Centre for Urban Greenery & Ecology
CUGE Standards

GUIDELINES ON **WATERPROOFING FOR ROOFTOP GREENERY**

CS E05:2012

Guidelines on Skyrise Greenery

CUGE CENTRE FOR URBAN GREENERY AND ECOLOGY

BCA / NPARKS GREEN MARK FOR PARKS

NATIONAL PARKS

CS E: Skyrise Greenery

CUGE STANDARDS CS E05:2012

GUIDELINES ON **WATERPROOFING LAYER FOR ROOFTOP GREENERY**

Published by:
Centre for Urban Greenery & Ecology
National Parks Board Headquarters
1 Cluny Road
Singapore 259569

The CUGE Standards Series is a set of published guidelines for adoption in the landscape and horticulture industry. They are written through a formal process that involves consultation with relevant bodies and reaching a consensus across all interested parties so that the final document meets the needs of business and industry. The standards take the form of either specifications, methods, vocabularies, codes of practices or guides.

The CUGE Standards Series comprises:

CS A Specifications on properties of planting media
CS B Landscape construction and management
CS C Urban ecology
CS D Landscape design
CS E Skyrise greenery

DISCLAIMER

While the information it contains is believed to be correct, it is not a substitute for appropriate professional advice. In no event shall NParks or CUGE be liable for any special, incidental, indirect or consequential damages of any kind arising out of or in connection with the use of this Standard, whether or not advised of the possibility of damage, and on any theory of liability.

This publication is provided "as is" without warranty of any kind, either expressed or implied, including, but not limited to, the implied warranties of merchantability, trees for a particular purpose, or non-infringement. Descriptions of, or references to, products or publications do not imply endorsement of those products or publications. This Standard will be reviewed every three years and changes may be made from time to time.

ISBN 978-981-07-1271-6

Waterproofing Layer for Rooftop Greenery

First Edition: CS E05:2012

The CS E05:2012 was prepared by the CUGE Standards Technical Committee (CS E05:2012).
The Technical Committee was represented by:

Dr. Tan Puay Yok (National Parks Board)
Mr. Edmund Koh Liang Teck (National Parks Board)
Mr. Poh Choon Hock (National Parks Board)
Mr. Ho Wan Weng (International Green Roof Association)
Mr. Wong Ngian Chung (Building and Construction Authority)
Ms. Tay Ah Ching (Building and Construction Authority)
Mr. Alan Tan (Housing and Development Board)
Mr. Tan Sze Tiong (Housing and Development Board)
Mr. Lim Peng Hong (Association of Consulting Engineers Singapore)
Mr. Russell Cole (Association of Consulting Engineers Singapore)
Mr. Siva. M. Sivakumaran (Association of Consulting Engineers Singapore)
Mr. Alfred Lim (Waterproofing Trades Association Singapore)
Mr. Chua Boon Hwee (Waterproofing Trades Association Singapore)

The CS E05:2012 was approved by the CUGE Standards Review Panel in Dec 2011.
The CUGE Standards Review Panel was represented by:

Dr. Leong Chee Chiew (National Parks Board)
Mr. P. Teva Raj (National Parks Board)
Mr. Henry Steed (Singapore Landscape Industry Council; Singapore Institute of Landscape Architects)
Mr. John Tan (Singapore Landscape Industry Council; Landscape Industry Association Singapore)

The CUGE Standards will be reviewed every three years. Concurrently, CUGE also gathers new information continually through on-going research.

Enquiries:
Poh Choon Hock
poh_choon_hock@nparks.gov.sg

Angelia Sia
angelia_sia@nparks.gov.sg

CONTENTS

Waterproofing for Rooftop Greenery

SECTION 1 SCOPE

1.1 INTRODUCTION

This specification sets out the basic requirements for the construction of the waterproofing layer of rooftop greenery.

This specification recognizes and acknowledges the existing and prevailing design standards, regulation and codes (such as CP82:1999), best practices and industrial norms relevant to the specialized field of waterproofing in the local industry; and is not intended to replace, substitute or dilute these standards, regulation and codes in any way. Rather, this specification is intended to complement by highlighting issues relevant to green roofs and roof gardens.

It is important to highlight that the fundamentals in design involving civil and structural engineering and detailing of the roof structure, that support green roofs and roof gardens, must be sound and not compromised in any way.

1.2 OBJECTIVE

This specification is intended as a guide for the construction of the waterproofing layer of rooftop greenery.

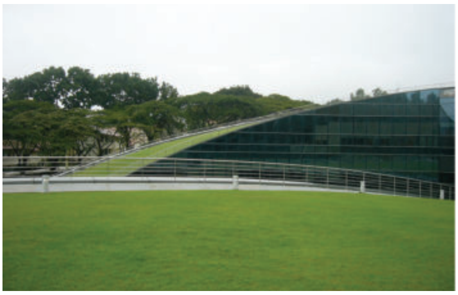
It is intended to act as a reference point for quality assurance of the waterproofing layer of rooftop greenery.

