Centre for Urban Greenery & Ecology
CUGE Standards

GUIDELINES ON **GENERAL MAINTENANCE FOR ROOFTOP GREENERY**

CS E07:2012

Guidelines on Skyrise Greenery

Published by:
Centre for Urban Greenery & Ecology
National Parks Board HQ
1 Cluny Road
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CUGE STANDARDS CS E07:2012

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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

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General Maintenance for Rooftop Greenery

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The CS E07:2012 was prepared by the CUGE Standards Technical Committee (CS E07:2012).
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The CUGE Standards will be reviewed every three years. Concurrently, CUGE also gathers new information continually through on-going research.

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General Maintenance for Rooftop Greenery

SECTION 1 SCOPE

1.1 INTRODUCTION

This specification sets out the basic requirements for the general maintenance of rooftop greenery.

1.2 OBJECTIVE

This specification is intended as a guide for the general maintenance of rooftop greenery.

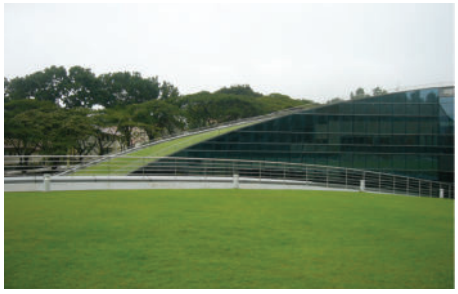
It is intended to act as a reference point for quality assurance of the general maintenance of rooftop greenery.

The general maintenance 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 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 systems can also be placed on pitched roofs of up to an inclination of 30 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 general maintenance of rooftop greenery should achieve the following:

- The general maintenance upkeeps and sustains the intended quality and performance of the installed rooftop greenery.

- The general maintenance ensures that the rooftop performance is not compromised by the growth of greenery on the rooftop. Where necessary, the greenery is to be managed in order to upkeep, mitigate and/or restore the rooftop performance.

- The general maintenance is also to identify and rectify potential future malfunctions and problems to the rooftop (such as falling plant debris, plants failing, fire risk, overgrown plants, roots compromising roof systems, water ponding, mosquito breeding, etc.)

- Safety of workers on site and people in the vicinity of the work site is ensured when working on rooftop and along roof edges. It is necessary that during the design phase, considerations and provisions be made for the maintenance of plants along roof edge. This not only allows effective plant maintenance and care, safety of workers is also ensured. Appropriate safety provisions, such as safe access to work-site, appropriate anchoring points, appropriate work-procedure, appropriate personal protective equipments must be in place and safely deployable.

SECTION 2 MAINTENANCE

2.1 MAINTENANCE IN GENERAL

2.1.1 Maintenance of modern day roof gardens (i.e. intensive-type green roofs) are much more demanding, regular and rigorous than green roofs (i.e. extensive-type green roofs).

Between roof gardens and green roofs, maintenance of roof gardens requires a more frequent maintenance schedule and a much wider work scope (that includes maintenance of plants, fixtures and amenities) than green roofs.

2.1.2 The activities commonly carried out on roof gardens and green roofs are shown below. The actual maintenance schedule and requirement for each site will have to be customized to suit the site's unique vegetation and micro-climatic conditions:

- Irrigation
- Application of fertilizer
- Pruning
- Mulching (More applicable for roof gardens)
- Checks on drainage and other underlayers
- Checks for fungi and pest infestation
- Checks to ensure stability of tall vegetation at the rooftop (More applicable for roof gardens)
- Removal of landscape debris
- Plant replacement
- Ensuring overall safe use of rooftop greenery components – which include the fixtures and fittings that needed occasional checks (check for rust, loose bolts & nuts, vandalism acts, etc) such as the landscape furniture, lightings, playground sets, rubbish bins, signage, loose pavers & kerbs, pot-holes, etc

2.2 APPLICATION OF FERTILIZER

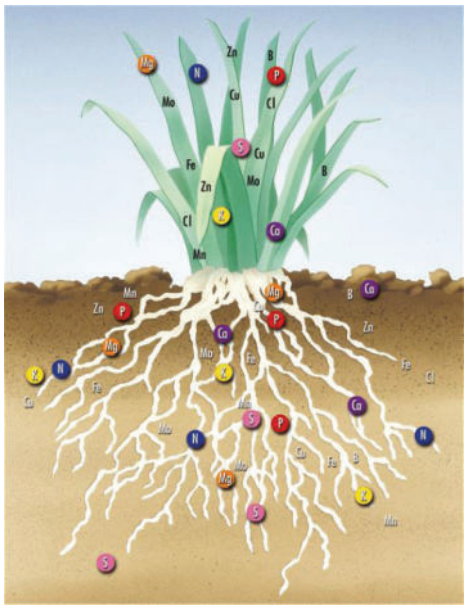


Fig 1:
The uptake and deployment of nutrients needed by the plant.

2.2.1 Fertlizers are chemical compounds applied to promote healthy plant growth. While most fertilizers are applied directly to the substrate for uptake by the plant roots, some are applied directly onto the leaves.

2.2.2 The typical fertilizer provides in varying proportions the three major plant nutrients - nitrogen (N), phosphorus (P), and potassium (K). Secondary plant nutrients contained in fertilizers include calcium (Ca), sulphur (S) and magnesium (Mg).

2.2.3 Upon the completion of planting works on green roofs and roof gardens, regular application of fertilizer is necessary to sustain healthy plant growth.

