VCAB Compliance Checklist Item 6: Green Roof/Planting on Structures General (6.2)

Fig. 6.2 - 1a Green roof at Sha Tin Sewage Treatment Works (STW)

Fig. 6.2 - 1b Green roof at Ma On Shan Sewage Pumping Station (SPS)

Fig. 6.2 - 1c Green roof at Shuen Wan SPS

Fig. 6.2 - 1d Green roof at Tai Yuen SPS

Fig. 6.2 - 1e Green roof at Sha Tin STW

Fig. 6.2 - 1f Brown roof at Sha Tin STW

Fig. 6.2 - 1g Low maintenance green roof (i.e. proprietary green roof system with a mix of succulent plants) at Sha Tin STW

With reference to Item 6.2.1 in the VCAB Checklist,

• All design options of green roof can be explored to suit the site and maintenance provision.

•Type i) Demonstration and education purpose green roofs proposed in large STWs can be a combination of different types of green roofs. Native plant species which provide food and shelter for wildlife and enhance biodiversity should be considered.

• Type ii) Beautification and aesthetic purpose green roof can be proposed for sites surrounded by residential development. Examples are shown in Fig. 6.2 - 1a to 1e.

• Type iii) Ecological purpose green roof is suggested for unmanned sites and places near woodland/remote areas. Examples include but not limited to brown roof (Fig. 6.2 - 1f), i.e. naturally inhabited by wild species nearby and self-seeded plants with minimum use of garden chemicals, machines, tools, transport and low carbon footprint; wild flower roof, meadow roof, etc.

• Type iv) Low maintenance green roof is recommended for construction site offices, retrofitting roofs with limited loading allowance and unmanned sites in less sensitive locations. Examples include but not limited to proprietary green roof system with a mix of succulent plants (Fig. 6.2 - 1g).

VCAB Compliance Checklist Item 6: Green Roof/Planting on Structures General (6.2)

Figure 6.2 - 2a

Kowloon Bay Sewage Interception Station (SIS)

Figure 6.2 - 2b

Kowloon City SPS No. 2

Fig. 6.2 - 2a and 2b are two examples of green roofs for beautification and aesthetic purpose at sites. The table below shows the typical requirements for such green roofs to help maintain and sustain the original roof design.

Requirements	Green roof at Kowloon Bay SIS	Green roof at Kowloon City SPS No.1
Sufficient soil depth	~450mm for shrubs and ground cover	150mm for ground cover and ~450mm for climbers
Automatic irrigation	Drip irrigation system	Sprinkler system
Water conservation measure	Rain sensor and rainwater harvesting	Rain sensor and rainwater harvesting
Drainage	Sufficient roof drains and inspection chambers	Sufficient slope gradient and roof drains
Hardy species are used	*Nephrolepis auriculata* (腎蕨), *Ophiopogon jaburan* (花葉沿階草); *Duranta repens cv.Golden Leaves* (葉假連翹); *Loropetalum chinense* and *Ruellia brittoniana* (翠蘆莉)	*Nephrolepis auriculata* (腎蕨), *Axonopus compressus* (地毯草) and *Allamanda cathartica* (軟枝黃蟬)
Planting edge	Dividing strips (brick paver) used to separate different plant species	Dividing strips (brick paver) used to separate different plant species
Proper access	Staircase is provided	Staircase is provided
Proper maintenance access	~800mm wide timber deck	~800mm wide timber deck
Sturdy parapet wall/railing	Parapet wall with railing	Railing
Roof utilities	Location of vents and UV panels are well coordinated with planting pattern	No utilities at green roof

VCAB Compliance Checklist Item 6: Green Roof/Planting on Structures General (6.2)

