

Bank of Green Roofs in Drainage Services Department

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Abstract:

In a congested and densely populated city like Hong Kong, there is a pressing need to carry out more greening works to attenuate the urban heat island effect. However, the conventional at-grade planting works are often limited by the presence of existing utilities. As an alternative, greening of the under-utilized roof areas in buildings (i.e. green roof) is one of the feasible options. Green roofs can filter fine air particulate and absorb greenhouse gases to improve the air quality, bringing significant aesthetic and ecological benefits to the surroundings and nearby residents. “Bank of Green Roofs” (天台綠化銀行) has been established in Drainage Services Department (DSD) recently. It consists of both technical details and cost data for carrying out green roof projects in DSD. This paper introduces 10 keys for successful implementation of green roofs projects. It also highlights unit cost data for green roof (\$/m²), staircase (\$/m in height), railing (\$/m in length), etc. It is hoped that these technical details and cost data will serve as useful reference to the professionals, academics and the general public who would like to carry out green roofs to their premises, contributing to a better and sustainable environment in Hong Kong.

Keywords:

Bank of Green Roofs, 10 Keys, Unit Cost Data, Knowledge Sharing

INTRODUCTION

Pursuing sustainable development and improvement to the environment, Drainage Services Department (DSD) has been paying a lot of efforts in carrying out greening works to the drainage and sewage treatment facilities. However, the conventional at-grade planting is often limited by the presence of existing utilities including the manhole and drawpit covers. There is not much difference at pumping stations and sewage treatment works. To overcome such constraints, DSD has explored green roofs as one of the alternative greening methods. It makes use of the under-utilized roof efficiently and provides an extensive greenery on roof rather than the piecemeal planting areas at-grade. **Figure 1** shows the great contrast before and after retrofitting of green roof at Air Blower House of Sha Tin Sewage Treatment Works, which brings significant aesthetic enhancement to the environment.



Figure 1 : Before and After Retrofitting of Green Roof at Sha Tin Sewage Treatment Works

The benefits of green roofs are numerous! For instance, they provide cooling effect to combat urban heat island effect and lowers the indoor temperature and hence save energy consumption inside the building. Besides, green roofs can filter fine air particulate and absorb greenhouse gases to improve air quality. Furthermore, they can bring significant aesthetic and ecological benefits to the surroundings and nearby residents.

The aesthetic merits of carrying out green roofs at pumping stations and sewage treatment works are more significant since they are low-rise buildings, meaning that the beautified roof areas could easily be seen and enjoyed by the general public in the nearby high-rise buildings. **Figure 2** shows the visually attractive green roof at Ma On Shan Sewage Pumping Station, which is adjacent to the high-rise residential buildings of Heng On Estate.

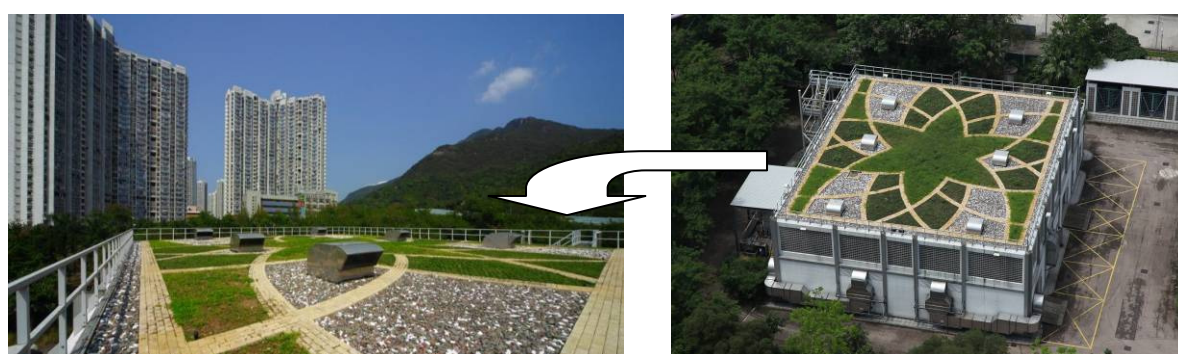


Figure 2 : Green Roof adjacent to High-rise Buildings of Heng On Estate, Ma On Shan