The design and construction of rooftop greenery shall comply with the relevant codes of practice and standards of the relevant authorities (such as CP82:1999).

1.3 DEFINITIONS

Green roof

Extensive green roofs are generally not designed for active recreational use. They are developed mainly for aesthetic and ecological benefits. Distinguished for being low in installation cost, lightweight (90 -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 green roof systems can also be placed on pitched roofs of up to an inclination of 40 degrees. They are common in European countries, especially Germany and increasingly being installed in North American cities as well.



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

1.4.1 The quality and installation of the waterproofing layer, underneath a green roof and/or roof garden, should effectively function to make the rooftop surface prevent the ingress of water under the specific mechanical, structural and chemical conditions expected on a green roof and/or roof garden.

1.4.2 The waterproofing layer should also allow for the establishment of plants on the green roof and/or roof garden without compromising the performance of the waterproofing layer and the structural integrity of the roof surface.

1.4.3 Other aspects of the building, such as the building's structural design, drainage provision, waterproofing additives (to concrete mix) also contribute to the effective performance of the adopted waterproofing strategy and system on the building rooftop surface.

Structural design

- The design of rooftop greenery (which also involves the selection and application of suitable waterproofing system) should respect and optimise the building's structural design and intent. Structures and systems should be designed to appropriately spread and effectively transfer the rooftop greenery loads. The design and quality of rooftop surface and structure influence the selection and application of suitable waterproofing systems that go over the rooftop surface.

- For example, waterproofing over movement joints will need special detailing to accommodate structural movement and keep the structure water-tight at the same time. Waterproofing construction over such areas can be complex and demand better workmanship, requiring comprehensive site-work inspections and tests. It is thus advisable, during onset of the design phase, to recognise the need for future and regular maintenance of such rooftop joints. Designing rooftop greenery over such critical joints, without provision for easy access for inspection and maintenance, may not be advisable.

Drainage provision

- Effective waterproofing is as much about preventing water-ingress as, in the context of roof greenery, the removal of excess water effectively and quickly. Effective drainage thus is relevant in enhancing waterproofing capacity.

- Effective drainage requires adequate fall of the surface and adequate drainage points in terms of location, efficiency and capacity. The fall of the surface should be at least 1:100, with adequate drainage points to cater for effective drainage of sudden influx of excess water, such as during a tropical torrential down-pour.

Importance of workmanship

- Waterproofing efficacy can be compromised by a lack of consistency in the installation of the waterproofing system. During application, careful supervision and control is needed, especially in ensuring thickness consistency and uniformity of the application procedure. Application must be by certified competent workers in accordance to installation-specifications of the selected waterproofing product. Quality of workmanship is crucial to waterproofing installation efficacy.

Conditions to note when waterproofing new and existing roofs

- During waterproofing of both new and existing roofs, prior to the application of the waterproofing system, full inspection of the receiving roof surface is necessary. Appropriate repair must be carried out to rectify all identified poor conditions of the receiving roof surface. This is to ensure that the installed waterproofing system perform optimally. The fall of the receiving roof surface must be adequate and smooth for effective drainage.

SECTION 2 WATERPROOFING LAYER

2.1 WATERPROOFING IN GENERAL

Fig 1:
The typical location of the waterproofing layer (The waterproofing layer lies below the green roof system)

2.1.1 Waterproofing, in the context of rooftop greenery, describes the process of making the roof structure on which the greenery sits resist the ingress of water under certain hydrostatic pressure or conditions (these various site conditions, pertaining to water may range from that of a light drizzle, a rooftop pond, to extreme situations such as hurricanes and typhoons).

2.1.2 "Hydrostatic" pressure is the pressure caused by stagnant water loads over a surface. This pressure can exert downward, lateral and even upward (as in the case of an uplift or buoyancy).

2.1.3 Waterproofing is usually achieved through the use and application of membranes and coatings onto surfaces to protect and safeguard structural and surface integrity of these surfaces. However, the construction industry has had technological advancements in waterproofing materials and techniques, such as the integral waterproofing systems that use additives in concrete. More suited to concrete structure, integral systems work within the matrix of the concrete structure, giving the concrete waterproof quality.

2.1.4 Waterproofing should not be confused with vapour-proofing. The former refers to resistance against penetration of liquid water, on which this set of Guidelines focuses, while the latter refers to the resistance against permeation of water vapor (which is the gaseous state of water). It is also to be noted that the accumulation of liquid water but from condensation, is a separate issue outside the scope of this set of Guidelines.

2.1.5 The basic criteria of a good waterproofing material are as follow:

Strength – The waterproofing layer has to be adequately strong to withstand stresses.
Flexibility – The waterproofing layer has to be adequately flexible to accommodate minute movements of the structure on which the material covers.

Good workmanship is crucial to the efficacy of waterproofing installation. The appropriate waterproofing system must be correctly installed to installation-specifications by trained competent installers.