Figure 6.2 - 3

Natural succession of self-seeded plants on the brown roof at Shatin STW

Self-seeded plants observed on the brown roof at Shatin STW

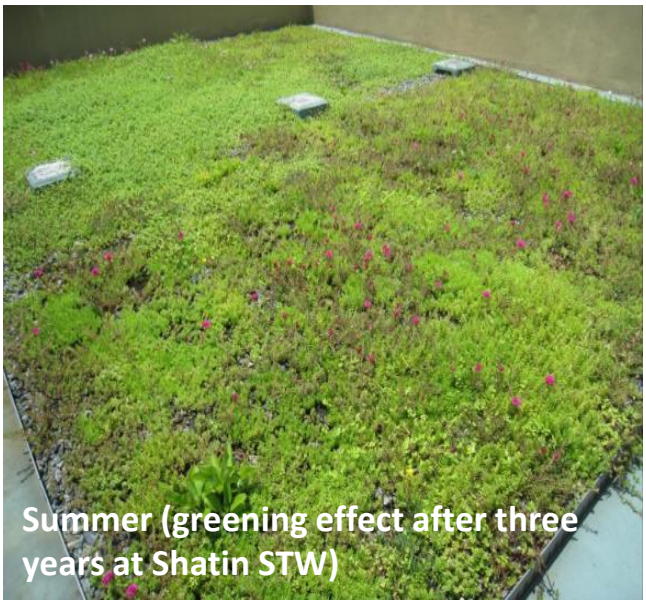
Fig. 6.2 - 3 shows some typical features of green roofs for ecological purpose (e.g. brown roofs for unmanned sites):

i) Minimum soil depth of 150mm for self-colonization by self-seeded plants/native species;
ii) Automatic sprinkler/drip irrigation system or water points;
iii) Sufficient roof drains and inspection chambers;
iv) Setback (~500mm) from exhaust fan/installation of screens (for retrofitting facilities);
v) Proper maintenance access;
vi) Sturdy parapet wall and railing; and
vii) Proper staircase to the green roof.

For ecological purpose, recycled materials such as wood logs and bricks may be used to install bird houses to encourage nesting of birds and other local fauna, while the soil may be seeded/planted with native species/wild flowers/grass or left to self-colonization by local flora.

VCAB Compliance Checklist Item 6: Green Roof/Planting on Structures General (6.2)

Figure 6.2 - 4



For construction site offices, retrofitting roofs with limited loading allowance and unmanned sites in less sensitive locations, low maintenance proprietary green roof system (with structural loading requirement of 0.5kpa) with a mix of succulent species is recommended.

Fig. 6.2 - 4 shows a low maintenance proprietary green roof system with:
-thin layers of well-drained soil substrate (i.e. geotextile, water retention mat, vegetation mat and stone aggregate) tailor-made for succulent plants;
-a mix of hardy, highly adaptive, self-seeded succulent species (e.g. *Sedum lineare*, *Sedum sarmentosum*, *Lavender Scallop, Portulaca oleracea, Portulaca grandiflora,* etc.*), which* perform well throughout the year under local climate. *Sedum sarmentosum* and *Portulaca grandiflora* perform better;
-some species that may turn brown in winter but will grow green again in spring; and
-minimum horticultural maintenance requirements in terms of weeding, fertilization, pruning and irrigation after establishment.

VCAB Compliance Checklist Item 6: Green Roof/Planting on Structures General (6.2)

Detailed green roof design will help avoid problems.

Fig. 6.2 - 5 to 7
For green roof type ii) Beautification and aesthetic purpose, planter edge/physical divider can help define the pattern and facilitate maintenance works.

All green roofs in Fig. 6.2 - 5 to 7 have complex geometric pattern, but that in Fig. 6.2 - 5 will require more frequent weeding because without the dividing strip, plant roots will spread into adjacent flowerbeds and develop there as weeds, altering the original pattern and have to be removed.

Figure 6.2 – 5

Figure 6.2 - 6

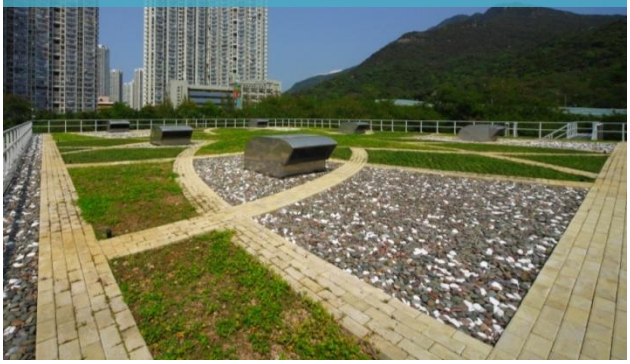


Figure 6.2 - 7

Figure 6.2 - 8

Figure 6.2 - 9

Fig. 6.2 - 8 & 9
Sharp corners of skylights on the timber deck may cause accidents. A buffer between the maintenance path and skylights may help reduce the risk.

