Centre for Urban Greenery & Ecology
CUGE Standards

GUIDELINES ON **DESIGN FOR SAFETY OF SKYRISE GREENERY**

CS E11:2014

Guidelines on Skyrise Greenery

CUGE
CENTRE FOR URBAN GREENERY AND ECOLOGY

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GUIDELINES ON
DESIGN FOR SAFETY OF SKYRISE GREENERY

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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

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Design for Safety of Skyrise Greenery

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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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SECTION 1 SCOPE

1.1 INTRODUCTION

These guidelines set out basic safety requirements and considerations for the design, planning and construction of rooftop and vertical greenery.

This publication in the CUGE Standards Series seeks to illustrate work safety issues from the standpoint of greenery design, installation and maintenance in a high-rise context and should be read in tandem with, inform design review and risk assessment processes, and shall not substitute for, the Guidelines on Design for Safety in Buildings and Structures, published by Workplace Safety and Health Council (WSHC). In regard to design-for-safety, this publication shall be taken as reference by way of the examples and illustrative suggestions provided.

This publication shall not, in any way, replace, substitute or supersede, whether in whole or in part, any existing and/or prevailing relevant statutory rules and regulations, and applicable codes of practice [although this reference should be verified for relevance and particular importance deserving of being highlighted] and standards and other technical references.

1.2 OBJECTIVE

These guidelines are intended as a guide in designing for, and realising, the safety performance of skyrise greenery throughout the two main life phases namely, the installation and maintenance phases.

It is intended as a common reference point for work safety endeavours for skyrise greenery and to promote a culture of safe practices at skyrise greenery work place (with every worker maintaining vigilance of potential hazards and risks).

It is a pivotal objective for this publication to support and enhance design-for-safety of skyrise greenery (pursuant to the Guidelines on Design for Safety in Buildings and Structures, as well as to promote

compliance with the requirements of the Workplace Safety & Health Act and its regulations and guidelines.

Engage and consult suitably qualified and experienced professionals to ensure the skyrise greenery implementation is well-considered, executed and safe throughout all two phases.

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. Generally, they are low in installation cost, lightweight (90-150 kg/m^2), with shallow mineral substrates and minimal maintenance required. Inspection should be performed, at the minimum, once or twice a year. Plants selected are usually of low maintenance and self-generative. Extensive systems are common in European countries, especially Germany and increasingly being installed in North America cities as well. Generally, they can also be placed on pitched roofs of up to an inclination of 30 degrees.

Roof garden

Intensive green roofs, or roof gardens, are designed 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 and bushes to trees and palms. As they are designed for usage, regular maintenance such as mowing, fertilizing, watering, and weeding is required.

Vertical greenery (Green wall)

Vegetated walls are built mainly for aesthetic and ecological benefits. The level of maintenance is often dependent on the design and safe accessibility of these vegetated vertical surfaces. Vertical vegetated wall surfaces are often comparatively more exposed to the drying effects of wind, especially with stronger wind at increase altitude. Growing plants in such harsh environment does require more care and frequent inspection of the plants and systems. The plant selection ranges from ornamental ground-covers, shrubs, to climbing vines and cascading plants. These are usually designed for visual appreciation. Regular maintenance such as fertilizing, irrigation and judicious pruning (if the vegetated surfaces are safely accessible) are required on a regular basis. There are various methods of planting on vertical surfaces, with cost getting competitive and more affordable in recent years.

Skyrise greenery

Is the collective term for rooftop greenery and vertical greenery.

Rooftop greenery

Is the collective term for green roof (for both flat and pitched types) and roof garden (including ledge greening).

Mobile Elevated Work Platforms (MEWP)

The mobile elevated work platforms (MEWP) are mechanical devices used to provide temporary, flexible access for people and/or equipment to inaccessible areas, usually for maintenance and construction works at height, often operable by one certified trained person. There are distinct types of MEWPs and the commonly known types are the "cherry picker" and the "scissor lift".

Personal Protective Equipment (PPE)

Personal Protective Equipment (PPE) are specialized clothes and equipment worn to protect the wearer from health and safety hazards. Please refer to *Workplace Safety and Health guidelines – Personal Protective Equipment for Work At Heights*.

Competent workers

A person who has through formal training and sufficient work experience in the relevant discipline, possesses the practical and theoretical knowledge to effectively and safely assess and carry out the required work.

1.4 PROTECTION FROM FALL

1.4.1 Fall From Height (FFH)

1.4.1.1 Fall from height (FFH) is a major cause of injury and fatality at workplace. Wherever possible, in the planning, design, construction and maintenance of rooftop and vertical greenery, reduce and manage the need to work at height.

1.4.1.2 Where not possible to avoid work at height, the following passive and active strategies should be considered.

	Access/Egress (to elevated work space)	**Edge-Protection** (of elevated work space)
Passive	Example: Building's permanent stair core	Example: Minimum 1m height fixed parapet
Active	Examples: MEWPs, ladders, vertical rail, etc.	Example: Safety line + PPE

1.4.1.3 The design, installation and maintenance of these safety features must comply with industry standards and regulations.

1.4.1.4 Safety features when appropriately introduced can safe guard against workplace accidents. However, when inadequately designed, installed, utilized and/or maintained, may create more risks and hazards.

1.4.1.5 Please refer to the Workplace Safety and Health Council's website, www.wshc.sg, for the Code of Practice for Working Safely At Heights.

1.4.1.6 The onus is on the building owner and relevant user to make sure that these safety features are appropriately incorporated, maintained and correctly utilized.

1.4.2 Passive Access/Egress

1.4.2.1 When using a passive access/egress, the worker is not required to use and/or wear PPE. A building's permanent stair-core is an ideal example of a passive access/egress.

1.4.2.2 "Passive" access/egress is preferred over "Active" access/egress and should be integral to the building design whenever possible.

1.4.3 Active Access/Egress

1.4.3.1 When using an active access/egress, the worker is required to use and/or wear PPE.

1.4.3.2 Examples include, but are not limited to, MEWPs, tower scaffolds, ladders, vertical rail, etc.

1.4.3.3 Deployment of such equipment must comply with:

- Manufacturers' requirements
- Relevant Singapore Standards
- Workplace Safety and Health Council's (WSHC) - Code of Practice for Working Safely at Heights

1.4.3.4 In the case of tower scaffolds and ladders, the anchor points for attaching PPE cannot be on the tower scaffold or ladder itself as, in the event of a fall, the forces imposed will cause it to overturn. Relevant PPE must be used correctly.

1.4.3.5 For safety reason, ladder-stand-platform must be used in place of the A-frame ladder. Ladder when used for active access must comply with WSHC's relevant guidelines.

1.4.3.6 When active access/egress is provided, have sufficient space for the equipment to be correctly deployed. When built-in maintenance equipment such as gondola is provided, the design shall take into consideration the maintenance and replacement of such equipment.

1.4.3.7 Vertical rail or vertical lifeline when used must comply with *Singapore Standards, SS 528, Specification for Personal Fall-Arrest Systems, Part 4, Vertical rails and vertical lifelines incorporating a sliding type fall arrester*. Please also refer to the WSHC document, *Information on Life Lines*, at the WSHC website, www.wshc.sg.

1.4.4 Passive Edge-Protection

1.4.4.1 On elevated work site, with passive edge-protection, the worker is not required to use and/or wear PPE. An ideal example of a passive edge-protection is the fixed parapet (of minimum 1m height from work-site landing finished level to top of parapet) or fixed safety guardrail (designed, engineered and installed to registered PE's requirements).

1.4.4.2 From a safety standpoint, "Passive edge protection" is preferred over "Active edge protection" and should be integral to the building design whenever possible.

1.4.5 Active Edge-Protection

1.4.5.1 On elevated work site, with active edge-protection, the worker is required to use and/or wear PPE. An example is the safety line/rail system, wherein the workers must correctly wear and deploy the PPE. The competent worker must deploy these safety features correctly with prior thorough check(s) by the supervisor.

1.4.5.2 These must be designed and engineered to comply with:

- *SS 541, Specification for Restraint Belts*
- *SS 570, Specification for Personal protective equipment for protection against falls from height – Single point anchor devices and flexible horizontal lifeline systems*
- *SS 528, Specification for Personal Fall-Arrest Systems, Part 1 to 6*
- Manufacturers' requirements
- Workplace Safety and Health Council's (WSHC) - Code of Practice for Working Safely at Heights

1.5 HOLISTIC APPROACH TOWARDS DESIGN FOR SAFETY

1.5.1 Skyrise greenery is gaining strong momentum for the building and landscape sectors in Singapore. The escalation in the number of skyrise greenery sites means that landscape workers face a new challenge of working at greater heights in unfamiliar surroundings. Designers and contractors also face new challenges in incorporating greenery and maintainability into their designs and implementation.

1.5.2 Design for Safety is a holistic and multi-disciplinary approach to integrate safe construction and maintenance at the start of the project from conceptual design stage onwards. The process requires the concerted efforts of all stakeholders including the Client/Developer, Consultants, Designers as well as Contractors to address risks through design before construction takes place. In this case, skyrise greenery worker safety and maintenance needs should be planned for from the start of the project with inputs from relevant stakeholders/users including landscape architects, landscape contractors and horticulturists.

1.5.3 The Guidelines on Design for Safety in Buildings and Structures provide guidance on the design review process and recommend the Client/Developer to appoint a member/members of the project team to facilitate the process. The outcome of the design review process is a Register which is handed over to the owner/occupier at the end of the project. The Register includes maintenance method advisory notes by the designer and/or contractor as guidance to the owner/occupant who will manage and maintain the building/structure.

1.5.4 For more information and resources on Design for Safety, please refer to https://www.wshc.sg/dfs

1.6 PERFORMANCE REQUIREMENT

1.6.1 Skyrise greenery is contrived for human benefits. The construction, operation and maintenance of skyrise greenery shall in no circumstance compromise on safety of users, workers and all personnel in its vicinity.

1.6.2 Design, construction and the maintenance of the skyrise greenery must comply with the Workplace Safety and Health Act.

1.7 SAFE DESIGN (Hierarchy of Controls)

1.7.1 Safe Design is the consideration of worker health and safety in the design of a project.

1.7.2 Occupational safety and health problem solving science advises that a prescribed hierarchy of controls be followed. In order of preferred problem solving efficacy, they are:

Hierarchy Of Control		Level of order	Stage of utilization
1	Elimination	Higher Order Controls- Aim to **increase control** of work system	Achievable in the **design and planning** phases of projects.
2	Substitution of less hazardous materials, processes, operations, or equipment processes		
3	Engineering controls		
4	Administrative controls (such as training and procedures)	Lower Order Controls- Aim to **reduce impact** of known risk of work system	Utilized by workers in the **operation phase and maintenance** of projects
5	Personal protection equipment (PPE)		

1.7.3 This hierarchy of controls model aims to draw attention to solutions that permanently remove or reduce hazards and risks from a system, and away from easy, "quick fixes" such as rules, procedures, and personal protective equipment.