2.1.6 It is to be noted that certain site conditions may require unique and site-specific waterproofing solutions not covered in this set of Guidelines. Such site conditions include:

- Presence of moisture (or water droplets) – In terms of duration and intensity, these range from a completely dry surface to one that experiences permanent presence of moisture or even totally submerged.
- Presence of cracks – These range from tiny surface tension-cracks to major deep cracks.
- Joints – These range from construction joints, expansion joints, to movement joints, etc
- Loading – These include heavy static loads to dynamic loadings.

2.1.7 It may be of interest to note that a roof slab with the following characteristics is sufficiently effective against water seepage in the absence of waterproofing provision:

- Sufficiently thick structural concrete slab of at least 200 mm (With conditions that the constructed roof slab is of high quality concrete casting, finish and detailing.),
- Sufficient fall of no less than 1:100, and
- Constructed of reinforced concrete of at least grade 40.

2.1.8 It is to be noted that should there be an intent to retro-fit a green roof system onto such a roof slab, consultation has to be done with the relevant green roof specialist and the civil and structural professional engineer to ensure that the subsequent installation of the selected green roof system will not compromise the initial intended performance integrity of the roof slab. From the onset, should such a roof slab be designed as a roof garden, provision must be made to allow for effective draining of excess water, proper transfer of the loadings from plants and human traffic, and possible movement of building joints, without compromising the intended performance integrity of the roof slab.

2.2. WATERPROOFING MATERIALS AND APPLICATION METHODS

2.2.1 Materials

Waterproofing materials, in the context of rooftop greenery, typically comes under the following categories:

- Liquid-applied or build-up membrane
- Pre-formed membranes that may be single-ply or multi-ply and come in rolls.
- Integral systems

WATERPROOFING MATERIALS

Liquid Applied Membrane | Pre-formed Membrane | Integral System

2.2.2 Liquid-applied membrane (LAM)

Fig 2:
Liquid-applied waterproofing material can be applied through the use of a brush, roller, spreader or spraying device.

Fig 3:
Liquid-applied waterproofing material is manually applied through the use of rollers.

- Liquid-applied and cold process waterproofing systems generally refer to waterproofing application that take place while the waterproofing material is in the liquid state of matter, and is not torched or hot-mopped down. It typically utilises a cold adhesive (which may be solvent- or water-based) in the adherence or fusion of the felt.

- These cold process and liquid-applied waterproofing systems are primarily designed to eliminate a major concern associated with hot bitumen applications, which is fire risk. Hot bitumen is first melted and applied while it is still in a liquid state at a temperature above 200 °C. The cold process hence eliminates the need to heat and melt the solid bitumen for application and removes all fire and burn hazards, such as the use of fire torches.

- When used on rooftop greenery areas, the liquid-applied waterproofing systems must also possess the ability to resist the penetration of roots. Such ability may come in either of the following modes:

  – Built-in root-resistant feature – This may be in the form of root-repelling chemical that is already included in the formulation and production of the liquid-applied waterproofing system.
  – Separate root-resistant layer – Commonly known as a Root Barrier, this is a separate item that is subsequently laid over the liquid-applied waterproofing system.

2.2.3 Pre-formed membrane

The following chart categorises the various pre-formed waterproofing membrane systems currently available in the industry.

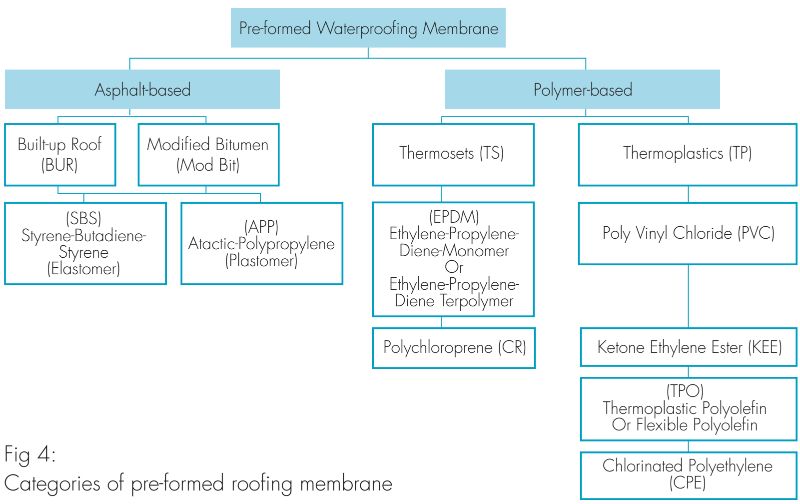


Fig 4:
Categories of pre-formed roofing membrane

Fig 5:
A polymer-based pre-formed waterproofing membrane

Fig 6:
An asphalt-based pre-formed waterproofing membrane

- The matrix material is usually asphalt-based or polymer-based.

- The membrane usually consists of reinforcing fibres or fabric sandwiched between two sheets of flexible matrix. The reinforcing fibres or fabric provides dimensional stability for the membranes as well as strength to resist stresses (such as thermal expansion and contraction stresses) during service.

- However, there are membranes available in the market that do not consist of reinforcing fibres or fabric, and are made entirely of flexible polymer. These membranes are known as "single-ply" membranes.