2.2.4 The amount and type of fertilizer used depends largely on the following factors:

- The inherent nutrients in the growing media.
- The greening objectives – Green roofs and roof gardens are designed to fulfill different intentions and purposes. The common rooftop greenery are designed to be an:
  - Aesthetic-ornamental (ie "manicured") garden – For roof gardens, the landscape is usually designed to provide visual and spatial appeals to the users. The consumption of fertilizer is usually higher.
  - Ecologically optimized (ie "naturally developing") greenery – For green roofs, the landscape is usually designed to allow the vegetation to develop naturally over time without much human intervention. The consumption of fertilizer is usually less than the above.

2.2.5 Types of fertilizers – There are generally 2 types of fertilizers:

Organic fertilizer

- These are naturally occurring fertilizers, such as animal manures, bone meal, humid acid, seaweed extract, blood meal, etc.
- Fertilizers from processed organic materials such as garden compost (mature). Use of such materials on roof gardens and green roofs is encouraged and advisable as they replenish the nitrogen levels of the growing media.

Inorganic fertilizer

- Naturally occurring inorganic fertilizers include sodium nitrate, mined rock phosphate. Lime stone is used to raise pH and calcium levels.
- Inorganic fertilizer, also known as chemical fertilizer or synthesized fertilizer, contain the three major plant nutrients (elements): nitrogen (N), phosphorus (P), and potassium (K) and other nutrients (elements).

Fig 2 :
Slow-release fertilizer pellets that are readily available in various NPK compositions.

2.2.6 Forms of fertilizer - There are generally 2 forms of fertilizers

- Solid – In the solid state, fertilizer is usually in the form of powder or pellets.
- Liquid

2.2.7 Modes of application

- For solid-state fertilizers, they are usually applied manually by broadcasting the fertilizers evenly onto the growing media.
- For liquid-state fertilizers, they may be applied either manually through the use of a water can or as part of the irrigation system through the use of a nutrient-reservoir (also known as the fertigator).

2.2.8 During the establishment period and subsequent maintenance period, it is recommended that nutrients be administered by means of coated NPK slow-release fertilizer granules or pellets.

It is necessary to carry out yearly lab analysis on the plant and soil samples to determine the amount and type of nutrients needed.

(Slow release fertilizer releases nutrients gradually, over a period of time. The nutrients are released slowly and steadily with no worry of fertilizer burn on the plant parts, which is ideal for optimal plant growth, reducing the need for frequent fertilizing.)

(Fertilizers are named according to the three major nutrients in the fertilizer. For example, such fertilizer that has, for illustration, "N-P-K 15-10-20" printed on its packaging will mean that 100g of that fertilizer contains 15g of pure nitrogen (N), 10g of pure phosphorus (P), and 20g of pure potassium (K)).

2.2.9 The recommended dosage, in general (with Nitrogen as the key ingredient), is as follows:

- Roof gardens 10 g of Nitrogen per sqm
- Green roofs 7 g of Nitrogen per sqm

(The recommended dosage is 30% higher than that stated in Germany FLL Guidelines 2008 to cater for the prolific plant growth in the tropical climate as opposed to that of the temperate climate for which the Guidelines are written)

Example on computation of fertilizer dosage:

Suppose a bag of slow-release fertilizer pellets with the NPK composition of 20-10-15 is to be used on the rooftop greenery:

Roof garden:

The required dosage is 10 g of Nitrogen per sqm of vegetated area.
Every 100 g of the fertilizer contains 20 g or 20% of pure Nitrogen (N). Therefore, to achieve the right dosage of 10 g of Nitrogen per sqm, the amount of fertilizer that should be evenly broadcast on every sqm of the roof garden is

10 ÷ 20% = 50 g

If the total vegetated area of a roof garden is 500 sqm, the total amount of fertilizer required for one round of application of fertilizer over the vegetated area is

50 g x 500 = 25 000 g or 25 kg

Green roof:

The required dosage is 7 g of Nitrogen per sqm of vegetated area.
Every 100 g of the fertilizer contains 20 g or 20% of pure Nitrogen (N). Therefore, to achieve the right dosage of 7 g of Nitrogen per sqm, the amount of fertilizer that should be evenly broadcast on every sqm of the roof garden is

7 ÷ 20% = 35 g

If the total vegetated area of a green roof is 500 sqm, the total amount of fertilizer required for one round of application of fertilizer over the vegetated area is

35 g x 500 = 17 500 g or 17.5 kg

2.2.10 The recommended frequency of fertilizer application is as follows:

Types of rooftop greenery	Categories of vegetation	Frequency
Roof garden	Tall vegetation such as trees and palms	Once every 3 months
	Shrubs	Once every 3 months
	Lawn	Once every 3 months
Green roof	Hardy, drought-tolerant, self-generating ground-covering plants	Once every 3 months

If a fertigation system (with a fertigator incorporated to the timer-automated irrigation system) is employed, the above recommended fertilizing frequency will not apply as the fertilizers will be applied as part of the irrigation system.

2.3 PRUNING

2.3.1 Pruning in landscaping and gardening is the practice of removing diseased, non-productive, or otherwise unwanted portions from a plant. Proper pruning is as much a skill as it is an art. Badly pruned plants can become diseased or grow in undesirable ways.