1.7.4 The lower order solutions (warnings, administrative controls, and personal protective equipment) aim to gain control over behaviour and increasing personal resistance to hazards *within* a work system.

1.7.5 The higher order solutions aim to gain control *of* a work system while the low-order solutions essentially aim to reduce the impact of a system with known risk.

1.7.6 Higher order controls can be effectively developed and implemented through holistic design and planning during the initial project phase. Once the project is built, workers can generally only utilize lower order controls.

1.7.7 Safe design thinking, upfront during the initial project design and planning phases, will contribute towards a safe, efficient, and more aesthetically holistic outcome. The earlier in the project design phase safe design thinking begins the more opportunity there is to develop creative solutions.

1.7.8 To gain control *of the system* rather than *within the system*, we need often to look beyond site management and to site planning, programming, construction methods, permanent works design, materials choices, etc[1].

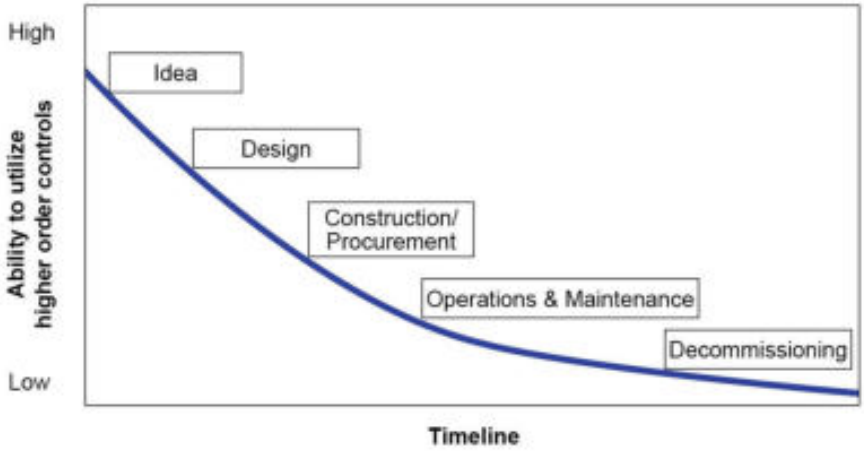


Figure 1. Ability to utilize the hierarchy of controls (adapted from Szymberski, 1996)

Consider safe design early in the project. As project progresses, there is lesser opportunity to utilize higher order controls

1.7.9 Please also refer to the WSH Council's Code Of Practice for Working Safely At Height.
www.wshc.sg

1.7.10 During mid design phase of building, conduct the WSHC's Risk Assessment to the design proposal, to identify safety issues and develop safe design solutions.

1.7.11 During project construction phase, conduct the WSHC's 1) Risk Assessment and 2) Risk Management, to identify site safety issues and develop safe work solutions.

1.7.12 Upon building completion, during building operation, periodically conduct the WSHC's 1) Risk Assessment and 2) Risk Management, to identify operation safety issues and develop safe work/operation solutions.

1.7.13 Building owners are encouraged to specify in their skyrise greenery design brief, that the consultant/contractor specifies/provides details on:

1) Safe access and;
2) Fall protection measures;

in the contract-bid process of the project. This will benefit the design and planning phases particularly for projects involving retrofitting skyrise greenery systems onto existing structures/buildings.

1.8 DESIGN TO ALLOW STRUCTURAL INSPECTION

1.8.1 For greenery and/or greenery systems integrated onto load bearing structures that require periodic structural inspection and maintenance, build in dedicated maintenance access walkway (or other relevant access means). Please refer to section 2.6.5.

1.8.2 To inspect and maintain the structures, the greenery and/or greenery systems in-front/on-top of these structures may need to be removed. To retain the established greenery, the greenery system must be designed to be open-able and/or mobile.

SECTION 2 SKYRISE GREENERY WORK-AT-HEIGHT (WAH)

2.1 COMMON WAH SITUATIONS

Skyrise Greenery WAH - common situations					
Green roof		**Roof garden**			**Vertical greenery**
Working near green roof edge with low or no parapet	Working on pitched green roof	Reaching out beyond roof edge	Working on narrow planted ledge with low or no parapet	Vertically accessing crown of rooftop tree/ palm	Vertically accessing the top of tall green wall beyond 3m height
					

2.1.1 All work at heights on Skyrise Greenery must comply with the WSHC's Code of Practice for Working Safely at Heights.

2.1.2 Do not position elevated work platforms (i.e. ladders, MEWPs, tower scaffolds, etc.) along rooftop edges.

2.1.3 On a rooftop garden, should there be a need to horizontally extend an elevated work platform (such as that of a small spider boom lift, etc.) close to the rooftop edge, the MEWP chassis:

- Must not be positioned along rooftop edges
  (In Zone 1 nor Zone 2 of the rooftop space)
- Must be sited (with outriggers deployed) no less than 5m from the nearest rooftop edges.
  (In Zone 3 and Zone 4 of the rooftop space)

Please refer to Section 2.5.

2.1.4 Refrain from planting tall plants that are more than 2m height along roof edges, to avoid:

- falling plant debris and/or tool(s) during maintenance
- the need to work in such high risk elevated environment

2.1.5 Use only simple hand-held tools for greenery maintenance along rooftop edges. These must be secured to the maintenance worker, to avoid dropping off the roof edge.

2.1.6 For rooftop tree/palm set-back recommendations, please refer to *CS E09:2012 – Guidelines on Planting of Trees, Palms and Tall Shrubs on Rooftop*.

2.2 TYPES OF ELEVATED WORK PLATFORM

- For work below 3m height, ladder stand platform can be deployed for horticulture works (i.e. clearing plant/shrub debris from roof ledges, planters, green walls or rooftop tree/palm crown pruning, etc.)
- For work beyond 3m height, deploy suitable elevated work platform.
- The diverse models of elevated work platforms can be broadly grouped into two types:
  - powered
  - non-powered

2.2.1 Mobile Elevated Work Platform (MEWP) - powered

2.2.1.1 On rooftop, an MEWP can elevate workers to reach targeted tree branches. Incorrect MEWP operation however can cause dire consequence, such as toppling of the MEWP.

Aerial lift - a powered MEWP

2.2.1.2 The MEWP must be inspected and certified by an Authorized Examiner (AE) every 6 months. Certified inspection by the AE, is a prerequisite to work commencement.

2.2.1.3 Only competent workers, correctly equipped with PPE, can operate the MEWP, with site supervision.

2.2.1.4 The MEWP operator must conduct site Risk Assessment and constantly monitor the wind speed throughout the MEWP operation. Beyond wind speed of 12m/s, MEWP operation must halt for safety reasons.

2.2.1.5 For more information on safe and correct operation of aerial lift/ MEWP, please refer to:

- All relevant Singapore Standards
- The International Powered Access Federation (IPAF) webpage at www.ipaf.org.

2.2.1.6 MEWP Reachable Heights (estimates):

- MEWP – Aerial/Personnel Lift can reach a platform height of about 12m and a working height of about 14m. (These are usually small and compact)
- MEWP – Spider Lift can reach a platform height ranging from 19m to 42m. (Generally, these are larger equipment. However, there are more compact models available.)
- MEWP – Boom Lift can reach a platform height up to 46m. (These are large equipment.)

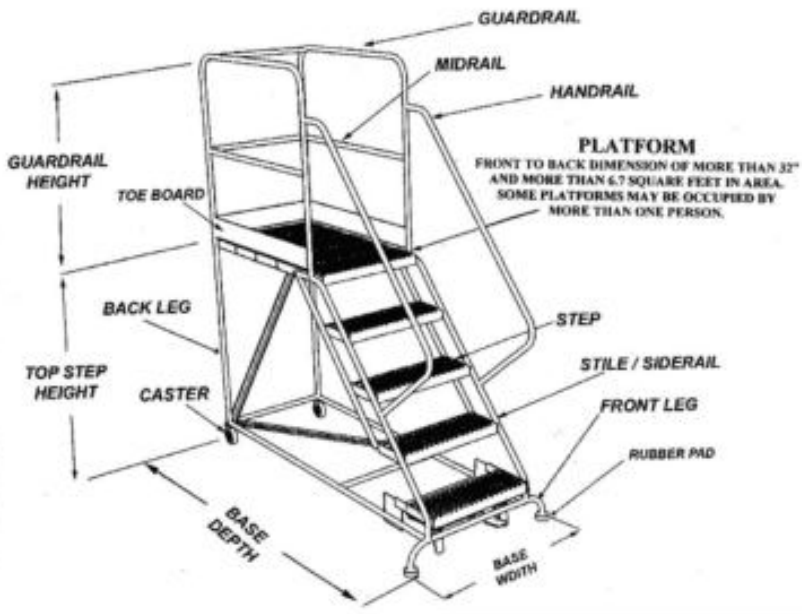
Where such equipment is needed for subsequent skyrise greenery maintenance, adequate access provisions (i.e. adequately dimensioned access route of adequate engineered load bearing capacity) must be well considered and planned for during the project design phase.

2.2.2 Ladder stand platform – non powered

2.2.2.1 Ladders are easy to set up and are commonly used during landscape works.

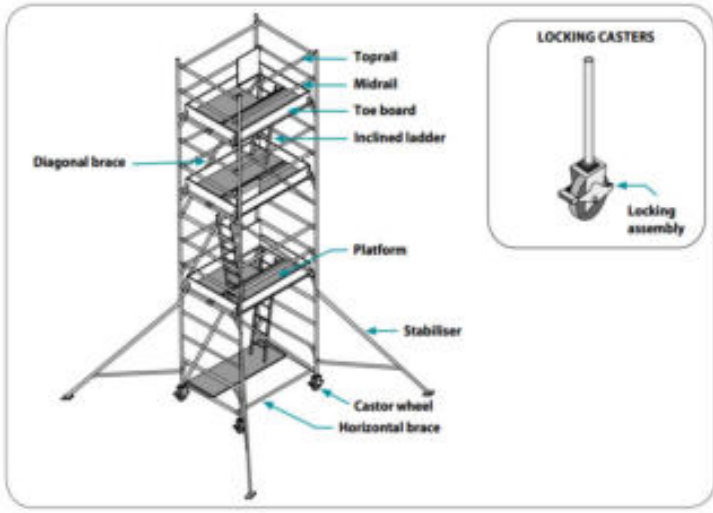
2.2.2.2 Incorrect use of A-frame ladders and leaning ladders has caused many fatal falls. Wherever possible, ladder stand platform must be used in place of the A-frame ladder.