- When used on rooftop greenery areas, the pre-formed waterproofing systems must also possess the ability to resist the penetration of roots. Such ability may come in either of the following modes:

  – Built-in root-resistant feature – Especially for asphalt-based pre-formed membrane, this may be in the form of root-repelling chemical or a physical barrier that is included in the formulation and production of the membrane. For the polymer-based pre-formed membrane, this is usually in the form of membranes with edges and seams homogenously fused together to form a continuous barrier.
  – Separate root-resistant layer – Commonly known as a Root Barrier, this is a separate item that is subsequently laid over the membrane.

2.2.4 Integral Systems

Integral waterproofing system refers to the waterproofing technique in which additives are added to concrete mix to render the cured concrete structure waterproof. Such waterproofing method, as with most other systems, will require coordination with structural design and detailing, to assure waterproofing effectiveness.

2.3. COMPARISON BETWEEN LIQUID-APPLIED AND PRE-FORMED MEMBRANES, ADVANTAGES AND DISADVANTAGES

This section objectively describes the advantages and disadvantages of the 2 types of waterproofing materials:

2.3.1 Liquid-Applied Waterproofing material

Advantages

- Seamless – There are no visible joints, overlaps, and the like.

Fig 7:
Seamless waterproofing

- Better elongation tolerance (of more than 500%, and some go as high as 1000%), and is able to bridge a larger crack or gap present at the surface of the structure on which the material covers. "Bridging cracks" and "elongation tolerance" is the ability and extend to which the waterproofing material (whether liquid-applied or pre-formed membrane) can be stretched to cover over a crack without compromising on its integrity or water-tightness. Hence, a higher "elongation tolerance" generally means that the material is able to cover over or bridge a larger crack.

Fig 8:
Cracks on an existing concrete roof

- Being in liquid form, the material is able to coat corners, curvatures, surface imperfections and the like better.
- Skill-dependency during application stage is lower.
- Ease of repairing any damaged waterproofing layer.
- As such liquid-applied waterproofing membrane, for its relative ease of application and its high tolerance to elongation, may be suitable for surfaces with tricky corners and edges that require waterproofing, such as the internal surfaces of a confined planter-pit on a roof slab. The tricky corners and the tight spaces may make application of pre-formed membrane more challenging.

Disadvantages

- Achieving a consistent thickness of the waterproofing layer can be a challenge. However, self-leveling materials are available in the market to address this concern.
- Time – To attain optimum performance, the material must be properly cured, which will take time. Depending on the waterproofing material used, the curing process can span from minutes to days.
- Most waterproofing products are prone to blistering. Surfaces receiving the material should be totally dry in most cases and be cleared of debris and dust before application of the waterproofing material. Primers are available to allow damp surfaces to receive the liquid-applied waterproofing material. All blisters must be properly rectified before the next stage of construction can be carried out.

Fig 9:
A blister in the liquid-applied waterproofing material that has been broken. If not rectified, this can be a problem spot which can compromise the waterproofing performance.

- Most waterproofing products need an appropriate primer and/or hardener; therefore, proper and thorough mixing and application sequencing must be ensured.
- Surfaces that are dusty, irregular and badly cracked are often not ideal in receiving the material. Therefore, surface imperfections must be rectified and made good to a reasonable extent before the waterproofing material is applied.
- There will be a marginal increase in labour requirement during the application process in terms of man-hour per area coverage.
- Prior to the installation of green roof system and rooftop vegetation, it is advisable to conduct site-work inspections on the installed waterproofing layer. Site-work test, such as the water ponding test, must be witnessed and endorsed by relevant qualified personnel, such as the registered Resident Technical Officer (for architectural elements). It is to be noted that once the green roof system and the rooftop vegetation are installed, inspection and rectification to improperly installed waterproofing layer can be a challenge. It is also important to make sure that future maintenance to the installed rooftop greenery is carried out without damaging and compromising the performance of the waterproofing layer.

2.3.2 Pre-formed Waterproofing Membrane

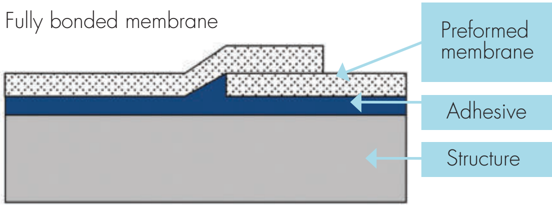
Advantages

- Consistent thickness of the waterproofing layer is assured.
- Seams are heat welded or homogeneously fused.

Fig 10:
Two separate pieces of pre-formed waterproofing membrane are joined together at the seam through a heat welding process. In this case, a hand-held hot air torch and roller are used.

- The options of fully-bonded and non-bonded (that is, to the receiving surfaces) membranes are available in the market.