Fig 3 :
An example of a roadside tree which shows how poor quality pruning can adversely affect the shape and growth of a tree

2.3.2 Purpose of pruning is to:

- Maintain and improve plant health and vigor (pruning is not remedial, but an aspect of regular maintenance.)
- Manage plant size and form (for tree, pruning is done to reduce and thin the tree crown and to allow for better air movement, for new growth, to control the height of the tree and to shape the tree into the desired form, look)
- "Train" young plants – To shape the plant and its subsequent growth pattern into the desired future form and shape.
- Manipulate flowering and fruit production
- Improve safety (to users)(to remove obstructing lower branches and dead branches)
- Rejuvenate old plants
- Ease transplanting (pruning is sometimes undertaken before transplanting)

2.3.3 General guidelines on "How to" prune

2.3.3.1 **Trees**

Rooftop trees need to be pruned for the following reasons:

- Remove the dead, diseased or broken twigs and branches.
- Crown thinning for better air flow (and to reduce wind load on the tree crown).
- To remove obstructive branches.
- To control the height of the rooftop tree.
- To control the shape of the rooftop tree.

Do not over-prune rooftop trees for the following reasons:

- Tree pruning stresses the tree. The pruning cuts are susceptible to disease infection. Prune only when necessary.
- As a rule-of-thumb, no more than 25% of the tree crown should be pruned.

For saplings, all formative pruning shall be made with appropriate tools such as secateurs, loppers or curved pruning saw. No chainsaws shall be used on branches less than 80mm in girth.

Cordon off the area under which tree pruning operations are being carried out. If the rooftop tree is near the roof edge, the ground floor area under the pruning operations shall also be cordoned off. In addition, deploy a minimum of two ground staff to ensure that the pedestrians and vehicles do not unknowingly stray into the drop zone at the ground level.

For tree on rooftop, it is not advisable to plant tree close to the roof edge, which makes for cumbersome, inefficient pruning and maintenance and may compromise safety.

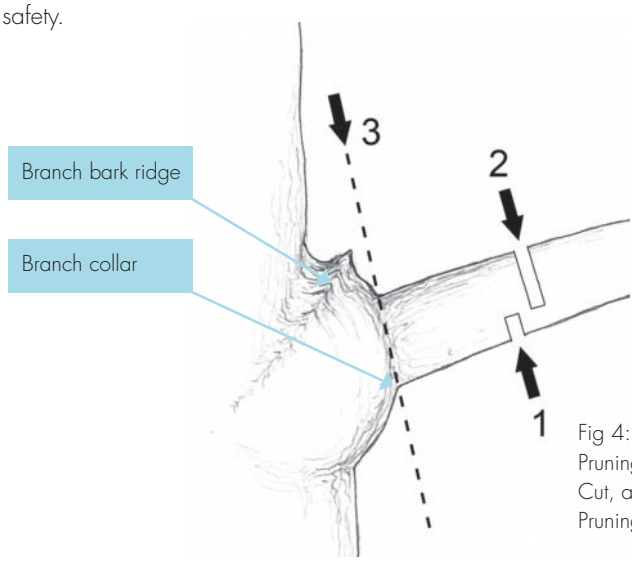


Fig 4:
Pruning of tree - 3 Point Cut, also known as Target Pruning

Essential points on the standard of pruning include:

a) avoid bark tearing by using "3-point cut" method (cut from below (1), top cut (2) and final cut (3) – also known as Target Pruning)

b) prune with reference to the branch bark ridge or branch collar,

c) do not leave a stub, (In situation where the branch collar is not discernable, it is advisable to leave a stub to avoid wounding the tree.)

d) prune as close as possible to branch collar but do not cut into the branch collar.

- After studying the tree form, select the best spaced and positioned permanent branches.
- For crown cleaning, selectively remove dead, diseased, broken, parasitic plants or weakly attached branches from a tree crown. Tree should not be excessively pruned. For crown thinning, selectively remove branches to increase light penetration and air movement through the crown and to reduce excessive wind load on the branches.
- For crown reduction, reduce the overall height and spread of a tree by cutting terminals and scaffold branches back to laterals that are large enough (at least 1/3 the diameter of the main supporting branch) to support the growth of the limb. The method of cut must conform to the above 'Essential points on the standard of pruning' herein to avoid bark tearing and splitting.
- Permanent branches should be spaced between 0.15 - 0.5m apart on the trunk, depending on the estimated mature size of the tree. For trees that remain small at maturity, 0.15m spacing is adequate; otherwise a 0.3 - 0.6m spacing is ideal.
- Remove fast growing tree suckers at the base of and along the trunks.
- Water sprouts along branches should be left intact in most cases. They typically indicate a struggling tree attempting to grow its way to health. However, when sprouts become overcrowded, prune away the weaker sprouts, keep only the strong ones. Long and sizable water sprouts should be pruned back to laterals to reduce growth of sprouts and to ensure adequate attachment for the size of the sprouts.
- Appropriate equipments must be employed and site-work procedures adhered to ensure site safety.
- For pruning of trees planted along/or near rooftop edge, care must be taken to avoid falling debris.
- All pruning works shall conform to the practices and standards specified in the latest ANSI A300 Part 1.
- Certified arborist is to be consulted for tree pruning. Certified competent maintenance worker to do the pruning.

2.3.3.2 **Palms**

Rooftop palms may be pruned (maintained) for the following reasons:

- When the fronds are dying, have turned brown (desiccated) or are damaged.
- When fruit stalks need to be removed for various reasons.
- When the clustered palms have grown too crowded and big.

Do not over-prune rooftop palms for the following reasons:

- Removing too many fronds weakens the palm, affecting its growth because photosynthesis is reduced.
- Over-pruned palms with pruning cuts are more susceptible to disease infections.
- The mature fronds, which may take a few years to mature, shield and protect the growing fronds.

