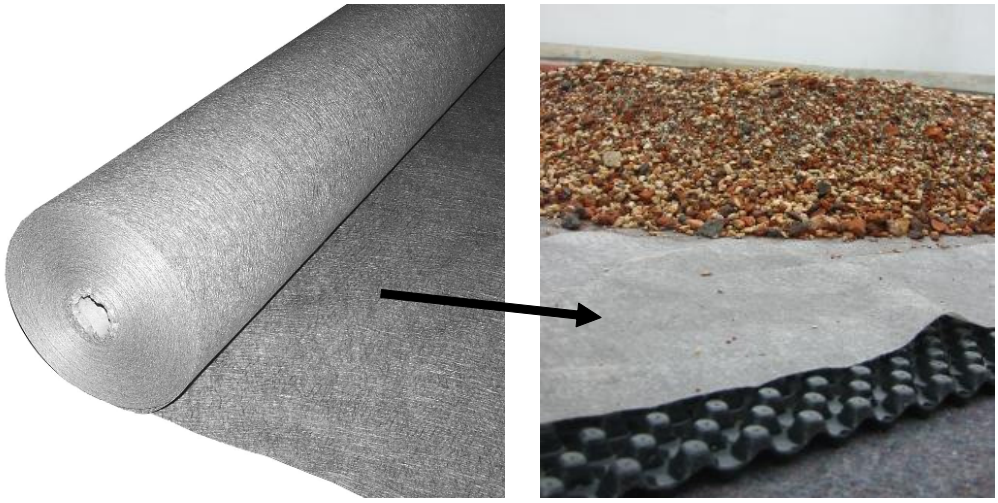


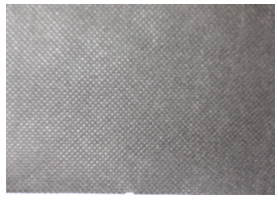
Figure 1 & 2
Filter sheet and its typical location within the build-up of the green roof system.

2.1.2 Geo-textiles usually come in the following forms:

- Fleece fabrics – These consist of generally-aligned or randomly-laid synthetic fibres that are of any length and bonded to one another through mechanical and/or thermal processes. In general, those with longer fibres and which are bonded thermally have a higher quality.

Fleece

- Woven fabrics – These are flat fabrics consisting of two mutually perpendicular sets of threads bonded with fabric weave. Woven fabrics have high tensile strength. These are manufactured by interlaying (usually at right angle) two or more sets of yarn, fibres, tapes or other products such as polyester.



Woven fabric

2.2 REQUIREMENTS - TECHNICAL PROPERTIES

2.2.1 Density

- For substrate depths of up to 250 mm on a flat surface, the recommended minimum density of the filter layer is 100 g/sqm, but the acceptable range is between 100 and 200 g/sqm.

- For deeper depths on a flat surface and pitch roofs, filter layers of a higher density should be used in order to meet the following criteria:
  - Resistance to root penetration
  - Tensile strength
  - Elasticity

2.2.2 Mechanical stress resistance

- Filter layer should be able to withstand a penetration force of at least 0.5 kN or 50 kg.

2.2.3 Width of aperture - Effectiveness of mechanical filtration

- The effectiveness of the filter layer in providing mechanical filtration is directly related to the width of the aperture (which refers to the tiny gaps between the fibres of the filter layer).

- The effective aperture width or $O_{90,w}$ denotes the diameter of the grains of a standard test soil from which the geo-textile retains 90% of the soil and allows the remaining 10% of the soil to pass through.

- The recommended range of $O_{90,w}$ is between 0.06 mm and 0.2 mm.

2.2.4 Susceptibility to root penetration

- While there are root-resistant geo-textile products available in the market, they are not recommended for use on green roofs. The filter layer must permit the roots of vegetation to penetrate through it.

- This is especially so for green roofs where the build-up of the green roof structure or system is shallow or thin. The roots of the vegetation must be allowed to penetrate through the filter layer to reach and rest at the underlying drainage (cum reservoir) layer.

- The roots should be inspected from time to time to ensure that they are not choking the drainage layer.

2.2.5 Resistance to weathering

- Geo-textiles are not weather-proof materials, and are susceptible to deterioration under the direct effects of the environment and climate. Therefore, they should not be exposed to the elements beyond that specified by the manufacturers.