2.2.2.3 Please comply with the WSH ladder safety guides and the manufacturer's requirements.



Ladder stand platform
– a non-powered MEWP

2.2.3 Tower scaffold – non powered



A mobile scaffold with access ladder, opening and other features to provide a hazard-free working platform

2.2.3.1 The following are relevant guidelines and standards on tower scaffold:

WSHC Guidelines

- Workplace Safety and Health Act (Chapter 354A) Workplace Safety and Health (scaffolds) Regulations 2011
- WSH Guidelines Landscape and Horticulture Works

Singapore Standards

- *CP 14:1996, Code of practice for scaffolds*
- *CP 20:1999, Code of practice for suspended scaffolds*
- *SS 280: Part 1: 2006, Specification for metal scaffoldings (Part 1: Frame scaffoldings)*
- *SS 280: Part 2: 2009, Specification for metal scaffoldings (Part 2: Modular scaffoldings)(Incorporating Corrigendum No. 1, May 2011)*
- *SS 311: 2005, Specification for steel tubes and fittings used in tubular scaffolding*

2.2.3.2 Please also refer to Ministry Of Manpower (MOM) legislation on requirements involving scaffolds.

2.3 RELEVANT SINGAPORE STANDARDS

2.3.1 The following are existing Singapore Standards on fall prevention equipment and systems.

Singapore Standards
(and any revision thereafter)

SS 541: Specifications for Restraints Belts

SS 528: Specifications for Personal Fall-Arrest Systems Part 1 – Full Body Harness

SS 528: Specifications for Personal Fall-Arrest Systems Part 2 – Lanyards and energy absorbers

SS 528: Specifications for Personal Fall-Arrest Systems Part 3 – Self-retracting lifelines

SS 528: Specifications for Personal Fall-Arrest Systems Part 4 – Vertical rails and vertical lifelines incorporating a sliding-type fall arrester

SS 528: Specifications for Personal Fall-Arrest Systems Part 5 – Connectors with self-closing and self-locking gates

SS 528: Specifications for Personal Fall-Arrest Systems Part 6 – System Performance Tests

SS 570: Personal protective equipment for protection against falls from height – Single point anchor devices and flexible horizontal lifeline systems

2.4 MANUAL TREE ACCESS (MTA)

2.4.1 Where elevated work platforms cannot be safely deployed to access a rooftop tree canopy for periodic crown maintenance (i.e. crown thinning, crown reduction, etc.), Manual Tree Access (MTA) is the next option.

2.4.2 MTA requires operator skill, fitness, persistent concentration and alertness. The operators (a minimum of two on site to keep vigilance of each other) must be trained, competent with his equipment, and able to spot potential tree hazards.

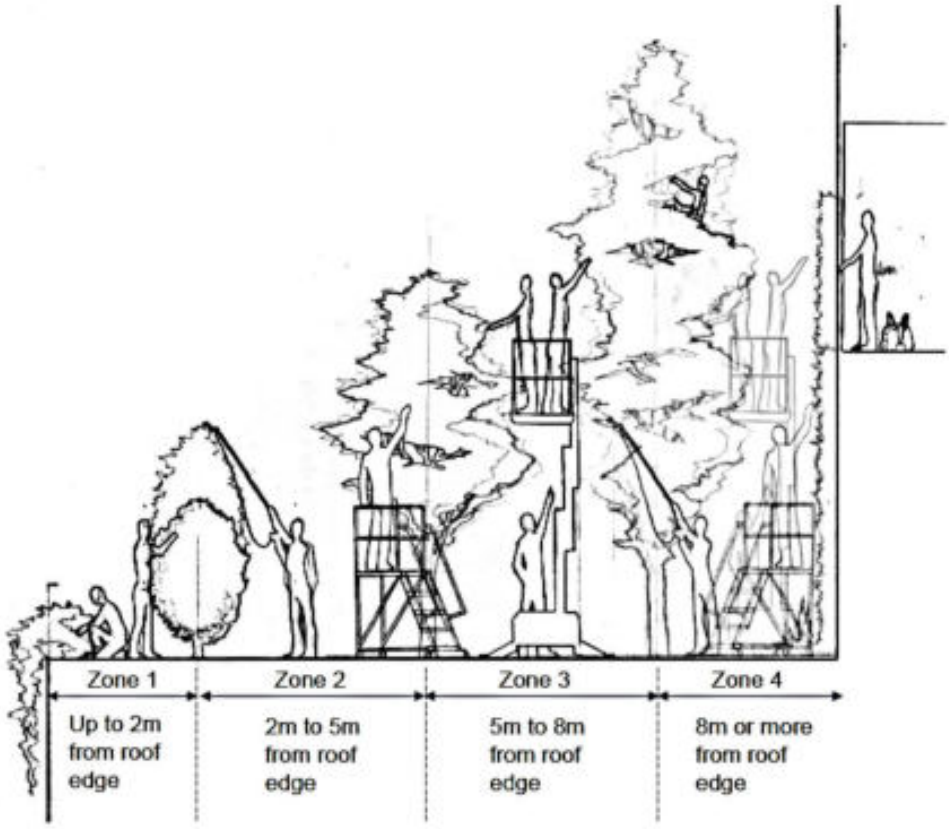
2.4.3 The operational task of MTA requires constant commitment from managers, supervisors, operators and all other team members to ensure personnel safety and operational objectives are met.

2.4.4 For safety reasons, MTA should never be exercised on rooftop trees planted along the rooftop edges and rooftop zone 1. Please refer to section 2.5.

2.4.5 For more information on MTA procedures and requirements, please refer to the Singapore Arboriculture Society website, www.sas.sg and their relevant guidelines:

- Code of Practice – Tree Pruning
- Tree Inspection Report Guidelines
- SAS Advice on Portable Ladders

2.5 SAFE DESIGN SUGGESTIONS – ROOFTOP GREENERY MAINTENANCE SETBACKS



Roof edge

- Avoid tree branching beyond railing/roof edge, for safe efficient maintenance. Set rooftop tree away from roof edge and prune tree crown regularly. Please refer to section 2.1.4.
- Tall plants along roof edge must be maintained regularly at no more than 2m height and should be staked (or guy-wired) for stability against wind loads, as advised by certified landscape architect and/or certified horticulturist.
- When greening rooftop edges, consider cascading shrubs/ground-covers. Roof edge planter trough when holistically design-integrated with the railing/parapet will allow safe access to the planter, soil, foliage and plant roots, without the need to lean over the railing/parapet during maintenance. Please refer to section 2.7.2.
- Cordon off the rooftop work area.

Zone 1 (up to 2m from roof edge)

- Use only simple hand-held tools in this zone. For taller plants, use a pole-pruner.
- Do not position ladders, tower scaffolds and MEWPs in this zone, for safety reasons.
- Avoid planting trees/palms/tall shrubs that are more than 2m height in this zone. Tall foliage beyond 2m can be difficult to reach and be maintained.
- Tall rooftop plants, planted no more than 2m away from the roof edge, more than 3m in plant height, which are not regularly maintained, can become a hazard.
- Set back rooftop trees/palms/tall shrubs from the roof edge by the estimated/maintained grown-height of the plants.
- Cordon off the rooftop work area.

Zone 2 (2m to 5m from roof edge)

- Set back rooftop trees/palms/tall shrubs from the roof edge by the estimated/maintained grown-height of the plants.
- Ladder stand platform can be used where necessary. Please comply with WSH ladder safety guides. Landing surface must be flat and stable.
- Landing surface (for ladder stand platform, tower scaffold, MEWP, etc.), must be flat and stable, with sufficient load bearing capacity.
- Cordon off the rooftop work area.
- Tower scaffolds and MEWPs' chassis must not be positioned in this zone.

Zone 3 (5m to 8m from roof edge)

- Set back rooftop trees/palms/tall shrubs from the roof edge by the estimated/maintained grown-height of the plants.
- Ladder stand platform can be used where necessary. Please comply with WSH ladder safety guides. Landing surface must be flat and stable.
- Tower scaffolds and MEWPs' chassis can be positioned in this zone by competent workers, with supervision.
- Landing surface (for ladder stand platform, tower scaffold, MEWP, etc.), must be flat and stable, with sufficient load bearing capacity.
- Cordon off the rooftop work area.
- The maximum working height (elevated platform height + 2m human working height) of the tower scaffold and/or MEWP must be lesser than the shortest horizontal distance between the roof edge and the tower scaffolds and/or MEWP base. Consider MEWP models with extension limit.

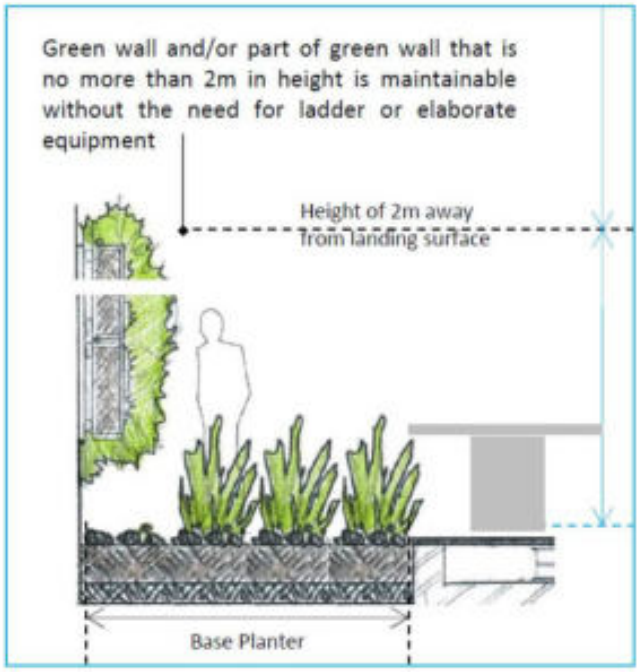
Zone 4 (8m or more from roof edge)

- Set back rooftop trees/palms/tall shrubs from the roof edge by the estimated/maintained grown-height of the plants.
- Ladder stand platform can be used where necessary. Please comply with WSH ladder safety guides. Landing surface must be flat and stable.
- Tower scaffolds and MEWPs' chassis can be positioned in this zone by competent workers, with supervision.
- Landing surface (for ladder stand platform, tower scaffold, MEWP, etc.), must be flat and stable, with sufficient load bearing capacity.
- Cordon off the rooftop work area.
- For maintenance of tall rooftop trees, access to tree crown can be via tower scaffold, MEWP (such as aerial platform, etc.) or by an experienced and certified arborist, with supervision at roof garden level. Cordon off the work area beneath the tree.
- Ideally, for maintainability, keep the rooftop trees/palms height at no more than 5m.
- Maintenance access to tall green walls can be from the front via ladder stand platform, tower scaffold, MEWP, or from the back via back-access maintenance walkway. Please refer to section 2.6.5.