How to prune a palm:

- Only remove fronds that are dying, turned brown (desiccated) or damaged.
- Palms grow a certain number of new fronds yearly. Do not remove more fronds than can be produced in a year.
- Fronds should not be cut too close to the trunk of the palm. This is to avoid damaging the palm trunk.
- When pruning palms, care must be taken not to cut or injure the terminal bud/spear. Otherwise the palm may die.
- When palms such as the royal palm (Roystonea regia) shed their large and heavy fronds, the falling fronds can potentially damage property and cause injury. If the palms are growing where the falling plant debris may be hazardous, measures must be taken to manage and remove these safety hazards.
- Large fruits of coconut palms (Cocos nucifera) can be dangerous to pedestrians and automobiles passing beneath the palms. Safety measures that should be considered include:
  - Locating the palms away from human and/or vehicular traffic.
  - Fruit stalks on manila palm (Veitchia merrillii) and others can be left on the palm to take advantage of the ornamental characteristics of the fruit.
- The pruning of rooftop palms, may involve use of cutting tools and machinery, such as the aerial platform, in case of taller palms. It is thus advisable to engage an experienced professional to carry out the rooftop palm pruning works.

2.3.3.3 **Shrubs**

How to prune shrubs:

- Remove all dead, diseased, or injured branches.
- Remove branches that look out of place.
- If the shrub is still too dense or large, remove some of the oldest branches. Head back excessively long branches to a bud or lateral branch that is 0.15-0.3m below the desirable plant height.
- If the shrub is 0.5-1.0m too tall, heading and thinning may be desirable. Cut each branch separately to different lengths with hand pruners (secateurs). This will maintain a neat informal shrub with a natural shape.
- For pruning of shrubs planted along roof edges, extra care must be taken to ensure no falling plant debris and equipment when maintaining and pruning the shrubs.
- It is advisable that during the design phase, considerations and provisions be made for the maintenance of shrubs along roof edge. This not only allows effective plant maintenance and care, safety of workers is also ensured.

2.3.3.4 **Hedges**

How to prune hedges:

- Hedges should be clipped while the new growth is green and succulent.
- Hedges should be trimmed so the base of the hedge is wider than the top.
- Taller hedges are sometimes planted along the edges of roof gardens, to provide screening from view or from strong winds. Extra care must be taken to ensure no falling plant debris and equipment when maintaining and pruning the hedges.
- It is advisable that during the design phase, considerations and provisions be made for the maintenance of hedges along edges of roof gardens. (Such as setting back these tall hedges, so that the outer-most surface of the hedge foliage can be inspected and pruned when necessary. This not only allows effective maintenance and care of these hedges, safety of workers is also ensured.

2.3.4 The recommended frequency of pruning (including mowing of turf) is as follows:

Types of rooftop greenery	Categories of vegetation	Frequency
Roof garden	Tall vegetation such as trees and palms	Once every 3-6 months (dependent on species and rate of growth)
	Shrubs	Monthly (dependent on species and rate of growth)
	Lawn	Weekly or Fortnightly (dependent on species and appearance)
Green roof	Hardy, drought-tolerant, self-generating ground-covering plants	Once every 3 months (dependent on species and rate of growth)

Removal of cut branches

Rooftop greenery maintenance services generate horticultural debris, which shall be removed from site and disposed. All cut branches and attached foliage for disposal shall be covered securely with a canvas during transit to the dumping ground to prevent loose branches from falling onto trafficable surfaces.

2.4 MULCHING

Mulch is either any approved friable organic product or inorganic material that is suitable for placing over the surface of the soil as a covering. It is used to retain moisture in the soil, suppress weeds, keep the soil cool and make the garden bed looks more attractive. Organic mulches like mature compost also help improve the soil's fertility. Coco-peat will not be allowed on its own unless mixed in a proportion of 50 - 50 with another mulching material free from soluble salts or toxic materials and resistant to rapid decay. Mulches shall have a pH of between 5.5 - 7.0

Fig 5:
Mulch around the base of a tree.

2.4.1 Mulching is common for roof gardens, but not required for green roofs. Mulching procedure for rooftop greening is similar to that done for the general ground-level landscape.

2.4.2 The mulch material for rooftop greening should be properly stored (with sufficient space allocation and in bags) and sheltered from the elements.

2.4.3 Types of mulch

- Organic - Examples of organic mulch include bark, shredded wooded chips, grass clippings, shredded leaves and shredded straw.
- Inorganic - Examples of inorganic mulch include pebbles, rubber, black plastic chippings, etc.

2.4.4 When deciding on the type of mulch, consideration should be given to the site conditions of the rooftop greenery, including wind effects that may sweep the mulch material away.

2.4.5 Thickness - The thickness of the mulch layer is usually about 25 – 100 mm depending on the type of vegetation. For tall trees, the mulch layer can be as thick as 100 mm.

2.4.6 General guidelines on "How to" mulch

2.4.6.1 A useful reference website is:
http://mygreenspace.nparks.gov.sg/how-to-mulch-your-trees-shrubs/

2.4.6.2 Trees

- Remove any vegetation around the base of the tree trunk before applying the mulch.
- Create a circular vegetation-free border around collar of the tree. This border can be around 0.3 - 0.5m wide depending on the size of the tree.
- Spread the mulch to the required thickness and shall not be heaped up into a high mound more than 100 mm thick.
- The mulch shall be forked slightly into the soil
- Settle the mulch by watering it.
- The mulch materials should not come in contact with the collar of the tree trunk or palm. There should be a zone of 50mm – 80mm around the collar without mulch. Under no circumstances shall mulch be piled around the tree trunk like a 'volcano'.