Fully bonded membrane



Non-bonded or loose-laid membrane

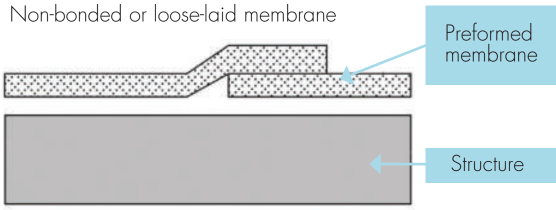


Fig 11:
The diagrams depict the fully-bonded and non-bonded waterproofing membranes.

- Non-bonded pre-formed waterproofing membranes, without the need for the application of a suitable adhesive material between the receiving surface and the membrane, can be installed within a shorter time.
- Fully-bonded pre-formed waterproofing membranes on the other hand, provide better source-of-leak identification and control features than non-bonded ones.

Fig 12:
A primer being manually applied onto the receiving roof surface to provide a better bond for the pre-formed waterproofing membrane that will go on top.

- Both the bonded and non-bonded pre-formed waterproofing membranes are loose-laid allowing for quick setting-out and installation on relatively large, even-surfaced rooftop – suitable for large planar extensive green roof.

Disadvantages

- Seams are essential features of pre-formed waterproofing membranes, and are also the weak points in the application:

Skill requirement

In order to achieve proper, homogeneously fused seams, a higher set of skills (in hot-air welding) and workmanship is required. If the welding is not done properly, for example at a lower-than-desired temperature and/or at a faster-than-desired pace, the seam will not be homogeneously fused. On the other hand, if the seam is done at higher-than-desired temperature and/or at a slower-than-desired pace, the seam will melt. Both situations result in a seam that is not water-tight, which allows passage of water through the membrane, causing a leak.

Efficiency and wastage

Site configurations bear significant impact on the efficiency of the material. A site with considerable number of corners, curvatures, surface imperfections and the likes will require lots of patching work to the waterproofing membrane, which in turn produce lots of seams. Hence forth, the risk of water leakage increases. In addition, material wastage increases for more complicated site configurations for the similar reason.

Fig 13:
Site conditions pose challenges to the proper installation of pre-formed waterproofing membrane.

Fig 14:
Details such as a corner (left picture) and a weep hole (right picture) require patching work to the waterproofing membrane that result in a number of seams.

Ponding

At the micro-level, surfaces in between seams are potential water-collecting locations.

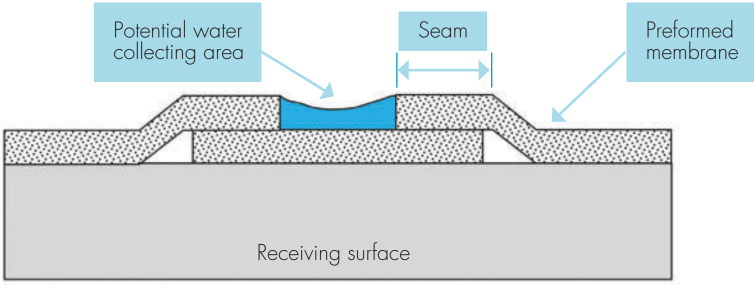


Fig 15:
Cross section of pre-formed waterproofing membrane at the seams

Space requirement

Installation of pre-formed waterproofing membrane requires a larger working space than liquid-applied materials; a person needs the space to reach the seam and perform a proper heat welding process to ensure that the seam is properly fused.

Fig 16:
Deep and narrow planters such as the one shown in the photo above, with vertical and horizontal corners, may also pose challenges to the proper installation of a pre-formed waterproofing membrane due to the lack of working space.

- Compared to liquid-applied waterproofing materials, pre-formed waterproofing membranes provide lower elongation tolerance which however should still be adequate to meet normal site requirements.
- Pre-formed waterproofing membranes are available in pre-determined dimensions and rolls. The detailing and lay-out of these waterproofing systems should be properly planned and executed, with adequate site supervision and engineer-endorsed tests, to optimize the potential efficiency of the system, with minimal seams prior to applying the rooftop greenery system and vegetation.

2.4 PROTECTION FROM PHYSICAL DAMAGE

2.4.1 Common causes of failure to the waterproofing membrane (that is when water-tightness of the membrane is compromised) include, but are not limited to the following:

i. Physical damage by mechanical means such as cuts and tear.

ii. Deterioration due to prolong exposure to ultra-violet rays from the sun.

iii. Expansion and contraction stresses cause by changes in temperatures between day and night.

iv. Weak molecular structure of the selected waterproofing material.

2.4.2 A proper rooftop greenery system build-up addresses points (i to iv), and combined with good material selection, extends the service life span of the waterproofing material by 3 or even 4 times (about 30 to 40 years).

2.4.3 While failure modes in points (ii and iii) may come about after a considerable period of time, the failure mode in point (i) (that is, failure by physical damage) is almost immediate.