TYPES OF GREEN ROOFS

In general, there are two types of green roofs, namely intensive green roofs and extensive green roofs. Intensive green roofs contain a thicker soil growing medium and hence a wider variety of plants including trees could be planted on. However, they are heavier and may be limited by the loading capacity of the existing roof structure. Also, they require more horticultural efforts during routine inspection and maintenance. In comparison, extensive green roofs contain a thinner layer of soil growing medium and are lighter than the intensive green roofs. This enhances the feasibility for retrofitting into existing roofs. At present, the green roofs constructed by DSD are extensive green roofs. **Figure 3** shows typical extensive green roofs at Tseung Kwan O Preliminary Treatment Works.



Figure 3 : Extensive Green Roofs at Tseung Kwan O Preliminary Treatment Works

10 KEYS FOR IMPLEMENTATION OF GREEN ROOFS

Since 2009, a number of green roofs projects have been carried out on trial-basis to verify the technical aspects such as the planning, design, construction and maintenance of green roofs. At present, the technical aspects are quite well addressed. To promote knowledge sharing, DSD is glad to present 10 keys for implementation of green roofs as follows:

Key 1



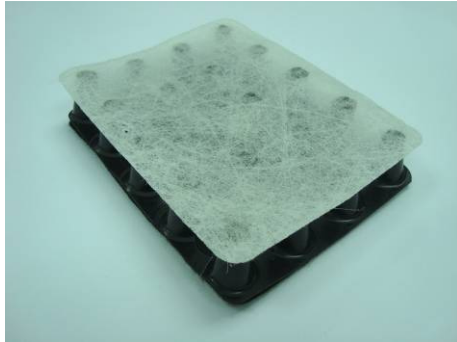
Carry out structural assessment to ensure the roof slab, beams, etc. could resist the additional loading. Inspect the existing drainage and waterproof and carry out necessary repair works prior to the construction of green roof.

Key 2



Install root barrier (high density polyethylene, bitumen resistant and resistant to UV light) to prevent root penetration. Allow sufficient overlap between any two rows of root barriers with welding.

Key 3



Install drainage composite to drain off subsurface flow to prevent water ponding and mosquito breeding.

Key 4



Lay water retention mat with capacity of minimum 5 litres/m² to supplement water to the roots of the plants.

Key 5



Provide suitable growing medium with minimum 150mm thick soil mix. Provide 10mm mulching on top.

Key 6



Select suitable plant species which could adapt to Hong Kong's weather with low maintenance requirement.

Key 7



Install pebbles channel and drainage inspection chamber to facilitate daily inspection and maintenance.

Key 8



Provide irrigation system with fully automated sprinklers and field sensors to monitor the soil moisture.

Key 9



Construct access pathway to prevent stepping on the plants. Install railings around the roof edge for safety reason.

Key 10



Erect new staircase to replace any existing cat ladder to facilitate safe and convenient access to roof.

Figure 4 : 10 Keys for Implementation of Green Roofs

UNIT COST DATA

There are many researches and papers discussing the benefits of green roofs. However, the cost aspects of green roofs are seldom covered in details. To a certain extent, this limits the wide application of green roofs as the budget could not be worked out easily.

In order to obtain well-analyzed, readily available and user-friendly cost data for the green roofs, DSD takes the initiative to establish the Bank of Green Roofs which contains comprehensive cost data of green roofs. The unit cost is derived upon analysis of the Bills of Quantities of a total of 15 greening projects of DSD from 2009 to 2012. Taking into account the price adjustment/inflation over the past few years (i.e. 3.1% for 2009, 2.9% for 2010, 5.7% for 2011 and tentative 7% for 2012), all the cost data has been adjusted to September 2012 price level.

As some projects contain more than one green roof, the total number of green roofs analyzed is over 30. The total number of staircases examined is over 20. The total length of railings involved is over 1,000m. With such large batch of data, the analyzed unit cost is considered to be comprehensive, representative and convincing enough.

Basic Elements of Green Roof

The cost for the basic elements of green roof includes the cost of root barrier, drainage composite, drain pipes, drainage inspection chambers, water retention mat (5mm thick geotextile), soil mix (150mm thick), plants, paving, pebbles, etc. It is expressed in unit cost per square meter of green roof (i.e. \$/m²). For ease of reference, the unit cost data for basic elements of green roof is presented in the size of small, medium and large, which corresponds to the area of a volleyball court, basketball court and swimming pool respectively. It could be seen from **Table 1** that green roofs of smaller area have higher unit cost.