Fig. 6.2 - 10
Installation of the fall arrest system on the timber deck should be avoided as it is inconspicuous and may pose tripping hazard.

Figure 6.2 - 10

VCAB Compliance Checklist Item 6: Green Roof/Planting on Structures
Soil depth/loading (6.3)

Figure 6. 3 - 1a

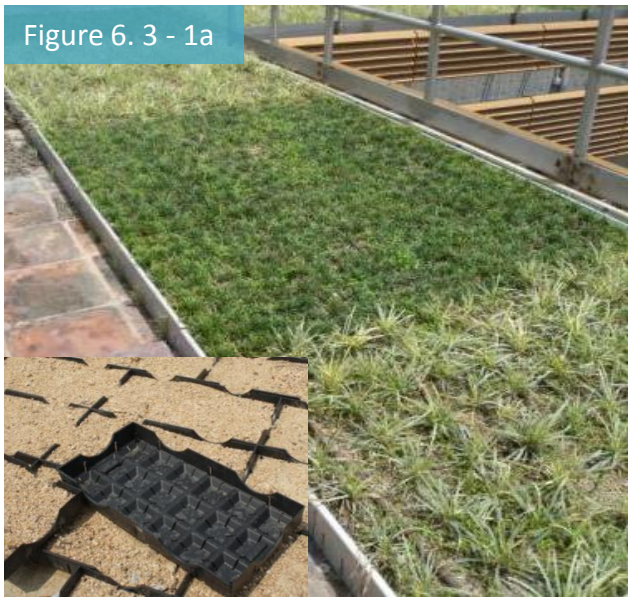


Figure 6.3 - 1b

For retrofitting of roofs with limited loading allowance:
Shallow portable planter trays with limited soil depth (75mm or less) as shown in Fig. 6.3 - 1a and 1b are not recommended as they limit plant growth and require regular irrigation.

- These green roofs have been handed over to DSD for less than six months, but the irrigation systems have been shut down for several times due to various reasons and the plants died.

Remarks:

- **Planter trays with shallow soil depth** (i.e. 75mm or less) **should not be used for a green roof system** . As most DSD facilities are unmanned with weekly inspection, plants in shallow soil may die within one or two days if the automatic irrigation system fails. If loading is the concern, low maintenance proprietary green roof system with a mix of succulent plants should be considered.

VCAB Compliance Checklist Item 6: Green Roof/Planting on Structures
Roof/structure gradient and drainage (6.6)

Figure 6.6 - 1a

Figure 6.6 - 1b

Figure 6.6 - 1c

Fig. 6.6 - 1a to 1c

Failure cases of green roofs

- Waterlogging which causes plants to die is one of the major problems in green roofs.

Possible causes:

- Insufficient roof drains/roof gradient less than 2%;
- Very complex roof pattern which slows down the water flow/lengthens the drainage path;
- Use of wrong materials. For example, horticultural rock wool is used to form the water retention layer to hold water and drain away excessive water. However, if insulation rock wool (looks similar to horticultural rock wool but is water impermeable) is used, water will be trapped in soil;
- Improper workmanship; and
- Blockage of drainage inlets.

Suggestions for improvement:

1. Sufficient roof drains shall be included at the design stage. Secondary drains (surface drains/overflow drains) other than subsoil drains shall be provided in the green roof.
2. Compliance check and water test shall be carried out at the submission stage.
3. Water test shall be conducted prior to backfilling of planting areas.
4. Close monitoring shall be undertaken during the green roof installation.
5. Inspection chambers of drainage outlets shall be installed.
6. Regular checking and cleaning of inspection chambers shall be carried out.

VCAB Compliance Checklist Item 6: Green Roof/Planting on Structures
Roof/structure gradient and drainage (6.6)

Figure 6.6 - 2

Fig. 6.6 - 2
- Gravel smaller than the inspection chamber slot may fill up the chamber and block the drain.