- In a tropical climate such as that in Singapore, geo-textile of 100 g/sqm density would exhibit deterioration symptoms (eg. tearing easily and breaking up into fragments) after being exposed to and unprotected from direct sunlight for three weeks.

2.2.6 Resistance to micro-organisms

- The resistance of the filter layer against micro-biological attacks can be tested by burying it in peat soil.

- Test standards governing such tests include the BS EN 12225:2000.

2.2.7 Resistance to chemicals

- The filter layer should be able to resist and withstand a range of chemicals associated with those commonly found in green roofs.

- The proof of resistance to chemicals, including test certificates, is usually obtainable from manufacturers of the geo-textile.

2.3 CONSTRUCTION

2.3.1 The filter layer is typically laid on top of the drainage (cum reservoir) layer within the build-up of the green roof system.

2.3.2 The filter layer can be separated from or integrated with the underlying drainage (cum reservoir) layer.

2.3.3 Overlapping – There must be a minimum overlapping of 100 mm between any two pieces of filter layer.

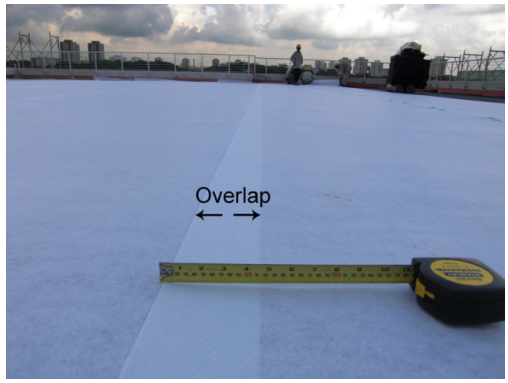


Figure 3
Illustration on overlapping between two pieces of filter sheet

2.3.4 Up-turn – At the least, the up-turn of the filter layer at the boundaries or edges must be at the same level of the top surface of the substrate layer. This is to minimise the possible migration of substrate materials out of the substrate layer and into the underlying drainage (cum reservoir) layer.

2.3.5 As the filter layer will deteriorate with exposure to other elements, efforts should be carried out to minimise any exposed filter layer.

2.3.6 Upon laying the filter layer, it should be covered by the substrate layer as quickly as possible with minimal time lapse. Under no circumstances should the filter layer be exposed beyond that specified by its manufacturer.

2.3.7 In areas where the filter layer is not covered by the substrate layer, consideration and efforts must be taken to protect the filter layer against negative wind pressures or wind suction effects.

SECTION 3 DRAINAGE LAYER

3.1 INTRODUCTION

3.1.1 While "drainage layer" is a common term used to depict that layer beneath the filter and substrate layers within the build-up of the green roof system, there are products available in the market that perform:

- Drainage-only function, or
- Drainage cum water-retention function.

Figure 4
Typical build-up of a green roof system, indicating the location of the drainage layer within the system.

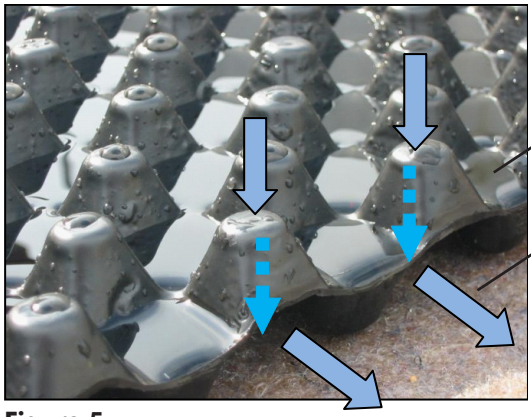


Figure 5
Typical moulded drainage board, showing the water storage capacity and draining of excess water

3.1.2 This section addresses "drainage layer" generically, encompassing products with both functions mentioned above.

3.1.3 In the context of greenery, the functions of the drainage layer are:

- To drain excessive water and to prevent stagnation of water.
- To supply water through the water-retention function.
- To make available additional space for root penetration.
- To support the form and type of vegetation that is intended for the green roof.

3.1.4 The design and installation of the drainage layer should take into consideration the following criteria:

- The drainage function (that is, mode of drainage, capacity, etc.) of the layer.
- The design loads that the drainage layer is expected to withstand.
- The protective function, and the intensity of which, that the drainage layer is expected to perform.