Size of Green Roof	Area of Green Roof (m²)	Reference Size	Unit Cost for Basic Elements of Green Roofs (Sep 2012 Price Level) (\$/m²)
Small	up to 200	Volleyball Court (18m x 9m = 162m ²)	967
Medium	201 to 400	Basketball Court (28m x 15m = 420m ²)	782
Large	401 to 1500	Swimming Pool (50m x 25m = 1250m ²)	777

Table 1 : Unit Cost for Basic Elements of Green Roof

Staircases

Some roofs are inaccessible or difficult to be accessed (e.g. by cat ladder). To suit operational and maintenance requirements, staircase will need to be provided for access to the green roof. The staircase is made of fiber-glass reinforced plastic (FRP) material. FRP is adopted due to its light-weight but relatively high-strength properties. Since the staircase is not a substantial structure, its footing including any foundation is also minimal. This greatly enhances its constructability. Upon analysis of the cost data, it is found that the higher the staircase, the higher the construction cost. The unit cost for FRP staircases is expressed in unit cost per meter in height (i.e. \$/m) as shown on **Table 2**:

Height of Staircase (m)	Unit Cost for FRP Staircases (Sep 2012 Price Level) (\$/m in height)
Up to 2.0	26,669
2.1 to 4.0	32,936
4.1 to 6.0	44,306

Table 2 : Unit Cost for FRP Staircases

Railings

For safety reasons, railings shall be installed around the edge of the roof (if parapet walls or railings are not in existence) to prevent people from falling at height. For some cases, there are existing parapet walls (approx. 0.5m high) which are not high enough (min. 1.1m). Hence, additional railings (approx. 0.6m high) shall be installed on top of such parapet walls.

For the material of the railings, FRP is adopted due to its light-weight but relatively high-strength properties. The unit cost of FRP railing is expressed in unit cost per meter run (i.e. \$/m) as shown on **Table 3**:

Height of Railing (m)	Unit Cost for FRP Railings (Sep 2012 Price Level) (\$/m in length)
Up to 0.6	1,067
0.6 to 1.1	1,288

Table 3 : Unit Cost for FRP Railings

Irrigation System

A site with or without readily available water point may affect significantly the cost of irrigation system for the green roof. If additional pumping facilities, water tanks, pipeworks, etc. are needed, the cost of irrigation system may increase sharply. From the cost data, it is noted that the irrigation cost varies widely amongst the projects under examination. This may be due to contractors' different understanding on the site condition and different pricing strategies in their tenders. For the completeness of this paper, the unit cost of irrigation system, expressed in cost per square meter of green roof area (i.e. \$/m²) at September 2012 price level, is calculated and found to be in the wide range from \$78/m² to \$486/m². Collection of more data from upcoming projects is recommended for further analysis of the unit cost of irrigation system.

Establishment Works

As part of the contractual requirements under the greening contract, the landscaping contractor is required to carry out establishment works for a period of 12 months after the completion of green roofs. The establishment works include regular inspections, cultivations, fertilizing and other operations. From the cost data, it is noted that the cost of establishment works varies widely amongst the projects under examination. This may be due to the fact that the contractors have limited experience in knowing DSD's requirement for the establishment works of green roofs, which are new to them, and hence they adopted different pricing strategies in their tenders. For the completeness of this paper, the unit cost of establishment works, expressed in cost per month per square meter of green roof area (i.e. \$/month/m²) at September 2012 price level, is calculated and found to be in the wide range from \$2.9/month/m² to \$20.7/month/m². Collection of more data from upcoming projects is recommended for further analysis of the unit cost of establishment works.

DISCUSSION

Bank of Green Roofs

Bank of Green Roofs comprises both technical details and cost data for carrying out green roof projects in DSD. With the "10 Keys for Implementation of Green Roofs", engineers will know more about the technical details in carrying out green roof projects. For the unit cost data, the capital cost for green roofs are now available for reference in preparing cost estimate. As the green roofs in DSD have just been completed for two to three years only, there is limited data to assess the recurrent cost. However, DSD has been collecting more data on the horticultural and maintenance works of green roofs and will prepare recurrent unit cost data in future.