Figure 6.6 - 3

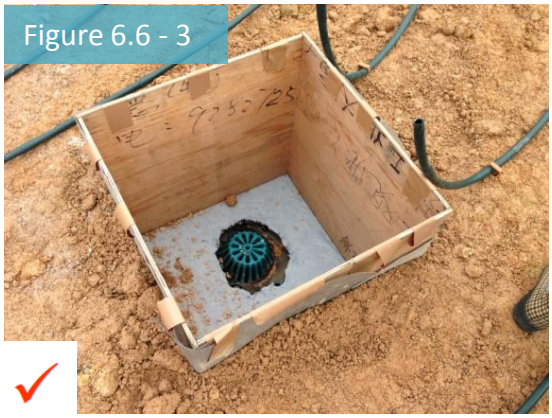


Figure 6.6 - 4

Fig. 6.6 - 3 & 4
- Both figures illustrate the proper installation of a filter membrane between the soil and the inspection chamber.

Figure 6.6 - 5

Figure 6.6 - 6

Fig. 6.6 - 5 & 6
- Owing to insufficient roof gradient and complicated layout design, standing water was observed a few days after rainfall.
- Recommendation: Simplify the layout of green roof planters.

VCAB Compliance Checklist Item 6: Green Roof/Planting on Structures Irrigation (6.7)

Figure 6.7 - 1

Remarks:
For each green roof,

- **independent water sources** should be provided for manual watering in case the automatic irrigation system fails; and
- **effective alert system should be installed and connected to the plant room with resident staff/regional office** to monitor the irrigation system.

Fig. 6.7 - 1 to 3:

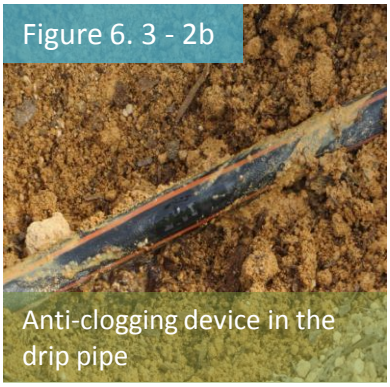
- **Water conservation measures,** i.e. proprietary green roof system to sustain the green roof just with rainfall (Fig. 6.7 - 1, the proprietary green roof system installed at the Water Supplies Department's plant room next to Shatin STW); sub-surface automatic drip irrigation system (Fig. 6.7 - 2a to 2c); rain sensor (Fig. 6.7 - 3) and rainwater harvesting should be considered.

Figure 6. 7 - 2a

Sub-surface automatic drip irrigation system can conserve water as water loss by evaporation is reduced and plant roots can absorb the water at sub-surface directly.

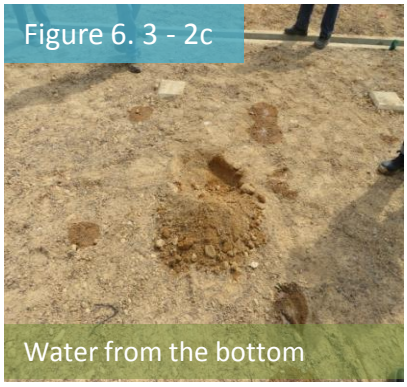
Figure 6.7 - 3

Figure 6. 3 - 2b



Anti-clogging device in the drip pipe

Figure 6. 3 - 2c



Water from the bottom

VCAB Compliance Checklist Item 6: Green Roof/Planting on Structures
Pitch roof (6.11)

Figure 6.11 - 1a

Figure 6.11 - 1b

Fig. 6.11 - 1a & 1b
Case study of pitch roof without erosion control
Observation: Soil was eroded by a heavy rainstorm.
Possible causes: Roof gradient over 45 degrees; no soil erosion control; and insufficient drains.

Fig. 6.11 - 2a & 2b
Mitigation measures: The roof was flattened to around 35 to 40 degrees in gradient. A modular grid/cell planting system was installed and additional drains were provided.

Figure 6.11 - 2a

Figure 6.11 - 2b

Recommendations:

-Pitch roof with gradient exceeding 30 degrees is not recommended due to significantly limited accessibility for maintenance.

-Pitch roof with hydroseeding/ground cover/shrubs cannot provide initial soil protection, i.e. the soil may be carried away by heavy rain before the plant root system is established. Additional shear barrier is required and the soil substrate shall be protected from erosion. Longer establishment period (24 months) shall be allowed.