3.2 MATERIAL GROUPS AND TYPES

The drainage layer may be made from a variety of materials and come in a number of forms:

- Aggregates from natural materials
  - Gravel and fine chippings
  - Lava and pumice stones
  - Expanded clay and expanded shale, whether crushed or uncrushed.
  - Expanded slate (crushed or uncrushed)

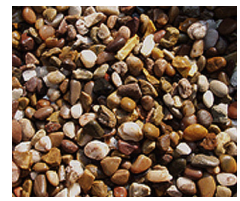


Figure 6
Gravel and fine chippings

- Aggregates from recycled materials
  - Crushed and unglazed clay tiles
  - Furnace waste material
  - Foamed glass

Figure 7
Recycled foam glass aggregate

- Drainage mat
  - Structured fleece matting
  - Studded plastic matting
  - Woven fibre matting
  - Foam matting
- Drainage board
  - Studded rubber board
  - Moulded rigid plastic board
  - Moulded plastic foam board
- Drainage and substrate board
  - A board made from modified foam

Figure 8
Studded plastic matting

3.3 REQUIREMENTS – TECHNICAL PROPERTIES

In assessing the suitability of the materials that make up the drainage layer, the technical properties of these materials have to be considered in tandem with:

- The state of condition in which the materials are being used; and

- Site conditions and requirements.

Tests to verify certain technical properties may be conducted against Test Standards and prevailing Building Codes to assist in the above assessment. These tests are indicated in Table 1.

From the vegetation perspective, the overview of the important technical properties of aggregates used as the drainage layer is indicated in Table 1. Please refer to page 29.

3.3.1 Granulometric distribution of aggregates

- Aggregates used in the drainage layer should be used in the compacted state.

- The amount of aggregates with grain size of diameter of less than 0.063 mm (i.e. d < 0.063 mm) should not exceed 10% by mass.

- Granular distribution for the corresponding depths of the drainage layer is as follows:

Depth of drainage layer (mm)	Granular size (mm)	
	Lower limit	Upper limit
40 - 100	2 - 8	2 - 12
> 100 - 200	4 - 8	8 - 16
> 200	4 - 8	16 - 32

3.3.2 Structural and layer stability

- Materials must have a certain level of integral strength for load bearing purposes and to maintain its form, shape & volume during the storage, installation and post-installation period. The loads imposed on the material include:

  - Weight of the material
  - Weight of the overlying material and/or structure
  - Weight of water, such as when saturated
  - Loads generated by maintenance and servicing activities

- For drainage boards and mats that are made of/from plastic material, they must be rot-resistant and crack-resistant even under the effects of materials and micro-organisms in the vegetation layer.

- Care should be taken to ensure that the drainage system is made rodent and vermin resistant so that the efficiency of the system is not compromised.

- The granular shape of aggregates plays a critical role in the stability of the material upon installation. Sharp and extremely angular grained aggregates are generally discouraged.

3.3.3 Behaviour under compression

- Drainage boards and mats, especially those made of/from plastic, must be able to withstand compressive forces that are exerted by overlying loads throughout the service life without compromising other technical properties such as water permeability or infiltration rate, etc.

3.3.4 Water permeability or infiltration rate

- Materials that make up the drainage layer should be highly porous or permeable, to ensure high efficiency in draining any excess water away from the green roof into the drainage or discharge outlets on the roof.

- The level of performance of the drainage layer in terms of the amount of water that the drainage layer is able to drain vertically can be calculated using the following formula:

q' **=** **(A x C x q) ÷ b** (litres per second, metre)

Where

q'	=	The volume (litres per second, metre) drained through the drainage layer
A	=	The surface area to be drained (square metres)
C	=	The coefficient of surface runoff
q	=	Maximum rainfall (litres per second, square metres), as defined in the Singapore Standard SS525:2006 Code of Practice for Drainage of Roofs, clause 5.2.
b	=	calculated runoff width (metres)

Depth of drainage layer (mm)	Coefficient of surface runoff, C	
	Slope of up to 15°	Slope of more than 15°
> 500	0.1	-
> 250 to 500	0.2	-
> 150 to 250	0.3	-
> 100 to 150	0.4	0.5
> 60 to 100	0.5	0.6
> 40 to 60	0.6	0.7
> 20 to 40	0.7	0.8

- For extremely thin and shallow rooftop greenery systems, such as those on green roof (extensive roof greening), surface runoff during a heavy downpour could be expected. A properly designed green roof should have no surface runoff and if any, should only be of an insignificant amount.