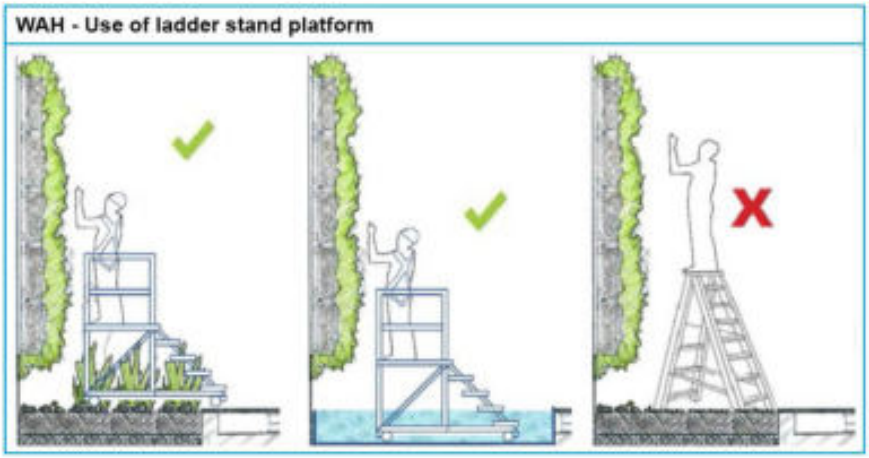
2.6 SAFE DESIGN SUGGESTIONS – VERTICAL GREENERY (non-exhaustive)

2.6.1 Front maintained green wall – 2m in height or less

- Green wall surface no more than 2m height is easily reachable.
- The base planter width and the types of ground plants will not impede access to the green wall surface.



2.6.2 Front maintained green wall – Between 2m to 4m in height



These illustrated situations are non-exhaustive.

2.6.2.1 Use of Ladder stand platform - on a base planter

- Green wall surfaces between **2m to 4m** in height can be reached via elevated work platforms (i.e. ladder stand platform, tower scaffold, etc.), pole pruner and/or a combination of these equipment.
- Have flat stable landing surface. In the base planter, if any, low ground covers is preferred over taller shrubs.
- Use of ladder must comply with WSH ladder safety guides and the manufacturer's requirements.

2.6.2.2 Use of Ladder stand platform - in a water body

- Some green walls are built above water bodies (i.e. swimming pool, wading pool or pond filled with aquatic plants and fishes).
- Have flat stable landing surface. In pools with pebbles, the elevated work platform footings must sit on the flat stable surface beneath.
- In pond, the base can be uneven (i.e. stepped, of diverse materiality, with recesses, etc.) and obscured by silt and water plants.

Predetermine the landing surface during design phase. Construct this flat and marked it out for easy identification.

- The deeper the water, the less accessible the top of the green wall to worker's reach.

- Use of ladder must comply with WSH ladder safety guides and the manufacturer's requirements.

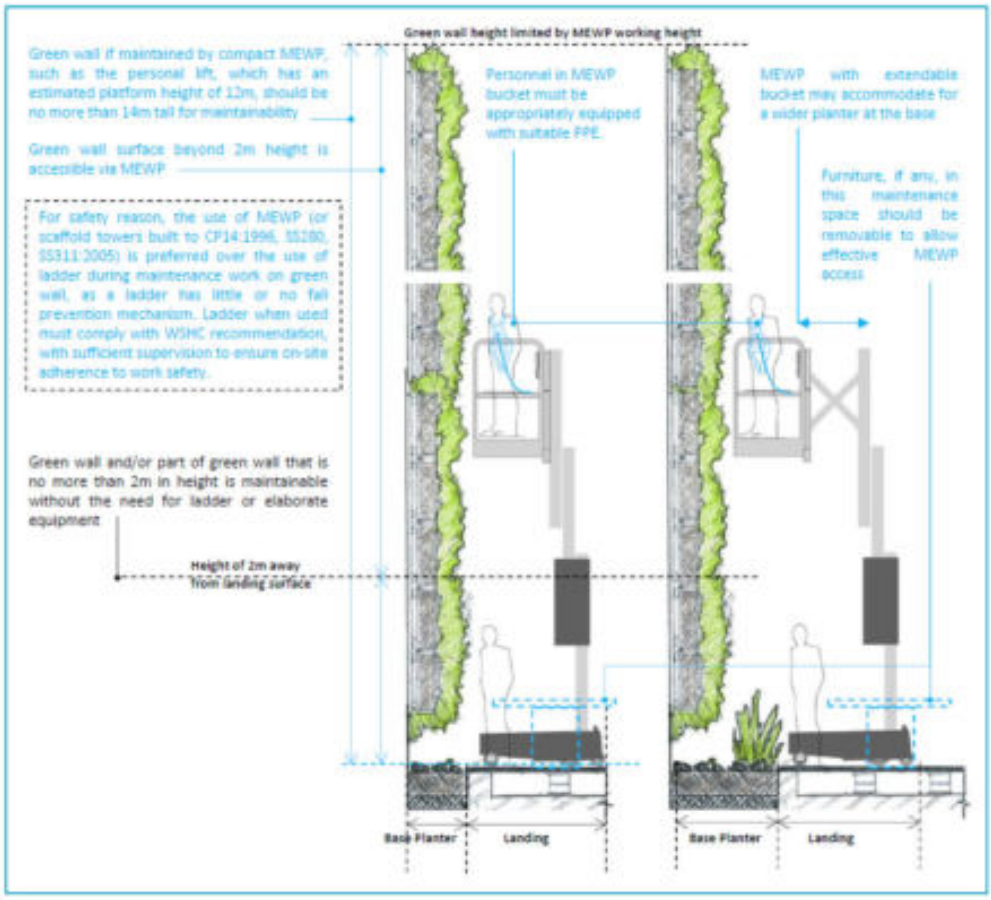
- Alternatively, consider boom type MEWP to avoid working in water.

2.6.2.3 Use of A-frame ladder or leaning-ladder

- There is a very high chance of workers losing balance/footing and falling from height when using the A-frame ladder and leaning-ladder. Instead, use the ladder stand platform.

- Worker on the ladder must at all times be assisted/supervised by a fellow worker. Worker must not be standing on the top rung. Use of ladder must comply with WSH ladder safety guides and the manufacturer's requirements.

2.6.3 Front maintained green wall – more than 4m in height



2.6.3.1 **<u>Green wall that is more than 4m height - Use tower scaffold or MEWP</u>**

- Consider using the tower scaffold or MEWP if the green wall is more than 4m height.

- Use of tower scaffolds should comply with CP14:1996, SS280 and/or SS311:2005. Use of MEWP must comply with manufacturer's requirements. Please refer to section 2.2.

2.6.3.2 **Type of MEWP will determine the maximum maintainable height of the green wall**

- Green wall maintained by compact MEWP, such as the personal lift, which has an estimated platform height of 12m, should be **no more than 14m** tall for maintainability.

- MEWP with horizontally extendable work platform may accommodate a slightly wider base planter.

- Furniture, if any, should be designed mobile/removable to allow effective MEWP access close to the green wall surfaces.

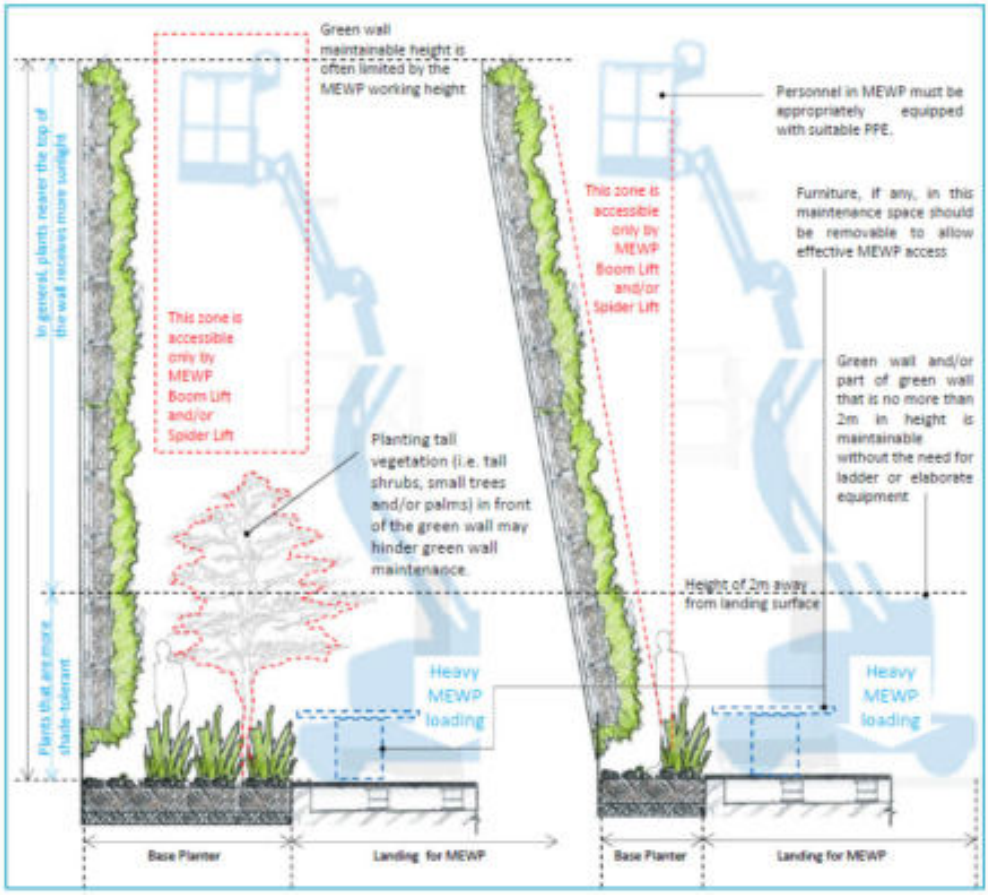
- Personnel in MEWP must be correctly equipped with PPE, to equipment manufacturer's requirements.

- If regular maintenance of such tall green wall is intended, it is economical to have an in-house compact MEWP in the building, deployable for multiple maintenance tasks (i.e. maintaining of light-fixtures, skylight, etc.)

- For green wall of higher and/or more versatile reach, consider lightweight boom type MEWP.

- Design with means of sustainable maintenance practice. Refrain from designs that require complex and difficult maintenance.

2.6.4 Front maintained green wall – with wide base planter and/or Inclined



2.6.4.1 Dense planting of tall shrubs/trees/palms in front of a green wall will block out sunlight and obstruct maintenance access to the green wall plants behind.

2.6.4.2 For tall inclined green wall, the top portion often cannot be reached by simple MEWPs (i.e. aerial personal lift, scissor lift). More versatile MEWPs (i.e. spider boom lift) may be required however these may be heavier (subject to MEWP model). Depending on the building design (i.e. access-way and structures' load bearing capacities and dimensions, etc.) bringing such heavy MEWPs onto the rooftop may not be feasible.

2.6.4.3 Designers should practice holistic design, allowing effective subsequent safe maintenance of the vertical greenery. Often, built vertical greenery

that cannot be effectively accessed for safe maintenance will become derelict and eventually removed.

2.6.4.4 Base planter requirements

- The base planter/gravel zone serves to catch drips and runoffs from the green wall foliage during irrigation.

- A wide base planter/gravel zone will prevent the MEWP from being deployed close to the green wall, rendering maintenance less effective, unless versatile MEWP (i.e. small spider boom lift, etc.) is selected.

2.6.4.5 Landing surface requirements

- Landing surface for MEWP must not be obstructed during operation. Furniture in this zone must be removable to allow MEWP deployment effectively close to the green wall. Alternatively, consider lightweight boom type MEWP (i.e. lightweight spider boom lift) for a more versatile reach.