2.4.4 Common methods of protecting the waterproofing layer from physical damage in a rooftop greenery environment include:

- Protection screed
- Protection mat
- Foam boards
- Combination of the above items

2.4.5 Protection screed

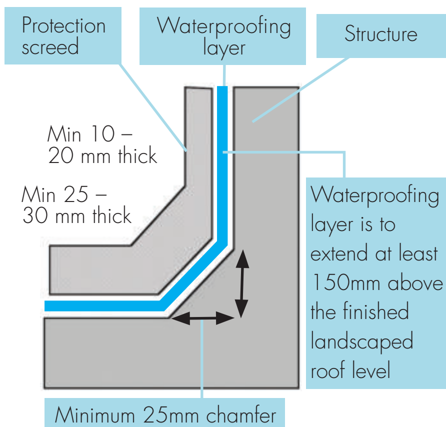


Fig 17:
Laying of the protection screed over the underlying waterproofing layer.

- The protection screed, applied on top of the successfully installed waterproofing membrane, is usually made by mixing cement, sand and water. The proportion between cement and sand is typically 1:3. Upon hardening, the layer forms a hard, rigid, partially impervious and structurally stable compound, on which the green roof system and vegetation can be installed.

- The minimum thickness of the protection screed layer on horizontal surfaces is about 25 to 30 mm, in order to fulfill its intended function of protecting the underlying waterproofing layer from physical damages. Application of protection screed is common in most rooftop construction work, including rooftop greenery installations.

- On vertical surfaces where the waterproofing layer upturns, the protection screed layer, covering the upturned waterproofing layer, is usually about 10 to 20 mm thick.

- Additives can also be added to the protection screed layer to further enhance the waterproofing capability of the roof construction.

- Screeds in planters must be laid to falls of flattest 1:100 to ensure water can flow to the drain outlets. Screed falls are specific to planters and are not the same as general roof drainage falls. Thus screed has two functions. A) to protect the waterproofing, and B) to ensure drainage from the planter.

2.4.6 Protection mat

Fig 18:
In less complicated site conditions, the protection mat can also be used to cushion the underlying waterproofing layer from physical damages.

Fig 19:
On horizontal and vertical surfaces, the protection mat can easily be laid over to protect the underlying waterproofing layer.

- For rooftop greenery installations, especially green roofs, where risk of physical damages to the waterproofing layer is lower than normal construction work, the protection mat may be an alternative option to the protection screed.

- Unlike the protection screed, the protection mat is usually made of recycled synthetic fibers of polyester, polypropylene and/or polyethylene; and hence, is flexible, soft and porous. If well shielded from sunlight, it provides a stable and well-cushioned material to protect the underlying waterproofing layer from physical damages during rooftop greenery installation.

- The minimum thickness of the protection mat on horizontal and vertical surfaces ranges from 5 to 10 mm depending on site conditions in order to fulfil its function of protecting the underlying waterproofing layer from physical damages.

- The protection mat comes in roll form, and is loose-laid by rolling out onto the waterproofing layer. With sufficient overlapping, the protection mat provides continuous protection to the waterproofing layer.

- However, it should be noted that the cushioning effect of the protection mat is limited. While it is able to withstand light knocks and thrusts as pose by green roofs installations, it is incomparable to the protection screed that is able to withstand much heavier and intense forces and loads (as expected in the case of intensive roof garden installation).

2.4.7 Foam boards

- Foam boards are typically made of expanded polystyrene (EPS) or extruded polystyrene (ExPS), 25 to 50 mm thick and are loose-laid onto the waterproofing layer.

- Similar to the protection mat, the foam boards provide cushioning to protect the waterproofing layer from physical damages.

- These boards also serve as a filler material and/or thermal insulation material in certain situations that require it.

- Foam boards must be sealed from water ingress to prevent moisture built-up. Water ingress to the foam boards can potentially compromise the foam boards' performance as a filler material. The trapped moisture, given the right condition, may even encourage growth of algae and fungus.

2.5 WATERPROOFING MEMBRANE WITH ROOT-PENETRATION-BARRIER PROPERTIES

2.5.1 Also available in the market are 2-in-1 products that perform as a waterproofing material as well as root barrier that resist the penetration of plant roots.

2.5.2 These products also come in 2 basic forms:

- Liquid-applied membrane
- Pre-formed membrane

2.5.3 The root resistance capability is typically built-into these products through:

- The addition of root repelling chemical into the composition of the material.
- The addition of a physical barrier within the material.
- The material itself, as in the case of some polymer-based pre-formed waterproofing membranes, is able to form a continuous, stable and durable, impenetrable membrane throughout the applied area.

2.5.4 Tests of varying standards, as well as procedures from different parts of the world are available to verify the effectiveness of such materials against root penetration. Currently, the most stringent is the Germany's FLL test procedure and certification:

- The test procedure and standards are described in the FLL publication, "Guidelines for the Planning, Construction and Maintenance of Green Roofing – Green Roofing Guideline," 2008 edition, Appendix 3.

- The procedure investigates the resistance of the following categories of materials against penetration by plant roots and rhizomes of various plants:
  – Root protection membranes
  – Roof and waterproofing lining sheets
  – Liquid surface treatment materials

- The test period is traditionally 4 year as it is conducted in an outdoor open environment, but the result of the 2 year test period is currently available.