- For ductile drainage layers, the critical factors that determine their performance in terms of drainage are the depth and coefficient of permeability (values of which are taken after a long-term stress versus load-bearing performance).

- For drainage layers that are formed using mineral aggregates, consideration must be given to the reduction in granular size of the aggregates in the long term due to mechanical effects, physical and/or chemical factors. Hence, using stable, durable and inert mineral aggregates is advisable.

- The roots should be inspected from time to time to ensure that they are not choking the drainage layer.

3.3.5 Water storage capacity

- For drainage layers that are formed using mineral aggregates, the aggregates should possess both high drainage and high water storage capacity to achieve an optimal water level that is good for vegetation growth. Such qualities are achievable when the aggregates are:
  - **Open-pore**, as opposed to closed-pore. Hence, crushed expanded clay is more suitable than uncrushed expanded clay in this instance.
  - **Water-absorbent**, as opposed to water-repelling.

- To ensure that the substrate layer that is above the drainage layer is not water-logged and that excess water can be drained away efficiently by the drainage layer, there must be sufficient dry space above the maximum water table within the drainage layer.

- Drainage layer formed using drainage boards usually have built-in water storage capacity. From the perspective of ensuring vegetation health, the drainage layer should concurrently allow efficient drainage of excess water and possess appropriate water storage capacity.

3.3.6 pH values

- For drainage layers that are formed using mineral aggregates, the pH value of the aggregates must be considered in tandem with that of the substrate as well as the needs of the vegetation. The pH values for both the substrate layer and the drainage layer should be similar, with a maximum deviation of 1.5 units from that of the substrate layer.

- The optimal pH values for the substrate layer are as follow:

Types of green roof	**pH value**
Roof garden	5.5 – 8.0
Green roof	5.5 – 8.0

- However, in the event that the particular vegetation requires acidic substrate or extraordinary level of pH of the substrate, then the unique pH value required should be specified.

3.3.7 Carbon content

- Materials that possess high carbon content, such as recycled concrete and calciferous aggregates, must not be used in the drainage layer because of the risk of drainage impediment caused by sintering.

- Sintering is the fusing, or forming of powdered material into a product without actually liquefying the material. The excessive release of carbonates from concrete materials such as the protective screed, concrete edging/kerbs, paving slabs and the like in the vicinity of the green roof may lead to the formation of lumps that may reduce the performance of such a drainage layer.

- In the event that sintering of the underlying concrete layers is inevitable, the surface of the concrete that receives the green roof should be treated with a suitable top coating or sealing it within a plastic sheet to prevent the carbonates from being dissolved by the discharging water.

3.3.8 Salt content

- From the vegetation perspective, the limits of the salt content within the drainage layer that uses aggregates are:

Types of green roof	**Salt content**
Roof garden	Maximum 1.5 g/l
Green roof	Maximum 1.5 g/l

- As a general guide, salt content should be as low as reasonably possible so as to prevent any risk of environmental pollution due to leaching.

- Alternatively, salt content can be measured by Electrical Conductivity (EC) which is the ability of the soil to conduct electrical current.

- The EC of the substrate layer should be less than 2.0 dS/m. (Please refer to CS A01:2009 – Specifications for Soil Mixture for General Landscaping Use)

3.4 CONSTRUCTION

3.4.1 A proper drainage layer should be laid over a flat and even surface.

3.4.2 The following are the allowable tolerances for the evenness of the roof surface over a distance of every 4 m, in relation to the thickness of the drainage layer:

Depth of drainage layer (mm)	**Tolerance on surface irregularities such as "pits or mounts" (mm)**
100	Maximum 10
> 100 to 200	Maximum 15
> 200	Maximum 20

3.4.3 The minimum depth of the drainage layer must be maintained in all relevant locations and at all times even when other layers that perform other functions may be added to the drainage layer. Otherwise, the performance of the drainage layer will be compromised.