- Landing surface must be level, stable and dimensionally adequate for safe operation of MEWP.

- Landing surface must be built to registered PE's specification to accommodate the estimated loads of the selected MEWP type(s) during operation.

- Uneven landing surface (i.e. stepped, of diverse materiality, with recessed water bodies, etc.) is challenging for safe MEWP operation. Where landing surface is not level, choose MEWP with outriggers designed to negotiate uneven surfaces.

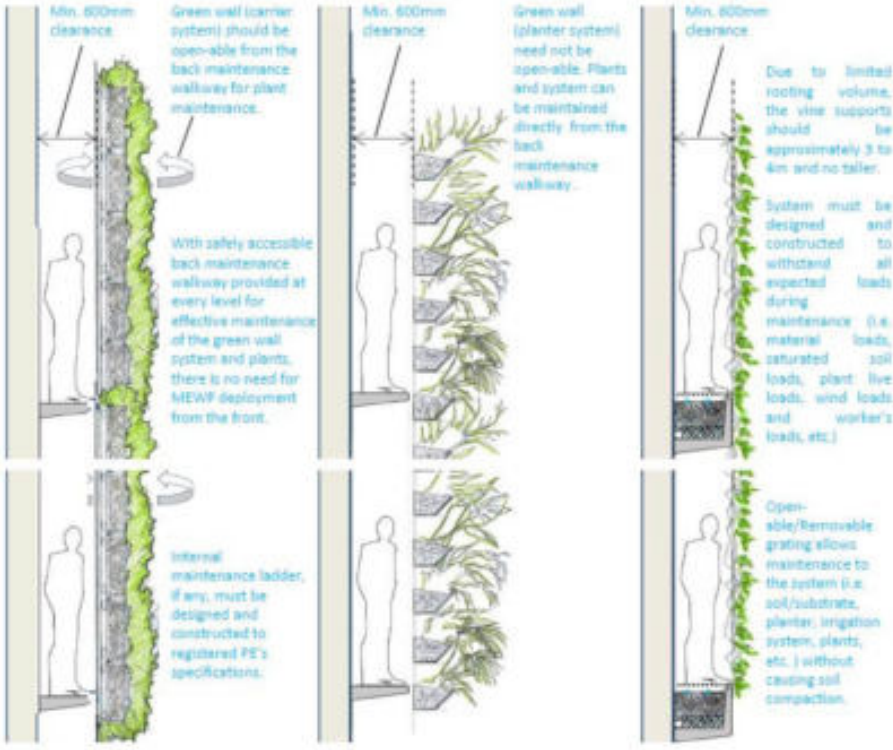
- Work area must be cordoned off during maintenance.

2.6.4.6 Engage competent workers

- This is a technically demanding work space. Engage only competent personnel and contractor/service-provider.

- Personnel, equipment and materials must be safely secured to prevent dropping from a height. Personnel must be correctly equipped with PPE throughout the operation.

2.6.5 Back maintained green wall



Green wall – Carrier system (example)

Green wall – Planter system (example)

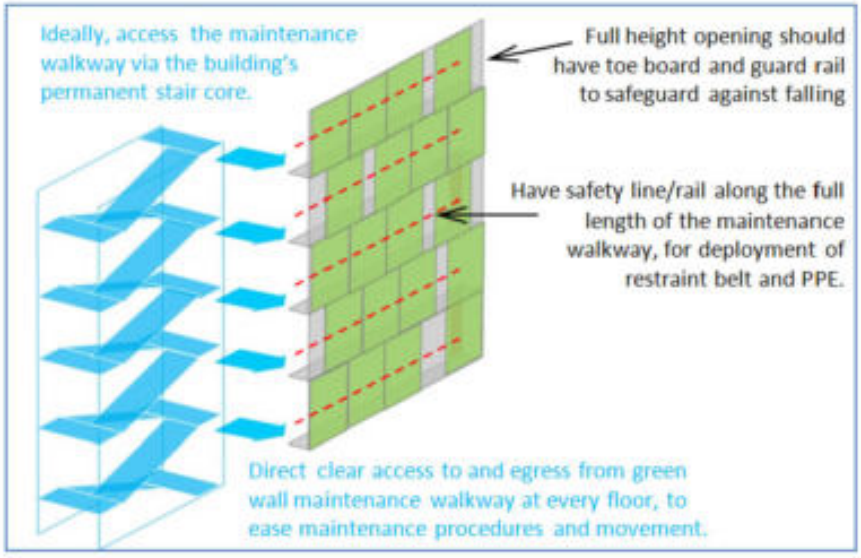
Green wall – Support system (example)

2.6.5.1 Back-access (walkway) requirements

- The back maintenance walkway should have a minimum 600mm internal clearance width.
- Maintenance walkway must be designed and constructed to registered PE's specifications.
- For green wall designed to be open-able/rotatable for maintenance, the width clearance of the maintenance walkway must accommodate the inward-swing of the green wall panels. Depending on design, this may require guardrails and mid-rails (or alternative) to prevent worker falling through the opening.

- The maintenance walkway edges must have toe boards (or alternative) to prevent tools rolling off and dropping from a height.

- Ideally, have safety line/rail designed and installed to the back wall along the full length of the maintenance walkway. These should be constructed to registered PE's requirements.



- Internal maintenance ladder if any, to connect the different walkway levels, must be designed and constructed to registered PE's specifications.

- Ideally, each maintenance walkway level should have direct access to the building's permanent stair-core, with clear spatial directionality, to allow ease of worker movement during emergencies and easy escape. Worker must not work alone in this maintenance walkway. Have a minimum of two workers per level to keep vigilance of each other.

2.6.5.2 **Back maintained green wall – Carrier type system**

- Open-able green wall panels should swing inwards, to allow easy access to the plants.

- Dimension the width of the maintenance walkway to accommodate the inward swing of the green wall panels.

- Generally, such back-maintained/accessed green walls do not require MEWP maintenance access from the front. The base of such green walls can be heavily landscaped without impeding green wall maintenance.

- With safely-accessible back maintenance walkway provided at every level, such green wall can be well maintained.

2.6.5.3 **Back maintained green wall – Planter type system**

- Generally, the planter type green wall is maintainable from the back maintenance walkway, without the need to open/rotate the green wall.

- Plant can be maintained and/or replaced from the back maintenance walkway.

- With safely-accessible back maintenance walkway provided at every level, such green wall can be well maintained.

2.6.5.4 **Back maintained green wall – Support type system**

- To achieve even foliage spread, the supports/surfaces for climber vines can range from 3m to 4m in height.

- The grown-height of the climber vines depends on the:
  - climbing/growth characteristics of the selected climber vine species
  - soil quantity and soil depth (no less than 700mm depth)
  - soil quality
  - maintenance regime
  - site microclimate

- Generally, climber vines can grow quite lush with:
  - good quality loam soil
  - regular horticulture care
  - adequate irrigation
  - suitable site microclimate

- The climber vine supports/surfaces must be designed and engineered to support the expected:
  - climber vines' grown weight
  - wind loads
  - human loads (during maintenance)

- Planter troughs must be designed and engineered to support the expected:
  - soil volume saturated weight
  - climber vines' grown weight
  - weight of the supports/surfaces
  - human loads (during maintenance)

- All climber vines require deep soil to allow growth to reach maximum height. Shallow soils will result in weak and low growth. A minimum soil depth of 700mm and ideal soil depth of 1.0m is recommended.

- Please also refer to *CS E10:2014, Guidelines on Design Loads for skyrise greenery*.

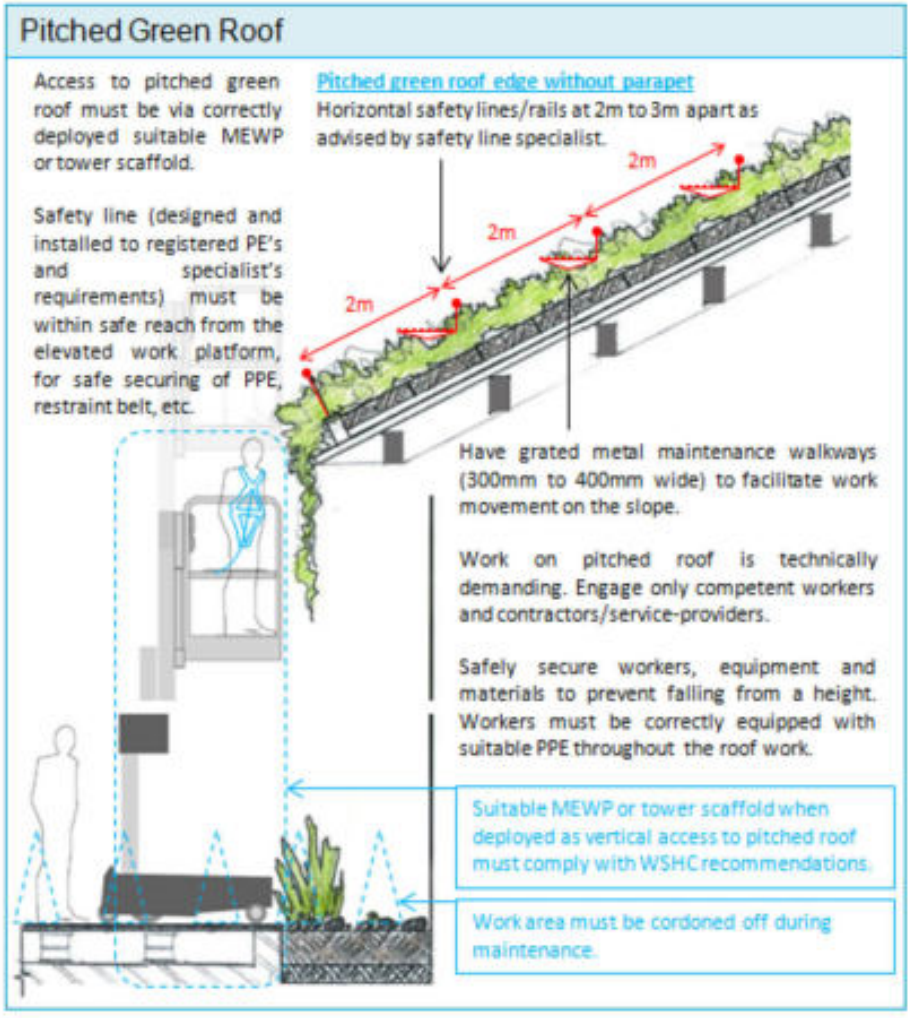
- Avoid walking directly on the planter soil/substrate during maintenance, as this will compact the soil, damaging the sensitive plant roots, adversely affecting foliage growth.

- One design option is to have open-able/removable metal grating designed over the planter to allow maintenance work to the climber vines, soil/substrate, planter, irrigation system, etc. without causing soil compaction.

- With safely-accessible back maintenance walkway provided at every level, such green wall can be well maintained.