2.4.6.3 Shrubs

- Clear the area around the base of the stems of any weeds or leaves.
- Form a border of about 100mm around but at least 20mm away from the base of the stem.
- Spread a 20 - 30mm thick layer of mulch with your hands.

2.4.7 When to mulch – While mulching benefits rooftop greenery in the same manner as ground-level landscape, mulching is on a need-to basis and there is no regular mulching schedule to adhere to. All trees and shrubs need to be mulched immediately after planting. Replenish the mulch when the thickness has subsided.

2.5 CHECKS ON DRAINAGE AND OTHER UNDERLAYERS

2.5.1 Checking on underlayers

2.5.1.1 It is good practice to do a cut-and-cover exercise to visually inspect the underlayers of the green roof and roof garden at least once if not twice a year. The layers or components that form the build-up of the green roof and roof garden systems are to be cut open and ripped one at a time till the bottom-most layer or component is exposed for a visual inspection. Then after, they are carefully covered up / reinstated one at a time.

2.5.1.2 Size of cut-out area:

Types of rooftop greenery	Recommended sizes of cut-out area
Roof garden • Overall Depth <300 mm • Depth between 300 – 500 mm • Depth between 500 – 800 mm • Depth > 800 mm	 350W x 350L mm at the top and tapers down 500W x 500L mm at the top and tapers down 500W x 500L mm at the top and tapers down Not advisable due to safety reasons
Green roof	250W x 250L

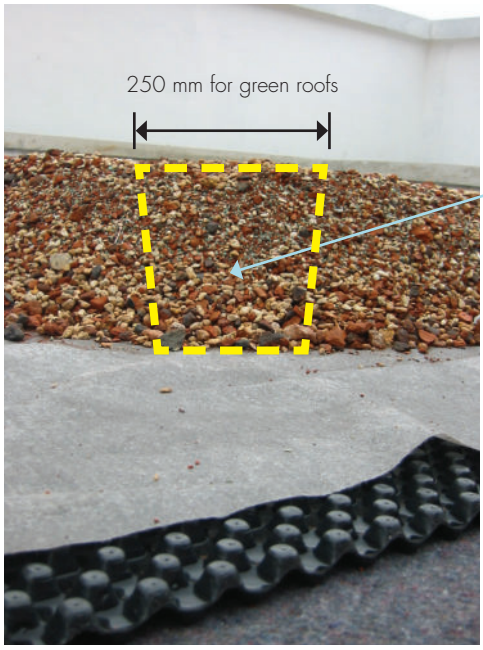


Fig 6:
The profile of the substrate to be dug-out and the underlying portions of the green roof to be cut-out

2.5.1.3 Checklist of Inspection

Types of rooftop greenery	Underlayers	To inspect for:
Roof garden and/or Green roof	Substrate	• General assessment of its porosity (ie drainage capacity). • Depth. • General assessment if there is excessive foreign materials including top soil, pests, organic matter, etc.
	Filter sheet	• General assessment of its drainage capacity. • General assessment of its integrity vs signs of deterioration.
	Drainage cum reservoir	• General assessment of its water retention capacity. • General assessment of its drainage capacity.
	Moisture retention / protection mat	• General assessment of its water retention capacity. • General assessment of its integrity vs signs of deterioration.
	Root barrier	• General assessment of its integrity vs potential root penetration.

2.5.2 Checking on drainage fixtures

2.5.2.1 Drainage fixtures should also be checked visually on a regular basis, at the frequency recommended below:

Types of rooftop greenery	Recommended frequency of checks on drainage fixtures
Roof garden	Once every 3 months
Green roof	Monthly

2.5.2.2 The kind of drainage fixtures to be checked at the vicinity of the rooftop greenery include:

- Inspection chambers
- Surface drains
- Weep holes
- Rainwater downpipes
- Gutters
- Spouts
- Boundary edgings

Fig 7:
An inspection chamber that is covered by a removable lid, surrounded by granite stones that serve as vegetation-free zone to enhance drainage.

2.5.2.3 The focus should be on eliminating any unintentional, undesired matter, vegetation and/or debris that may have gathered in the immediate vicinity outside as well as inside the drainage fixtures thereby compromising the full drainage efficiency of these fixtures.

Fig 8:
The inspection chamber, with the lid removed, to reveal the good functioning state of the drainage downpipe below.

The inspection chamber should be adequately sealed and/or netted to prevent mosquito from entering the down pipe drainage.

2.6 CHECKS FOR FUNGI AND PEST INFESTATION

2.6.1 All plants need to be inspected periodically for pest infestation and disease infection. Remove any pests, pest infested plant parts, diseased plant parts or diseased plants immediately upon notice.

2.6.2 The use of herbicides, pesticides, fungicides and similar products are generally discouraged so as to avoid their introduction to the run-offs and eventually, the groundwater.

2.6.3 Such products should be used only when necessary and not on a regular basis.

2.6.4 For more details on tropical plant-diseases, plant-disease-identification and plant-disease-rectification, please refer to the following publication by CUGE (Centre for Urban Greenery and Ecology) - Tropical Gardeners' Guide to Healthy Plants and Pictorial Guide in CD (ISBN: 978-981-08-6286-2).

2.7 CHECKS TO ENSURE STABILITY OF TALL VEGETATION AT THE ROOFTOP

2.7.1 While ground-covers and low-lying plants are commonly planted on green roofs, tall vegetation, such as big shrubs, hedges and small trees are usually planted on roof gardens. Checks to ensure stability of tall vegetation at the rooftop is hence necessary for roof gardens.