3.4.4 In the event that drainage matting and boards are used, the even-ness criteria of the surface should be comparable to that of the roof structure. In addition, as there will be gaps or spaces between any two pieces of matting or boards, care should be taken to ensure that these gaps are not eventually occupied, whether partially or wholly, by the overlying materials such as the substrate. Such occurrences are undesirable as it will impede drainage.

3.4.5 For a flat roof where the slope is less than 2% or 1:50, measures should be taken to smoothen out the irregularities of the roof surface. Otherwise, a thicker drainage layer should be used instead.

3.4.6 Where sharp and extremely angular grained aggregates, or rigid/hardened plastic drainage items are used as the drainage layer, the risk of puncturing the underlying waterproofing layer and/or root barrier increases. This is especially evident at the edges of such aggregates and plastic drainage items. In such situations, having a protective lining or layer over the aggregates and plastic drainage items should be considered.

3.5 DRAINAGE FACILITIES

3.5.1 Types of drainage facilities – These comprise of the following:

- Roof drainage outlets
- Interior piping
- Gullies or scupper drains at doorways and parapet walls
- Gutters
- Spouts
- Emergency overflows

3.5.2 Design code

- Drainage facilities must be designed in accordance to Singapore Standard SS525:2006 – Code of Practice for Drainage of Roofs, regardless of whether the area in the vicinity is covered with greenery or not.

3.5.3 Requirements

- The drainage facilities must be designed for the collection and removal of water from the following sources:
  - Overflow from the drainage layer within the green roof system; and
  - Surface runoff (if any) from the vegetation layer.
- Drainage of water accumulated from the surrounding surfaces (whether horizontal, vertical or inclined) and adjoining walls, facades and structures should be designed such that the functions of the vegetation layer and green roof system are not compromised in any way.
- Irrespective of the size of the roof, the minimum physical quantity of drainage facilities located within the roof greenery area is as follows:
  - At least one facility to cater for surface runoff (if any) and excess water draining through the drainage layer; and
  - At least one emergency overflow facility.

- Pressurised flow drainage (such as siphonic drainage system)

    - Where pressurised drainage is used in conjunction with roof greening, design should be made on a project-by-project basis, complemented by frequent on-site checks, to optimise the functions of both entities without compromising either one.

    - For small-size roofs that are vegetated (whether partially or wholly), design checks must be made to ensure that the reduced volume of rain water accumulated on it is sufficient to maintain the self-cleaning characteristic of the pressurised drainage system.

    - At the roof area where there are differential water discharge rates arising from the presence of different roof situations (such as roof gardens, green roofs, hard surfaces, etc), design checks must be made to assess the suitability of the pressurised drainage system in this situation.

    - For roof greenery areas with unintentional, free-standing water in the drainage layer, there must be open channel drainage facilities system provided to drain such water, to prevent breeding of mosquitoes.

- Roof drainage outlets, such as rainwater down pipes (RWDP) and emergency overflows must remain exposed, identifiable, accessible and visible at all times, and not covered by vegetation or loose material such as gravel, granite stones, etc.

- Regular maintenance of and checks on the drainage system must be ensured.

3.6 INSTALLATION

3.6.1 Roof drainage outlets in vegetated roof areas

- An inspection chamber, or a facility to enable inspection with ease of the outlet, should be installed over each outlet. This allows visual inspections to be conducted at any time and with ease; it helps to prevent contamination and stop plants from growing over & into the outlet thereby impeding the drainage of water though it.

Figure 9
A typical inspection chamber covering a roof drainage outlet in a vegetated roof area

- Choices of inspection chambers range from prefabricated metal and rigid plastic ones to those made from block-work.

- Under no circumstances should the inspection chamber be a hindrance to drainage.

3.6.2 Roof drainage outlets in non-vegetated roof areas

Figure 10
A typical framed-grating covering a roof drainage outlet in a non-vegetated roof area

- For roof drainage outlets that are located clearly away from vegetated areas, they should be covered by suitable gratings or perforated covers that are stable and durable, and effective in filtering out large particles and grains from entering the roof drainage systems via these outlets.

- In the event that the roof drainage outlets are clearly located away from vegetated areas and in a sunken location (such as in a raised platform/floor situation), there should be a sturdy, framed-cover above the outlet that is accessible and also flushed with the raised surface.