2.7 SAFE DESIGN SUGGESTIONS – ROOFTOP GREENERY (non-exhaustive)

2.7.1 Pitched green roof – safe access



2.7.1.1 Pitched green roof

- Pitched green roof is usually non-accessible, except for periodic maintenance. Designers should practice holistic design, allowing effective subsequent safe maintenance. Often, pitched green roof

that cannot be effectively accessed for safe maintenance will become derelict, may eventually be deemed irrelevant and removed.

- Generally, pitched green roof of 10° to 15° inclinations are adequately gentle to walk on. Steeper pitched green roofs are challenging to access.

- Wherever possible, safe access to the pitched roof surface should be considered and provided for upfront, during the project design phase.

- The roof must be designed and engineered to support the expected:
  - green roof saturated load
  - human loads during maintenance (which include, but not limited to, the loads of the maintenance personnel, equipment and landscape materials, etc).

- The expected loading must be ascertained, designed and engineered by the registered PE, architect, and landscape architect.

- Please refer to CS E08:2012, Guidelines on Design and construction of pitched green roof.

- Please refer to CS E10:2014, Guidelines on Design loads for Skyrise Greenery.

2.7.1.2 **Safety line/rail requirements**

- Horizontal safety lines can be spaced 2m to 3m apart along the 'contours' of the pitched green roof, to allow maintenance worker to 'ascend' the pitched green roof when appropriately equipped with PPE and restraint belts of suitable lengths.

- Safety lines can also be installed to run along the incline of the roof slope, in which case the safety line will operate much like a vertical lifeline on a slope. For such set up, sliding type fall arrester must be part of the fall-protection assembly. Please comply with SS 528, Part 4.

- The fall-protection assembly must be complete with:
  - Safety line(s)

- Sliding type fall arrester (where necessary)
- Restraint belts (of suitable lengths)
- Full PPE
- Competent maintenance worker(s)
- Site supervision

- Safety line/rail system must be inspected at the start of every work shift to ensure that they are in good working condition and are safe for use, by the appointed competent person, with compliance to the following:
  - Workplace Safety and Health (Work At Heights) Regulations
  - SS 570:2011- Specification for Personal protective equipment for protection against falls from a height.

2.7.1.3 **Access to the pitched green roof**

- When securing the restraint belts to the safety line on the pitched green roof, the worker must be doing it while safely on a safe and stable access space/surface.

- Pitched green roof must be designed with safe maintenance access (i.e. permanent stairway, cat-ladder with cage, etc). In the absence of safe maintenance access to the pitched green roof, elevated work platform (i.e. suitable MEWP, tower scaffold, etc.) are possible options.

- The elevated work platform must be positioned over a floor surface that is level, stable, with adequate spatial dimensions and loading capacity.

2.7.1.4 **MEWP/Tower scaffold landing surface requirements**

- Landing surface for MEWP must not be obstructed during operation. Furniture in this zone must be removable to allow MEWP deployment effectively close to the green roof. Alternatively, consider lightweight boom type MEWP (i.e. lightweight spider boom lift) for a more versatile reach.

- Landing surface must be level, stable and dimensionally adequate for safe operation of MEWP.

- Landing surface must be built to registered PE's specification to accommodate the estimated loads of the selected MEWP type(s) during operation.

- Uneven landing surface (i.e. stepped, of diverse materiality, with recessed water bodies, etc.) is challenging for safe MEWP operation. Where landing surface is not level, choose MEWP designed with outriggers for negotiating uneven surfaces.

- Work area must be cordoned off during maintenance.

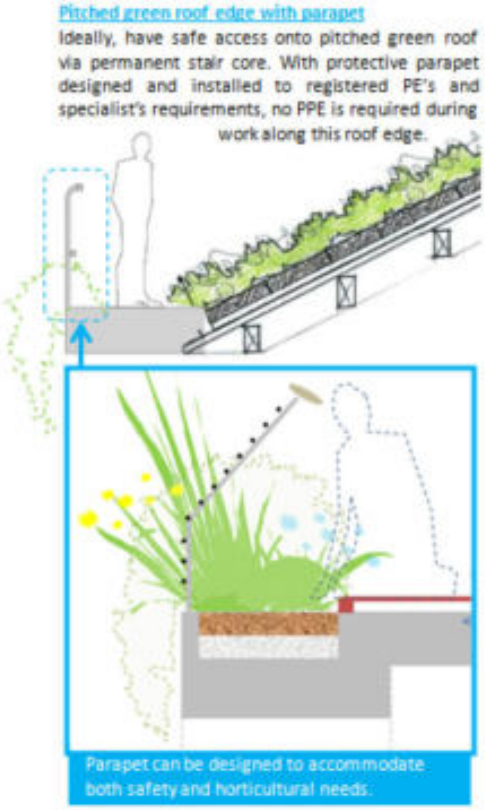
2.7.1.5 **Engage competent worker**

- This is a technically demanding work space. Engage only competent personnel and contractor/service-provider.

- Personnel, equipment and materials must be safely secured to prevent dropping from a height. Personnel must be correctly equipped with PPE throughout the roof work.

- A minimum of two certified workers on site to keep vigilance of each other. Have at least one worker at ground level to manage ground level work site. Site supervision is necessary.

2.7.2 Pitched green roof - safe design option



2.7.2.1 Pitched green roof can be designed with access (maintenance walkway) along the lower roof edge. This allows safe maintenance access and movement on the pitched green roof, without the need for safety lines, PPE and specially trained workers.

2.7.2.2 Such unique roof edge treatments can be designed as an integrated planter trough that, when provided with adequate numbers of well-designed drainage outlets, can also effectively drain excess rainwater.

2.7.2.3 Designers can also creatively design the railings/parapets to coordinate with the building façade aesthetically.

2.7.2.4 Alternatively, the railings/parapets can be designed to allow the vegetation and system to be maintained passively, without the need to lean over the railings/parapets to reach the plants.

2.7.2.5 Ideally, such safe access along the lower roof edge should be designed with direct safe access to the building's permanent stair-core (if this is available). Where permanent stair-core safe access/egress is unavailable, suitable MEWP or tower scaffold may be considered.

2.7.2.6 This assembly must be designed and built to registered PE's calculations.

2.7.3 Elevated ledge greenery – safe design options

2.7.3.1 <u>Minimum width of non-accessible ledge greenery</u>

- Non-accessible vegetated ledge should be **no less than 2m wide**. Greenery maintenance on elevated sites requires safe access/egress, safe work environment and the safe operation of maintenance equipment. A narrow elevated workspace with no edge-protection is a high risk environment.

2.7.3.2 <u>Ledge Greenery – Design Option 1</u>

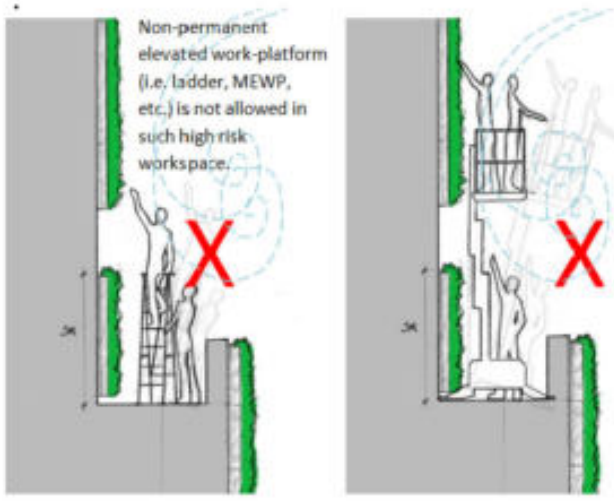
- Use simple hand-held tools only. Maintain taller shrubs with a pole-pruner. For maintainability, hedges should be kept at 2m height and no more than 3m height.
- For safety reason, passive edge protection (engineered and constructed to registered PE's requirements) is preferred. Ideally, detailed to cascading plants' growth and maintenance needs. (Please also refer to section 2.7.2)

2.7.3.3 **Ledge Greenery – Design Option 2**

- The green wall back maintenance walkway, should have a minimum 600mm internal clearance width. (Please refer to section 2.6.5)
- Green wall designed to be maintained along the narrow ledge should be no more than 2m in height for maintainability. (Please refer to section 2.6.1)
- Permanent gondola system, if any, must be constructed, maintained and operated to manufacturers' and registered PE's requirements. Worker operating the gondola must be competent.

2.7.3.4 **Ledge Greenery – Design Option 3**

- Where there is no passive edge protection (i.e. permanent 1m height railing/parapet/guard-rail, etc.), active edge protection (i.e. safety line, PPE and restraint belt, etc.) must be in place with compliance to Singapore Standards. (Please refer to section 2.3.)
- Hedge planted right up to the ledge edge should not exceed 2m height, with permanent staking, for stability and maintainability.
- Please refer to CS E09:2012, Guidelines on planting of trees, palms and tall shrubs on rooftop.
- Part of the positive wind pressures on building façade above will likely be redirected downwards, affecting especially the tall plants. Avoid placement of tall plants along the ledge edges for maintainability and safety reasons.



2.7.3.5 Temporary elevated work platform (i.e. ladder, tower scaffolds, MEWPs, etc.) must not be positioned on such narrow ledge. Stability of these equipment can be compromised during unforeseen windy conditions.

2.7.4 Green roof – safe design options

2.7.4.1 Unprotected green roof edge

Non-accessible green roof should ideally be accessed via a permanent stair-core, which is common for mid-rise and taller buildings. Lockable entrance/exit door from the permanent stair-core onto the rooftop must be at least 3m from the closest unprotected roof edge.

2.7.4.2 Green roof with unprotected roof edge must be installed with active edge protection (i.e. safety line/rail, PPE, restraint belt, etc.) with compliance to relevant Singapore Standards. Please refer to section 2.3.

2.7.4.3 Wherever possible, install safety line/rail no less than 3m from the unprotected roof edge.

2.7.4.4 The restraint belt must be of suitable length, to prevent worker moving off the roof edge. Multiple restraint belts, of different suitable lengths, may be necessary to address the different roof edge conditions on a single green roof. Please seek professional advice from PPE consultants.

2.7.4.5 Workers must be competent to maintain the green roof, with correct use of the safety line, PPE and supervision.

2.7.4.6 Green roof with unprotected roof edges and without safety line/rail must deploy the temporary edge protection system, with compliance to *Workplace Safety and Health Guidelines – Anchorage, Lifelines and Temporary Edge Protection Systems*, prior to green roof maintenance.

2.7.4.7 Single storey building/shelter is usually designed without permanent stair access to the roof. Access to roof will require tower scaffold, ladder stand platform, MEWP, etc. As such, it is common to see safety line installed close to the unprotected roof edges, for worker's reach. Please refer to section 2.7.1 for example of life line installed near unprotected roof edge of a pitched green roof.

2.7.4.8 This is an example of an active-edge-protection. Please refer to section 1.4.

2.7.4.9 <u>Protected green roof edge</u>

Green roof with passive edge protection (i.e. parapet/railing/guard-rail of minimum 1m height measured from green roof finished level to top of parapet/railing/guard-rail) can be maintained with relative safety. No PPE and specially trained workers are required. Worker supervision on roof is still necessary.