- This shorter test is conducted under a climate-controlled greenhouse environment which allows the plant species to grow throughout the year and, be less susceptible to seasonal changes, with optimal light and temperature conditions.

- Both the 2 - year and 4 - year tests are considered to be equal in standard.

- Plants with strong rhizome growth are excluded from the test certification. Products attaining the FLL certification of being “root resistant” do not include resistance to the root penetration of plants with strong rhizome growth (such as bamboo species).

- Products are considered “root resistant” when, upon the expiry of the test period, the following circumstances occurred:
  - No root has established itself (or root ingress) on the surface or in the seam of the tested product; where plant parts actively created cavities and have damaged the product.
  - No roots have penetrated the surface or the seams of the tested product such that the roots used pores (or micro air pockets) present in the product to create cavities for their own growth.

2.5.5 Advantages and disadvantages of using 2 - in - 1 waterproofing cum root barrier products compared to 1- for -1 product:

Advantages

- Operation efficiency in terms of:
  - Material handling

    Handling 1 item is faster and easier than handling 2 items.
  - Installation

    It is a one-operation installation to serve two functions instead of two operations.
  - Labour

    Less labour is required.

Disadvantages

- In general, the cost of such material is higher.
- Waterproofing and root resistance approaches are pre-fixed and are not interchangeable thereby restricting choices.
- A compromise in the material integrity (as a result of, for example, a tear in the material) will result in a compromise on both functions – waterproofing and resistance to root penetration.

2.5.6 Differences in terms of detailing and operations between waterproofing material and root barrier (when they are used as separate items) are:

S/No	Subject	Waterproofing	Root barrier
1.	Primary function	To resist the ingress of water under certain hydrostatic pressure or conditions into the building structure.	To resist the penetration of roots of plants into the building structure.
2.	Coverage	Must cover the entire potential water collecting area.	Cover at least the greenery area and, if the condition allows, a specific safety margin.
3.	Termination-point/edge-Location	Must be terminated on an elevated level, and at a minimum distance above the water-collecting area and "splash zone."	Depending on the greenery configuration, there is no absolute need to terminate on an elevated level. Root barrier may even terminate on the same level as the surface level of the substrate or on a horizontal surface at level with the greenery area.
4.	Termination-point/edge - Methodology	Must be properly sealed by mechanical means and/ or the use of a suitable & durable sealant.	Proper sealing at the termination or edge is ideal but not necessary.
5.	Sequence of laying	Especially for pre-formed membrane, the sequence starts from the lowest point so the seams will not impede the flow of water.	There is no requirement to start laying from the lowest point.

2.6 MANDATORY TESTS FOR SITE-WORK

2.6.1 Thickness test

- Especially for liquid-applied waterproofing materials, the use of the mil-thickness Tooke gauge is commonly used to verify the thickness of the waterproofing material that was already cured and laid on the receiving surface.

  – This activity can be conducted with minimal disruption to other on-going work on site.
  – The usual practice is to take a reading off the gauge at every 10 – 15 sqm.
  – Where readings indicate that the thickness of the applied waterproofing material is less than that specified, additional quantity of the same material should be used to make up for the difference in accordance with the manufacturer's instructions on how it should be done.
  – The achieved thickness and consistency of the selected and installed waterproofing membrane must be based on the product's recommended installation-specifications. This is to ensure waterproofing installation efficacy.

- For pre-formed waterproofing membrane, a small piece of the membrane that has been laid should be cut out and measured using a set of calipers.

  – Where readings indicate that the thickness of the applied waterproofing membrane is less than that specified, the membrane has to be removed and replaced by the membrane of correct thickness.
  – To conduct repair work at the location of the cut-out piece, a larger and clean patch of the same material with sufficient lapping all round the cut-out opening should first be prepared. It should then be placed centrally over the opening and fused with the already-laid membrane in accordance with the manufacturer's instructions on how it should be done.

2.6.2 Water ponding test

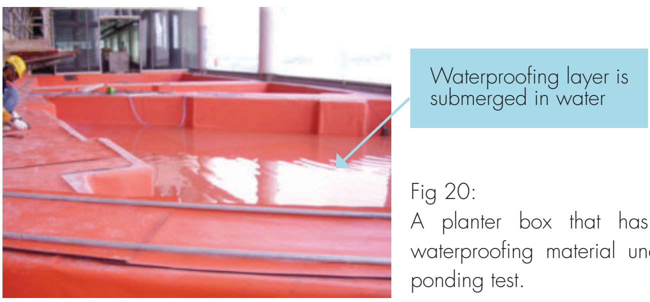


Fig 20:
A planter box that has been laid with waterpoofing material undergoing a water ponding test.

- For horizontal surfaces on which the waterproofing material is applied, they are made to submerge in at least 50 mm of water for at least 48 hours.

- The objective of the test is to validate the integrity of the applied waterproofing layer against the ingress of water under normal atmospheric and hydrostatic pressure.

- Visual inspections are conducted during the progress of the test and after the expiry of the test period to determine if the test passes or fails.