2.7.2 Supplemental support systems (which include staking and guying) are used to provide supplementary support to leaders, individual limbs, and/or the whole plant. Objectives for support systems shall be clearly defined prior to installation. Installation of staking and guying can take reference from the methods and standards specified in the latest ANSI A300 Part 3 and should be read in conjunction with the rest of the ANSI A300 when carrying out such installations. For tall vegetation such as tall shrubs, trees and palms, on rooftop, there is a need to implement measures and to conduct subsequent checks to ensure the stability of these tall vegetation.

2.7.3 Stability measures that can be implemented include:

- Staking the tree trunk
- Guying the tree
- Anchoring the tree root-ball

2.7.4 **Staking:**

- Staking serves to provide temporary stability to woody plants. It is important to have sufficient overall depth or thickness in the substrate layer and the support layers that make up the roof garden system, for the roots of tall vegetations to establish and take hold. Established roots provide the long term anchorage for tall vegetation. With tall vegetation, design provision allowing for adequate root-establishment and root-hold of the substrate volume, over a reasonable period of time, is important for the long-term bio-mechanical stability of the tall vegetation.

Fig 9:
Due to the higher wind velocity experience in raised elevations, staking needs to be more sophisticated and more structurally secure than that for general landscape at ground level with guying and sub-soil anchoring being preferred over staking.

- If metal components are used as part of the staking systems, they must be rust-proof.
- During the period of staking, the plants ought to be checked at regular intervals (typically once in 3 – 4 months) for signs of constriction and rubbing. The design of the staking should be such that adjustments can be made if necessary to tighten or loosen the hold on the plant.

2.7.5 Guying

- These should be fitted with a tightening mechanism so as to ensure that the tautness of the wires or ropes can be adjusted from time to time.

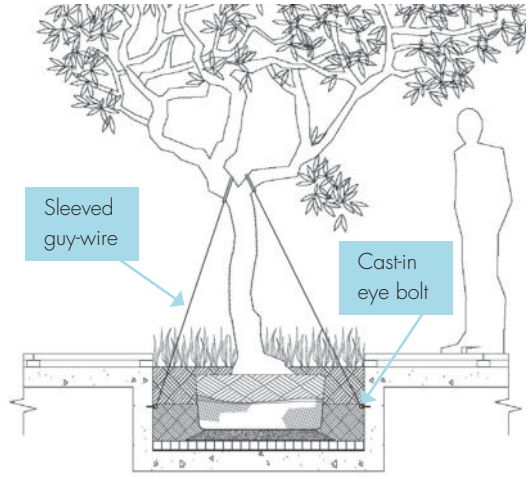


Fig 10:
The use of steel cables for guying a tree at a roof garden. In more confined planters for tree and palm planting, guy-wires attached to cast-in eye bolts are preferred. In all cases wires must be sleeved to prevent wires rubbing against bark.

- These can be secured by means of:
  - Threaded anchors set into the building structure without penetrating the waterproofing layer. It should be designed with a screw-thread connector.
  - An appropriate construction element designed for adequately holding the tree in place. For example, roof edging, walls, large paving slabs.
  - Point ballast. For example, slabs or blocks laid within the build-up of the roof garden system that act as a ballast or plinth or anchor point for the wire or robes. It is important to ensure that any load-bearing properties of the roof garden system or the thermal insulation are not adversely affected by the loads of these point ballasts. In addition, the wires and ropes to these point ballast should form an angle of less than 60° to the horizontal.

2.7.6 **Anchoring to supporting frames**

- Rectangular or triangular supporting frames are suitable for anchoring trees.
- Typically made of steel pipes or tubing with surfaces treated against corrosion.
- Each frame ought to have adequately stable and broad supporting base plates.

Fig 11:
An alternative method to support and anchor tree using metal frames.

2.7.7 **Anchoring to dead-man anchors**

For trees on the rooftop, if the planter is broad with a square area in excess of 16 square metres, with adequate substrate volume and depth exceeding 1.5 m, then the use of "dead-man" weighted blocks on the base of the planter is recommended.

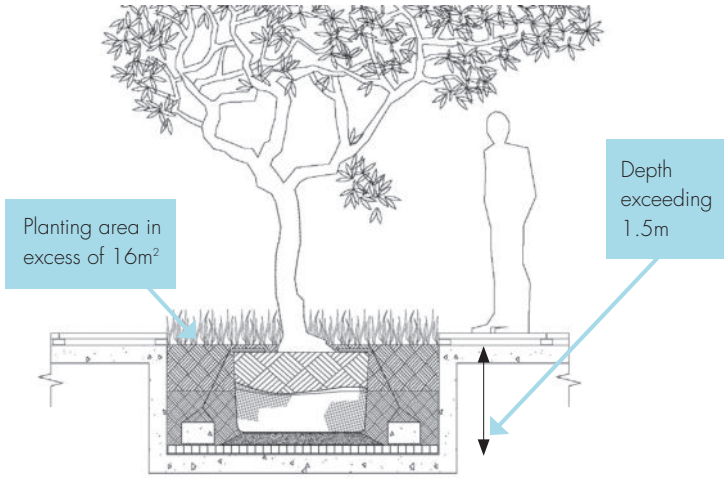


Fig 12:
Dead-man anchors to root-ball of rooftop tree. This is only recommended for rooftop tree that is experiencing low wind load.