3.6.3 Emergency overflows

- Emergency overflows must not be hindered in any way (eg. edging, kerb, stumps, grills, etc) as they sought the emergency overflow discharge point.

- The immediate area surrounding the emergency overflow discharge point must possess the following characteristics:

  - Free of vegetation, whether intentional planting or unintentional weeds.

  - Allow for instant visual inspection of the condition of the discharge point.

  - Allow water to flow away freely and easily.

3.6.4 Removal of water from pitched roofs

- As the use of gutters at the eaves of a pitched roof is discouraged in Singapore, there must be proper edging that is structurally stable to withstand the sliding force of the roof greenery as well as sufficiently pervious to drain away surface run-off and sub-surface drainage water.

- For steep roofs (with slope exceeding 25° to the horizontal), higher volumes of surface run-off and sub-surface drainage water should be expected, especially at the eaves. The use of overhanging or dangling vegetation, especially at the eaves, is highly discouraged.

TABLE 1: Test requirement pertaining to properties of materials used in drainage layer.

S/No	Properties	Mineral aggregates materials		Synthetic drainage mats and/or boards	
		Suitability test	**Pre- & On-site inspection**	**Suitability test**	**Pre- & On-site inspection**
1	Density • Bulk • Dry • Wet	TC	TC	-	-
2	Load bearing capacity when materials are: • Dry • Wet	-	-	TC	TC
3	Granulometric distribution	TC	TC	-	-
4	Structural and bedding stability	Mfg	-	-	-
5	Water permeability	TC	-	TC	-
6	Water storage capacity (max)	TC	-	TC	-
7	pH value	TC	TC		-
8	Salt content	TC	TC		-
9	Plant compatibility and risk of phytotoxicity	Mfg / P	-	Mfg / P	-
10	Environmental compatibility	Mfg / P	-	Mfg / P	-
11	Fire behaviour	-	-	P	-
12	Compatibility of materials	-	-	P	-

TC denotes Test Certificate or Test Report based on a certain internationally recognised standard is required.

Mfg denotes that Letter of Confirmation from the manufacturer and/or Specialist is required to provide some form of assurance.

P denotes testing in accordance to the prevailing (including local) standards, regulations, codes and guidelines is required.

SECTION 4 ROOT PENETRATION BARRIER LAYER

4.1 TYPES AND MATERIALS

Figure 11
Laying of sheet type root barrier for a green roof

4.1.1 Products that serve the function of protecting the structural roof slab (on which the green roof rests) against root penetration may come in the following forms:

- Protective sheets or membranes
- Full surface coating or liquid-applied sealant

4.1.2 The following roof types are deemed to be resistant to root penetration:

- Roof structures constructed using waterproofed concrete (through the use of quality waterproofing additives). However, construction and expansion joints of such structures are considered "weak points" in the context of root penetration, and so, they have to be specially treated and detailed against root penetration.
- Metal roofs construction using of fully welded metal sections and sheets.

4.1.3 Root penetration barrier layer and waterproofing layer

- While these are usually two separate items as they each serve different functions, "2-in-1" products that fulfil both root resistance and water proofing functions are available in the market. However, such "2-in-1" products should already attained high levels of quality standards such as the Germany FLL (Guidelines for the Planning Construction and Maintenance of Green Roofing – Green Roofing Guidelines – 2008 edition) certification for Products Effective Against Root Penetration as well as internationally recognised standards for waterproofing.

4.2 REQUIREMENTS

4.2.1 Whether in green roof (extensive) or roof garden (intensive) roof greening, the primary function of the root penetration barrier layer is to protect the underlying layers (such as the waterproofing layer, structural slab, etc) from being damaged by the ingress or penetration of the roots of the vegetation; which may be intentionally or unintentionally planted.

4.2.2 Where grasses are involved, especially those species that have strong rhizome or root growth (such as bamboo and reeds), special measures, including maintenance arrangements, in addition to the installation of the root penetration barrier layer must be taken to reinforce and protect the structure against root penetration.

4.3 EXECUTION

4.3.1 When dealing with two separate products

- In the construction of the roof, the root penetration barrier layer such as those mentioned in pt 4.1.1 above may be laid on top of the waterproofing layer (which may be a separate layer altogether) to act against root penetration. The root penetration barrier layer should not be laid below the waterproofing layer.