- Symptoms that infer failure of the waterproofing layer include:
  - A series of air bubbles rising through the water, originating from a common location at the waterproofing layer during the early stages of the test period.
  - Presence of moisture (verified by sight and sense of touch) on the soffit of the structure (such as the roof slab on which the test is conducted) upon the expiry of the test period.

- Repair
  - Should a negative performance be concluded, appropriate repair has to be carried out in accordance with the manufacturer's instructions.
  - The same area should be tested again till a positive performance of the waterproofing layer is achieved.
  - Should the negative performance be attributed by existing poor conditions of the receiving roof surface, appropriate repair has to be carried out to rectify the poor conditions of the receiving roof surface, prior to repair on the waterproofing system.

2.7 ORGANISATION AND PRACTICES – RESPONSIBILITIES

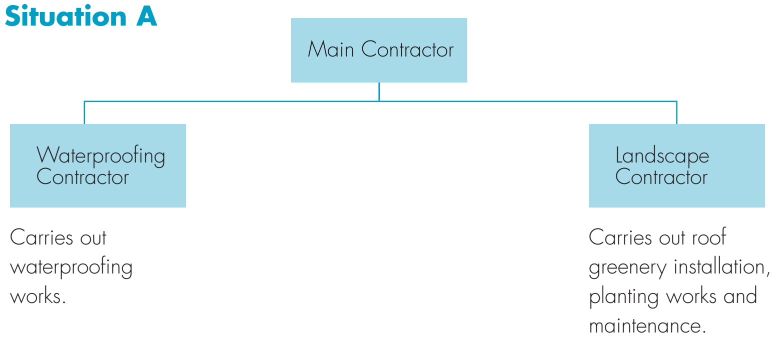
2.7.1 For any green roof and/or roof garden projects, the major packages of work, in chronological order, are as follow:

- Waterproofing works
- Roof greenery installation works
- Planting works
- Maintenance of roof greenery

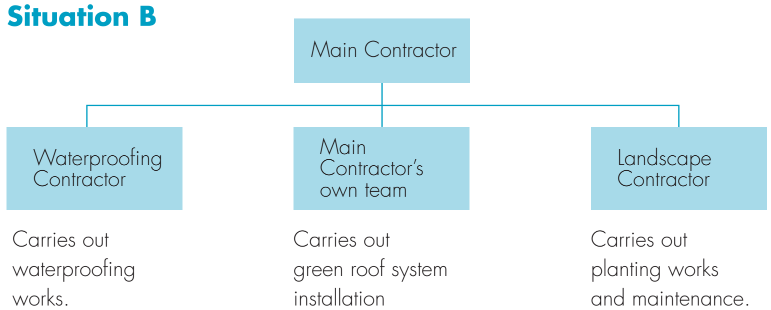
2.7.2 For waterproofing installation, with regards to the distribution of the above-mentioned responsibilities amongst the different parties, the following illustrate the types of situation in the local landscape and construction industry.

The waterproofing installation and the landscape installation are managed by separate contractors, both under the supervision of the main contractor.

Situation A



Situation B



Accountability of each party and proper transfer of responsibility from one party to the other are important and must be properly administered. In the above situations, disputes arise mostly due to deficiency in either or both areas.

2.8 REFERENCE STANDARDS

Commonly referred to in Singapore:

- CP82:1999 - Code of practice for waterproofing of reinforced concrete buildings
- SS133:1987 - Bituminous emulsion for roof waterproofing
- SS374:1994 – Preformed waterproofing membranes for concealed roof

British Standards

- BS EN 1849-2:2009 Flexible sheets for waterproofing. Determination of thickness and mass per unit area. Plastic and rubber sheets
- BS 8000-4:1989 Workmanship on building sites. Code of practice for waterproofing
- BS EN 1847:2001 Flexible sheets for waterproofing. Plastic and rubber sheets for roof waterproofing. Methods for exposure to liquid chemicals including water
- BS EN 13948:2007 Flexible sheets for waterproofing. Bitumen, plastic and rubber sheets for roof waterproofing. Determination of resistance to root penetration

ASTM Standards

- ASTM C1305 - 08 Standard Test Method for Crack Bridging Ability of Liquid-Applied Waterproofing Membrane
- ASTM C898 / C898M - 09 Standard Guide for Use of High Solids Content, Cold Liquid-Applied Elastomeric Waterproofing Membrane With Separate Wearing Course
- ASTM D6769 / D6769M - 02(2010)e1 Standard Guide for Application of Fully Adhered, Cold-Applied, Prefabricated Reinforced Modified Bituminous Membrane Waterproofing Systems
- ASTM C981 - 05 Standard Guide for Design of Built-Up Bituminous Membrane Waterproofing Systems for Building Decks
- ASTM D5957 - 98(2005) Standard Guide for Flood Testing Horizontal Waterproofing Installations
- ASTM WK29304 - New Guide for Selection of Roofing/Waterproofing Membrane Systems for Vegetative (Green) Roof Systems
- The NRCA Roofing and Waterproofing Manual