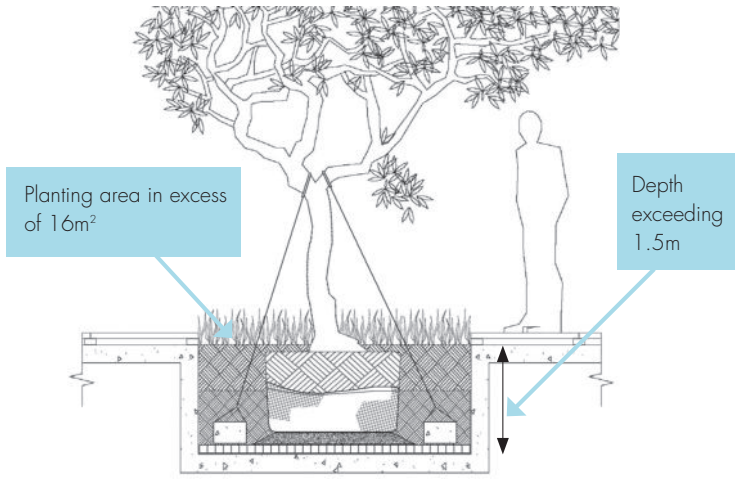


Fig 13:
Dead-man anchored guy-wires to stabilize rooftop tree. This is recommended for rooftop tree that is experiencing higher wind load.

2.8 SAFETY (PROCEDURE)

2.8.1 Maintenance work on rooftop greenery is undertaken at a height. During rooftop greenery maintenance, measures must be in place for workers' safety and to avoid objects and/or plant debris falling from height. A useful reference is the CS E02:2010 – Guidelines on Design for Safety on Rooftop Greenery, Section 2.2 – Safety Considerations During Installation & Maintenance Phase.

2.8.2 **Fall prevention**

- For all rooftop greenery works on superstructure components that are more than 3 m above ground, protection measures against falling is required and must be implemented.
- Fall prevention is relevant during the execution, construction, maintenance and servicing of green roofs and roof gardens throughout the life of the building.
- Suitable measures such as cordons, lanyard rails, fixed climbing rails with fall protection and entry features must be considered and adopted. Only approved products and systems can be used.
- During the construction stage, fall protection systems in the form of railings or roof scaffold is essential, and not to be removed till the completion of the rooftop greenery.
- For maintenance and servicing work, it is sufficient to employ the use of restraint-ropes of suitable lengths with pre-installed anchors or other fall prevention systems.
- Retrofitting anchors on already-completed and waterproofed roofs should be installed without compromising the waterproofing system that is already in place.

2.8.3 **Fire safety**

- To ensure fire safety on a roof garden or green roof, any vegetation encroaching onto the safety margin or vegetation-free zone must be removed.
- Safety margin - It is a general rule that a vegetation-free zone or strip or margin comprising stones must be provided to separate vegetation areas from the structural components (such as walls and columns) or protruding facilities (such as windows, doorways, ventilators, air-wells, skylights, air-coolers, water tanks, etc) of the building. The width of the safety margin ranges from 250 to 500 mm depending on the fire-sensitivity of the item to which the vegetation abuts.

Fig 14 :
The fire safety margin around a protruding skylight of a rooftop greenery. This margin must be kept clear of vegetation.

2.9 QUALITY OF MAINTENANCE FOR GREEN ROOF

2.9.1 The quality of maintenance for a green roof is said to be acceptable when the following points are displayed:

- **Frequency of maintenance**
  - It is recommended that maintenance be conducted at least once every 2-3 months by a qualified and experienced landscape contractor.

- **Vegetation coverage**
  - It is important to take note of the close and direct relationship between vegetation coverage, duration of the establishment period and the planting intensity (that is, the number of mini root ball plant plugs planted per square metre at the green roof).
  - After pruning, the vegetation coverage in general should be at least 65% of the installed green roof area. At the end of the establishment period, which is usually 6 – 8 weeks upon the completion of planting stage, the vegetation coverage should already achieve 60% of the installed green roof area. However, "seasonal" variations (i.e. between the dry/hot and wet months) in the condition of the different plant species need to be taken into account when verifying the extent of coverage of the ground-covering plants.

- **Vegetation mat**
  - If vegetation mats have been used, the vegetation must have taken root firmly so that it cannot be hand-lifted away from the underlayers.
  - If more than one species has been intended for the mat, all the different but intended species must be present on the mat, giving the required proportional cover.
  - The total vegetation coverage should exceed 80% of the installed green roof area.
  - The "seasonal" variations (i.e. between the dry/hot and wet months) in the condition of the different plant species need to be taken into account when verifying the extent of coverage of the plants.
  - The percentage of visible joints shall not exceed 10% of the total joint area.

- **Avoid overcrowding**

  Overcrowding of vegetation that has become rampant should be avoided because it weakens the vegetation and subject the vegetation to disease infection. Overcrowding can be due to several reasons:
  - Excessive watering and application of fertilizer.
  - Infrequent pruning.
  - Plants installed too close together without taking into account the plant growth rate.
  - Weeds invasion. Where there are excessive weeds, deep cuttings together with the removal of the cut material on a regular basis are necessary to contain the impact of weeds.

- **Clear safety zones**
  - Safety zones, margins or buffer that are typically filled with granite or pebble stones as well as joints/gaps between paving slabs are often occupied by some greenery over time. While low-growing plants such as moss and perennials should be tolerated, unwanted spontaneous growth of weeds, especially in the vegetation-free fire-prevention zones or margins must be removed on a regular basis.
  - Any deposits or matters that form/fall within the clear safety zones, whether at the joints or borders, that interfere with their intended function should be removed.