VCAB Compliance Checklist Item 6: Green Roof/Planting on Structures
Pitch roof (6.11)

Figure 6.11 -3

Fig. 6.11 - 3
Initial soil protection is important for pitch/curve roofs. Turf with rapid establishment/pre-cultivated vegetation mat is recommended.

A railing/parapet wall/fall arrest system should be installed at pitch roofs to ensure safety operation of maintenance works.

VCAB Compliance Checklist Item 6: Green Roof/Planting on Structures
Pitch roof (6.11)

Figure 6.11 - 4

Fig. 6.11 - 4
Proper maintenance access (staircase) and safety device (railings) are provided at this pitch roof for neccessary regular inspection and horticultural maintenance works such as drainage inspection and pruning.

Figure 6.11 - 5

Fig. 6.11 - 5
Without proper maintenance access (e.g. staircase) and safety device (e.g. railing) for these terraced planters, no proper maintenance works could be carried out and many plants died.

VCAB Compliance Checklist Item 7: Vertical Greening (VG)
Maintenance requirements (7.11)

Figure 7.11 - 1a

Figure 7.11 - 1c

Self-climbing plants/climbers with supporting wire mesh/guide wire/cable are more preferred than the modular vertical greening (VG) system.

Figure 7.11 - 1b

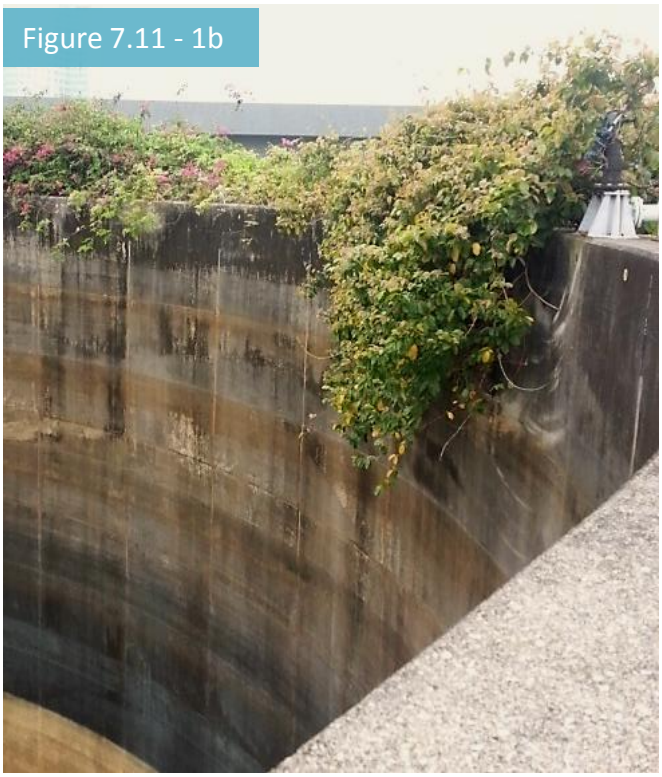


Fig. 7.11 - 1a & 1b
Periodic pruning is required for VG due to various reasons, e.g. clumps of climbing plants may detach from the wall and fall down after strong wind; broken branches of climbers may fall into the sedimentation tank and affect the sewage treatment process, etc. Therefore, maintenance access for VG should be provided.

Fig. 7.11 - 1c & 1d show climbers at inaccessible locations, requiring setting up of elevated platform/scaffolding.
Fig. 7.11 - 1e
For VG with maintenance access, mobile crane can be used for pruning.

Remarks: Appropriate recurrent cost (RC) should be earmarked at the funding stage for maintenance of VG.

Figure 7.11 - 1d

Figure 7.11 - 1e

VCAB Compliance Checklist Item 7: Vertical Greening (VG)
Maintenance requirements (7.11)

Figure 7.11 - 2a

Figure 7.11 - 2b

Fig. 7.11 - 2a & 2b

The modular proprietary VG system requires high initial installation and maintenance cost and is therefore rarely recommended.

If proposed, i) proper RC should be earmarked at the funding stage for future maintenance works; ii) low maintenance proprietary system should be adopted; iii) hardy plants should be selected; iv) automatic irrigation and proper drainage should be provided; and v) hard paved maintenance access should be used to set up elevated platform for plant replacement/pruning/inspection works.