2.7.4.10 This is an example of a passive-edge-protection. Please refer to section 1.4.

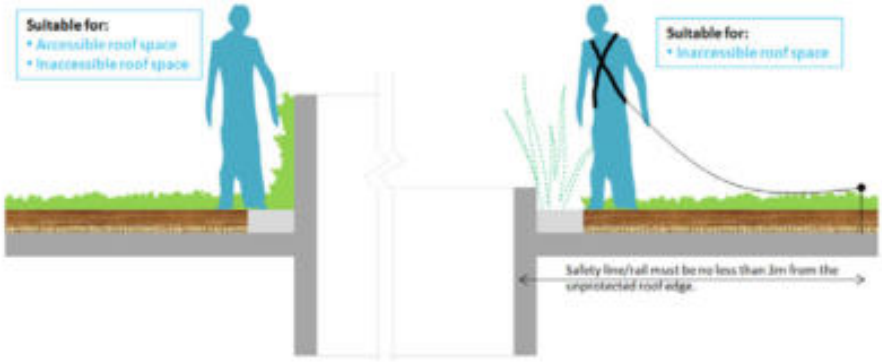
2.7.4.11 Protected green roof edge (design integrated with planter trough)

Please refer to section 2.7.4.9 and section 2.7.4.10.

2.7.4.12 Passive edge protection (in the form of parapet/railing/guard-rail) can be designed integrated with the planter trough. Planter may also be designed to be removable/ mobile for effective maintenance.

2.7.4.13 Please refer to section 2.7.2 for similar design example.

2.7.4.14 Roof penetration (Air-well)



On non-accessible green roof, roof penetration such as an air-well, may be designed with either protected and/or unprotected edges.

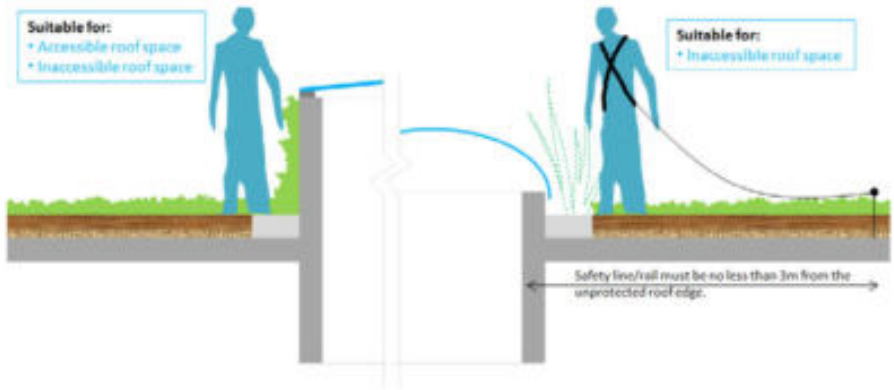
2.7.4.15 Unprotected green roof edges around the air-well, should not be vegetated. The vegetation may visually conceal the air-well, increasing the risk of worker stepping into the air-well unknowingly. Visually mark out the unprotected roof edges with a clear gravel zone, no less than 800mm, all round the air-well perimeter.

2.7.4.16 Please refer to section 2.7.4.1 through to section 2.7.4.8, on unprotected green roof edge.

2.7.4.17 Green roof air-well perimeter with passive edge protection (i.e. parapet/railing/guard-rail of minimum 1m height measured from green roof finished level to top of parapet/railing/guard-rail), can be maintained with relative safety. No PPE and specially trained workers are required. Worker supervision on roof is still necessary.

2.7.4.18 Should such green roof space be regularly accessed for plant maintenance, there is no restriction to the plant types that can be grown around the air-well.

2.7.4.19 Roof penetration (Skylight)



On non-accessible green roof, roof penetration such as a skylight, may be designed with either protected and/or unprotected edges.

2.7.4.20 Skylight cover designed and built to registered PE's specifications, to withstand breaking under the impact force generated by a person who tripped over, is considered a protected skylight. Such skylight perimeter on the green roof is considered protected roof edge.

2.7.4.21 Skylight cover that breaks under such impact is considered an unprotected skylight. Such skylight perimeter on the green roof is considered unprotected roof edge.

2.7.4.22 Unprotected green roof edges around the skylight, should not be vegetated. The vegetation may visually conceal the fragile skylight cover, increasing the risk of worker stepping through the skylight unknowingly. Visually mark out the unprotected roof edges with a clear gravel zone, no less than 800mm, all round the skylight perimeter.

2.7.4.23 Please refer to section 2.7.4.1 through to section 2.7.4.8, on unprotected green roof edge.

2.7.4.24 Green roof skylight perimeter with passive edge protection (i.e. parapet/railing/guard-rail of minimum 1m height measured from green roof finished level to top of parapet/railing/guard-rail), can be maintained with relative safety. No PPE and specially trained workers are required. Worker supervision on roof is still necessary.

2.7.4.25 Should such green roof space be regularly accessed for plant maintenance, there is no restriction to the plant types that can be grown around the skylight.

SECTION 3 VEGETATION AND BUILDING CONSIDERATIONS CHECKLIST - FOR SAFE OPERATION AND MAINTENANCE OF SKYRISE GREENERY

3.1 Plant considerations

3.1.1 Safe maintenance access to plants

3.1.1.1 Safe maintenance access to the plants should be considered during the design phase. Plant selection and placement should complement the building, the site and the design intention.

3.1.1.2 Provision of safe maintenance access and safe work space allows thorough maintenance operation, for well maintained and healthier plants.

3.1.1.3 In the case of extensive green roofs, designers must provide narrow maintenance paths 300 - 500mm wide through the planting areas so that workers can access wide areas of planting easily without having to step on plants and thus reducing the risk of losing balance.

3.1.2 Plant placement (rooftop trees/palms/tall shrubs)

3.1.2.1 On skyrise greenery, the selected plant palette and plant placement will influence the maintenance operations.

3.1.2.2 Rooftop tree/palm selection and placement in particular, have huge influence on the roof garden's subsequent maintenance regime and safety. For safe maintainability, rooftop trees/palms/tall shrubs should ideally be set back from the roof edges. Please refer to section 2.5.

3.1.2.3 Please refer to CS E09:2012, Guidelines on planting of trees, palms and tall shrubs on rooftop.

3.1.3 Plant selection

3.1.3.1 Hardy plant species can successfully establish in diverse conditions and should be considered. Seek holistic advice from experienced greenery system consultants and/or horticulturists.

3.1.3.2 Given the right plant care, selected plant species suited to the deployed greenery system(s) and site's microclimate, have high chance to establish well, with lesser horticulture issues and need for replacement.

3.1.3.3 Skyrise greenery microclimates are diverse. Some roofs/façades are shaded by surrounding taller buildings for most part of the day, while some roofs receive full sun. Due to wind funnelling by surrounding urban volumes, some roofs have wind eddies, while more sheltered roof spaces are likely to have low wind disturbance. Parapet height can also influence wind pressures on extensive green roofs.

3.1.3.4 Green roofs on open site (i.e. site facing the open sea, with low surrounding buildings), exposed to full sun and constant wind are likely to lose more moisture during dryer months. Drought tolerant plants need to be considered.

3.1.3.5 Depending on the green wall design, orientation and site conditions, a green wall may not receive direct sunlight throughout the day. Shade tolerant plants may be considered. Always seek holistic advice from experienced green wall consultants and/or horticulturists.

3.1.3.6 Where possible, in project phasing, set up plant test plots (mock-up surfaces, etc.) in consultation with the engaged skyrise greenery consultants to ascertain the horticultural performance of selected greenery systems and plant species, prior to the greenery installation. Such test plots will serve well to identify suitable plant species as well as manage the building owners' and users' expectations of the relevant greenery systems and the subsequent maintenance.

3.1.3.7 Some plant species (i.e. some species of bromeliad, alocasia) may trap water in their axials. Such plants when used should be regularly monitored every few days for signs of mosquito breeding. Such plants that can potentially trap water are not allowed on non-accessible skyrise greenery (i.e. extensive green roof), where inspection is infrequent.

3.2 Building considerations

3.2.1 Building's established load-bearing capacity

3.2.1.1 The maximum load bearing capacity of the roof and the wall, established by the registered PE, must never be exceeded.

3.2.1.2 The established load bearing capacity of the receiving building surfaces must be inclusive of the estimated wind loads (both the positive and negative wind loads) on the green roof system, green wall system and/or rooftop tree/palm.

3.2.1.3 When heavy equipment (i.e. MEWP) is expected to be used during skyrise greenery maintenance, the associated loading of such heavy

equipment during operation must be included when determining the load bearing capacity of the receiving building surfaces.

3.2.1.4 When retrofitting greenery systems onto existing building and structures, registered PE's evaluation is required to ensure the load bearing capacities of the existing load bearing structures are not exceeded.

3.2.1.5 Structural reinforcement and/or additional load bearing structures, designed and built to registered PE's and Architect's specifications, may be necessary to accommodate and transfer loads from retrofitted greenery systems.

3.2.1.6 Please refer to CS E10:2014 – Guidelines on Design Loads for Skyrise Greenery.

3.2.2 Pitched green roof

3.2.2.1 The design and installation of rooftop greenery on a sloped roof surface is more challenging than on a flat roof. Retention of the growth medium, the vegetation and moisture is technically more challenging on a steep pitch.

3.2.2.2 Please refer to CS E08:2012 – Guidelines on Design and Construction of Pitched Green Roof.

3.2.2.3 Engineered measures (i.e. horizontal stopper-posts) in combination with relevant horticultural practices (i.e. use of intermittently secured jute netting and/or other substrate stabilizing methods) must be in place to prevent substrate erosion and to manage the shear force(s) within the green roof system.

3.2.2.4 Rooftop greenery specialist(s) and the registered PE(s) must be consulted to address and resolve the expected shear force(s) during the design of the pitched green roof.

3.2.2.5 Relevant estimated wind loads must be accounted for in the registered PE's calculations. Please refer to CS E10:2014, Guidelines on Design loads for skyrise greenery.

3.2.2.6 Safety line(s), safety anchors and equivalents when installed on pitched green roof for the purpose of maintenance must be engineered and installed with compliance to SS 528 and SS 570. Please refer to section 2.7.1.

3.2.3 Vertical greenery (on both new and existing walls)

3.2.3.1 Vertical greening is more challenging with increased altitude because of expected stronger winds.

3.2.3.2 Please refer to CSE10:2014, Guidelines on Design Loads for Skyrise Greenery, section 3.3.

3.2.3.3 Green wall load bearing structures must be designed and built to registered PE's and Architect's specifications. Registered PE and green wall specialists must be consulted to estimate the wind loads on the selected green wall systems.

3.2.3.4 When retrofitting green wall systems on to existing buildings and structures, load bearing capacity of existing structures must be evaluated by registered PE. Structural reinforcement and/or additional load bearing structures, designed and built to registered PE's and Architect's specifications, may be required to transfer loads from the retrofitted green wall system.