2.10 QUALITY OF MAINTENANCE FOR PITCHED GREEN ROOF

2.10.1 In addition to all the points mentioned in the Point 2.9, "Quality of Maintenance for green roof" above, the following points are uniquely important to the maintenance of pitched or sloping green roof:

- Erosion prevention
- Safety (Fall protection)

2.10.2 **Erosion prevention**

- For pitched green roofs, erosion prevention against the effects of the tropical rainstorm is a critical factor that must not be underestimated.

- There are preventive measures that should be considered during the design stage and carried out during the installation stage; and corrective measures that should be carried out during maintenance.

- Preventive measures include:
  - Adequate specifications for the build-up of the green roof system.
  - Temporary and long term effective measures.
  - Special measures at specific locations to cater for extreme climatic conditions.

- Corrective measures, during maintenance, include:
  - Replace the growing media with one that is stable, porous and of higher density even when dry, to improve the settling of the growing media. Please refer to CS E03:2010 Guidelines on Substrate Layer for Rooftop Greenery.
  - Improve drainage at the critical locations (such as the eave and around the rainwater downpipe) through the introduction of drainage materials. Please refer to Section 3 of CS E04:2010 Guidelines on Filter, Drainage and Root Penetration Barrier Layers for Rooftop Greenery.
  - Replace the vegetation with suitable plant species – fast growing, good root system, ground-hugging ground covers, as well as plants that shield the affected growing media from the immediate elements.

2.10.3 **Safety against falling**

Refer to Pt 2.8.2 above, on Fall Prevention. Such provision for worker safety on site allows for maintenance work to be professionally carried out.

2.11 QUALITY OF MAINTENANCE FOR ROOF GARDEN

2.11.1 On the whole, the quality of maintenance for a roof garden is assessed on a similar level as the common garden that is on a true-ground condition. The specific areas that needed additional attention and care for maintenance of a roof garden (as the roof garden is seated on a man-made structure, and usually above ground level) include:

Issues related to tall vegetation

- Stability – Please refer to Pt 2.7 above.
- Pruning – Please refer to Pt 2.3 above.

2.12 MAINTENANCE CONTRACT AND REPORT (FOR LANDSCAPE CONTRACTOR)

2.12.1 There should be a Maintenance Contract between the Owner and the Landscape Contractor to ensure the proper care for the rooftop greenery.

2.12.2 The Contract should include detailed descriptions of:

- The maintenance objectives.
- The individual tasks (preferably with the unit rates stated) to be carried out, including details of the type of activities, scope, geographical boundaries, total duration of the task, and frequency.
- The general condition that the vegetation needs to attain.
- The Maintenance Report is to be submitted to the Owner upon the completion of each round of maintenance.

2.12.3 The Maintenance Report should include detailed descriptions, terms and conditions of the following tasks such as type, extent, intensity, timing and duration of the task:

S/No	Description of task	Green roof	Roof garden
1	Application of fertilizer	Y	Y
2	Check the function of the drainage system on the roof	Y	Y
3	Check the irrigation system	Y *	Y
4	Check the fall prevention safety systems	Y	n.a.
5	Mowing of turfed area	Y *	Y
6	Mulching	n.a.	Y
7	Pest control	Y	Y
8	Plant protection measures	Y *	Y *
9	Plant replacement	Y	Y
10	Plant stability – tightening of bracing and anchors	n.a.	Y
11	Tree inspection	n.a.	Y
12	Pruning of plants	Y	Y
13	Removal of debris	Y	Y
14	Removal of unwanted foreign vegetation (ie weeding)	Y*	Y
15	Replacing substrate that may have been eroded or washed away	Y (esp for pitched roofs)	Y *
16	Reworking of vegetation matting joints, eg turf mats	Y *	Y
17	Watering	Y	Y
18	Keeping technical installations and fixtures vegetation-free	Y **	Y
19	Keeping intended safety margins, shoulders and buffer zones and paved areas free of debris, weeds and overgrowing vegetation	Y	Y

Note:

1. Prior advice on the choice of each activity, type and extent of activity to be executed ought to be sought from a skyrise greenery specialist.
2. * This is valid if the task is relevant, or when the situation requires.
3. ** This include surface drains, drainage outlets, air-wells, ventilators, vicinity of air compressors, cooling towers, lamp posts, tap points, fire hose reels, access points, personal safety fittings, power supply points, antennae points, etc.

2.12.4 The tenure of the Maintenance Contract should persist to beyond Warranty Period (if any).

2.13 REFERENCE STANDARDS

2.13.1 Germany FLL – Guidelines for the Planning, Construction and Maintenance of Green Roofing – Green Roofing Guidelines 2008 edition

2.13.2 ASTM E 2400:2006 – Standard Guide for Selection, Installation, and Maintenance of Plants for Green Roof Systems

2.13.3 ASTM WK25385 - New Guide for Green Roof Systems

2.13.4 DIN 18916:2002 – Vegetation Technology in Landscaping: Plants and Plant Care

2.13.5 DIN 18917:2002 - Vegetation Technology in Landscaping: Turf and Seeding

2.13.6 DIN 18919:2002 - Vegetation Technology in Landscaping: Care of vegetation during development and maintenance in green area

2.13.7 OENORM L1131: 2010 - Horticulture and landscaping - Green area on roofs and ceilings of buildings - Directives for planning, building and maintenance

2.13.8 SS528:2006 – Personal Fall Arrest Systems

2.13.9 ANSI A300 – Standards for Tree Care Operations