- The root penetration barrier layer may be laid directly on top and in contact with the underlying waterproofing layer; or separated from the waterproofing layer by a layer of protection cement-sand screed.

- To effectively seal the roof structure against water seepage/leakage, the root penetration barrier layer (on a roof where there is roof greenery) should cover the greenery areas as well as a safety margin or buffer zone surrounding the greenery areas. Specialist advice should be sought pertaining the extent of the safety margin or buffer zone.

4.3.2 When dealing with a single "2-in-1" product

- To effectively seal the roof structure against water seepage/leakage, the product should cover the maximum roof area regardless of its proximity to the area occupied by roof greenery.

- It is important to engage qualified workers for proper installation.

4.3.3 Penetration or incursion

- Any intentional penetration or incursion of the root penetration barrier layer by fixtures and/or fittings should be carefully treated.

- During installation or construction stage, the root penetration barrier layer must not be damaged. Any other incursions of the root penetration barrier layer such as a tear or cut have to be repaired in an appropriate manner in accordance with the product's manufacturer's instructions.

4.3.4 Seams in membranes

- In the event when pre-formed membranes are used as the root penetration barrier layer, special care must be taken in treating the seam that joins any two pieces of the membrane together to form one continuous and integral membrane.

- For the root penetration barrier layer to be effective, the seams must be joined using the appropriate and durable material, technique and method in accordance with the product manufacturer's instructions. This is to ensure that any gaps, no matter how tiny or minute they may be, present at the seam are fully and adequately sealed.

Figure 12
Illustrating the tools and technique of welding the seams of membranes together at a kerb area.

Figure 13
Poor workmanship of welding the seams especially at corners often lead to the use of excessive patching-up work that are potential weak points for water to seep through.

4.3.5 Laying on rough or undulating surfaces

- In the event where the roof greenery area consists of rough or undulating surfaces, it would be prudent to have an additional protection or barrier layer on top of the waterproofing layer, before the root penetration barrier layer is laid. This is to further protect the root penetration barrier layer from being punctured or mechanically damaged by any sharp edges that may be present at the rough surfaces.

4.3.6 UV-resistance/UV-stablised

- The root penetration barrier layer and/or the waterproofing layer should be UV-resistant/UV-stabilised. Otherwise, they should be treated appropriately.

4.3.7 Joints, borders and fixtures & fittings

- When laying the root penetration barrier layer at joints, borders and fixtures & fittings, the work should be carried out in similar standards stipulated in SS374:1994 and CP 82:1999.
- For expansion joints where continuous and unrestricted access is a criteria, they must not be covered by any roof greenery.

4.3.8 Edging or termination

- The root penetration barrier layer should be appropriately terminated and secured at the edges (especially the top edges of upturns).
- Permanently affix the root penetration barrier layer firmly onto the supporting surface, through the use of adhesives and mechanical accessories.

REFERENCE STANDARDS

Germany FLL	Guidelines for the Planning Construction and Maintenance of Green Roofing – Green Roofing Guidelines – 2008 edition
BS EN 12225:2000	Geotextiles and geotextile-related products - Method for determining the microbiological resistance by a soil burial test; EN 12225 is the international equivalent
SS525:2006	Code of Practice for Drainage of Roofs
SS374:1994	Performed Waterproofing Membranes for Concealed Roof
CP82:1999	Code of Practice for Waterproofing of Reinforced Concrete Buildings

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About the National Parks Board
And Centre for Urban Greenery & Ecology

The National Parks Board (NParks) is responsible for providing and enhancing greenery of the Garden City of Singapore. Beyond managing public parks, the park connector network, lush roadside greenery, nature areas and nature reserves, NParks is committed to enhance the quality of life through creating memorable recreational experiences and lifestyles.

The Centre for Urban Greenery and Ecology (CUGE) is an initiative of NParks. Through its research and training programs, CUGE advances knowledge and expertise in urban greenery and ecology in the landscape and horticulture industry in Singapore. It works closely with industry partners to promote good work practices and create a thriving, creative, innovative and professional industry that will support Singapore's aspiration to be a City in a Garden.