3.2.3.5 Safety line(s), safety anchors and equivalents may be required for safe future maintenance. This is dependent on the green wall dimensions, location and design.

3.2.3.6 Please refer to Section 2.6 for Safe Design Suggestions.

3.2.4 Cordon off roof penetration during maintenance

3.2.4.1 On non-accessible rooftop greenery (i.e. an extensive green roof accessed only during maintenance), the design of any roof penetration (i.e. air-well, skylight, etc.) should allow roof maintenance work to be carried out safely, without the risk of workers falling through these roof penetrations.

3.2.4.2 Such roof penetrations are at times designed with low or no parapet, no railing, or covered with thin glass panel (or other translucent sheeting materials) of inadequate load bearing capacity.

3.2.4.3 Ideally, passive-edge-protection around such roof penetration will significantly improve worker's safety on roof. This can be in the form of a permanent parapet no less than 1m in height from roof-site finished level to the top of the parapet.

3.2.4.4 Alternatively, active-edge-protection system may be deployed. See section 1.4.

3.2.4.5 Where both passive and active edge protections are not provided, temporary-edge-protection system can be deployed. Please refer to WSH Guidelines, Anchorages, Lifelines and Temporary Edge Protection Systems.

3.2.5 Provide safe access to and egress from elevated work spaces

3.2.5.1 The design of the building must allow safe access/egress and safe maintenance of the skyrise greenery. Ideally, have permanent passive access/egress (i.e. permanent stair core)

3.2.6 Fragile roofing materials

3.2.6.1 Glass roof surfaces (i.e. covered skylight, covered walkway, etc.), if intended to be walked on during skyrise greenery maintenance, must be designed and engineered to accommodate the imposed loads expected, which include and are not limited to the loads from the maintenance worker(s), the maintenance equipment, the required landscape materials and the expected impact loads, etc.

3.2.6.2 Please refer to CS E10:2014, Guidelines on Design Loads for Skyrise Greenery.

3.2.6.3 Prior to installing extensive green roof system, metal roof (both new metal roof and existing metal roof) must be checked by the registered PE for any structural risk. Design of such metal roof must allow visual inspection to its underside for any sign of corrosion, before being accessed for maintenance.

3.2.6.4 There is the hidden danger of maintenance worker stepping onto an extensive green roof surface, without knowing the metal roof beneath has corroded. Worker can potentially step through the roof!

3.2.6.5 Roof surfaces/zones not engineered to be walked on must be visually/permanently demarcated either by installing barriers (i.e. guard rail) around these surfaces and/or have clear warning signage(s) attached.

3.2.7 Fire safety of skyrise greenery

3.2.7.1 Skyrise greenery, being an integral part of a building, shall comply with the Fire Safety Act, "Code of Practice for Fire Precautions in Buildings" and its relevant codes of practices.

3.2.7.2 When uncertain, the Qualified Person should consult SCDF (Singapore Civil Defence Force).

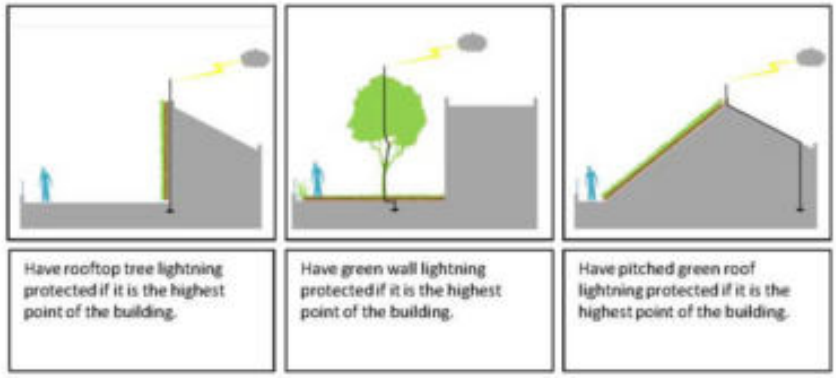
3.2.8 Lightning protection for Skyrise Greenery

3.2.8.1 Lightning protection for extensive green roof must be designed and installed in accordance to the latest BCA (Building and Construction Authority) Building Control Act and Regulations. Please refer to relevant web-link:
http://www.bca.gov.sg/Publications/BuildingControlAct/others/Approved doc.pdf

3.2.8.2 For the Lightning Protection Codes, please refer to L3.1 of BCA Approved Document Acceptable Solutions

3.2.8.3 Wherever possible, design the building such that the highest point is not the rooftop tree/palm. However, lightning protection on the rooftop tree/palm can be considered, as an option, to safeguard the rooftop tree/palm from being struck by lightning. Please seek arboriculture advice from certified arborist and engineering advice from registered PE.

3.2.8.4 Wherever possible, design the building such that the highest point is not the green wall. However, lightning protection on the green wall can be considered, as an option, to safeguard the green wall from being struck by lightning. The lightning protection must be built to registered PE's and green wall specialist's specifications.



3.2.8.5 The lightning and earth-ing protection systems must be engineered and built to registered PE's specifications.

3.2.9 Have an integrated fertigation system (as part of the automatic irrigation system)

3.2.9.1 Wherever possible, have an integrated fertigation system as part of the irrigation system to manage the fertilising schedules of the skyrise greenery. The fertigation system allows liquid fertilisers to be applied in controlled and measured doses through the automatic irrigation system. This increases maintenance efficiency and reduces worker's contact with chemicals.

3.2.10 Design to avoid water ponding (to cull mosquito breeding)

3.2.10.1 The design of skyrise greenery should avoid creating conditions conducive to mosquito breeding, e.g. impervious depressed areas, structural supports that when angled may trap water.

3.2.10.2 The skyrise greenery shall be managed in accordance to the latest NEA (National Environment Agency) guide in the Scope of Works for Mosquito Control.

3.2.10.3 Please refer to the following links to NEA:

1) Guidelines on mosquito prevention in domestic rainwater collection system for non-potable uses
http://app2.nea.gov.sg/data/cmsresource/20090618239106523150.pdf

2) Scope of works for mosquito control
http://app2.nea.gov.sg/docs/default-source/training-knowledge-hub/scope-of-works-for-mosquito-control.pdf?sfvrsn=0

An inclined steel L-section of a climber vine support screen may trap water. One solution is to have intermittent weep holes along the bend of the L-section to avoid trapping water

3.2.11 Have access to clean, potable water

3.2.11.1 Non-accessible rooftop and some high-rise environments can be isolated and harsh. Availability of clean potable water can be crucial during emergency. For example, should a maintenance worker be down with heat stroke, or should someone suffer a cut and require immediate cleansing of an open wound, proximity to clean water source can be crucial. Have at least one tap point with potable water on the rooftop greenery. Workers must be in pairs.

3.2.11.2 The green wall can be difficult to access. Often, tall green walls can only be accessed via MEWPs, tower scaffolds, gondolas, etc. In such elevated environments, the workers must have means of safe egress during emergency. Workers must be in pairs.

3.2.12 Stores for equipment and landscape materials

3.2.12.1 Having suitably sized, accessible, lockable store, for putting away maintenance equipment and supplies, keeps the rooftop space organised, reduces clutter and allow quick access to tools and materials for efficient maintenance operation. Leftover materials and tools must be cleared and never left on site. The store has to be well-ventilated for storage of chemicals used for landscape maintenance.

3.2.12.2 Spaces designated as maintenance access for skyrise greenery (i.e. back maintenance walkway of green wall) should never be used as ad hoc storage spaces. Unsecured leftover items in such exposed elevated space can be blown off, by expected wind gust, endangering unwary passers-by below.

3.2.12.3 Install controls and electrical boxes (i.e. irrigation timer) away from rain and sun, in lockable cabinets to prevent tempering.

3.2.12.4 Such non-accessible spaces must be lockable to prevent unauthorised entry.

3.2.13 Lighting fixtures

3.2.13.1 Provide light fixtures to allow safe effective maintenance in dim work spaces (i.e. back-access walkways of green walls). Where light fixtures are not provided or working, workers should at least be equipped with headlights and/or equivalent.

3.2.14 Ergonomic and noise consideration at design phase

3.2.14.1 When designing skyrise greenery, such as a green wall, consider the position and location of the plants to minimise awkward postures of workers during maintenance. Avoid positioning of plants which requires excessive stretching by workers. If unavoidable, provide appropriate tools to facilitate reaching the plants.

3.2.14.2 Some equipment or tools are inherently quieter than others. When procuring equipment or tools to be used for maintenance of skyrise greenery, specify the noise or sound pressure level and select the quietest ones. The permissible exposure limit for noise is 85 dBA for 8 hours of exposure.

3.2.14.3 For more information on ergonomics and noise, please refer to WSH Council's Guidelines on Improving Ergonomics in Workplaces and WSH Guidelines on Hearing Conservation Programme.

3.2.14.4 To find out more on other occupational health hazard management, please refer to WSH Guidelines on Landscape and Horticulture Management.

REFERENCES

Singapore Standards
(and any revision thereafter)

SS 541:Specifications for Restraints Belts

SS 528: Specifications for Personal Fall-Arrest Systems Part 1 – Full Body Harness

SS 528: Specifications for Personal Fall-Arrest Systems Part 2 – Lanyards and energy absorbers

SS 528: Specifications for Personal Fall-Arrest Systems Part 3 – Self-retracting lifelines

SS 528: Specifications for Personal Fall-Arrest Systems Part 4 – Vertical rails and vertical lifelines incorporating a sliding-type fall arrester

SS 528: Specifications for Personal Fall-Arrest Systems Part 5 – Connectors with self-closing and self-locking gates

SS 528: Specifications for Personal Fall-Arrest Systems Part 6 – System Performance Tests

SS 570: Personal protective equipment for protection against falls from height – Single point anchor devices and flexible horizontal lifeline systems

CP 14:1996 Code of practice for scaffolds

CP 20:1999 Code of practice for suspended scaffolds

SS 280: Part 1: 2006 Specification for metal scaffoldings (Part 1: Frame scaffoldings)

SS 280: Part 2: 2009 Specification for metal scaffoldings (Part 2: Modular scaffoldings)(Incorporating Corrigendum No. 1, May 2011)

SS 311: 2005 Specification for steel tubes and fittings used in tubular scaffolding

WSH Council

Code of Practice for Working Safely at Heights

WSH Guidelines on Landscape and Horticulture Management

Guidelines on Design for Safety in Buildings and Structures

Guidelines on Improving Ergonomics in Workplaces

Guidelines on Hearing Conservation Programme

Web-Links

Building & Construction: Scaffold Design & Safety Standards: Resource Guide: July 2011 http://www.ies.org.sg/temp/nlbjuly11.pdf

Workplace Safety and Health Act (Chapter 354A) (SCAFFOLDS) Regulations 2011 https://www.reach.gov.sg/Portals/0/EConsult/16/Annex%20A%20-%20WSH%20(Scaffolds)%20Regulations%20-%20for%20consultation.pdf

[1](Culvenor, 1996)

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