New DSD Standard Drawings for Green Roof

Since green roofs are relatively new greening technologies, many engineers may not have such hands-on design experience. They may find it quite difficult to work out the design and may need to spend a lot of time in finding out the relevant details from the research papers and reports. As engineers used to make reference to standard drawings, DSD is planning to promulgate a new series of DSD Standard Drawings to specify the relevant details of green roofs. Undoubtedly, the use of Standard Drawings has several merits.

First, all designers will adopt the same latest design standards for green roofs. The chance of adopting obsolete or imperfect details is much reduced. This safeguards the quality of roof greening works. The use of standardized design will also reduce long term maintenance efforts and costs.

Second, the Standard Drawings for green roofs will be subject to regular review. Any refinements to the standard details will be incorporated and promulgated in the revised drawings. As time goes by, valuable experience towards green roofs will be accumulated. This facilitates a continuous improvement to greening standard.

Third, DSD Standard Drawings are free for download at internet. All interested parties such as engineers, academics, other professionals, students, the general public, etc. could access the technical details of green roof freely and quickly. This facilitates knowledge sharing and promotes a wider application of green roofs.

The proposed list of DSD Standard Drawings is as follows:

Proposed Drawing No.	Drawing Title
DS xxx1	Green Roofs – General Notes
DS xxx2	Green Roofs – Typical Cross Section
DS xxx3	Green Roofs – Standard Planting Schedule and Photos for Common Species
DS xxx4	Green Roofs – Drainage Details
DS xxx5	Green Roofs – Irrigation System
DS xxx6	Green Roofs – Maintenance Pathway
DS xxx7	Green Roofs – Access Staircase and Peripheral Railing
DS xxx8	Green Roofs – Miscellaneous Details

Table 4 : Proposed List of DSD Standard Drawings for Green Roofs

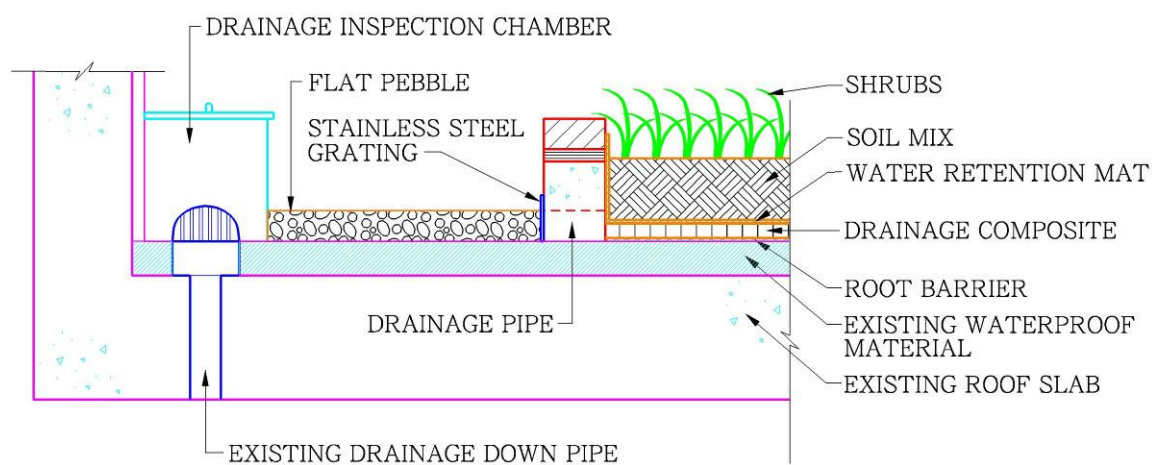
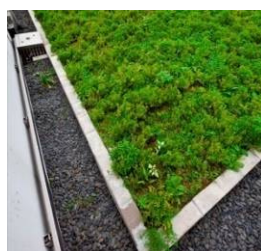


Figure 5 : Proposed Standard Drawing – Typical Cross Section of Green Roof

Standard Drawings are used to be presented in black and white. As an “innovative” measure, DSD will promulgate the first series of “Coloured” DSD Standard Drawings for the recommended common species of green roof suitable for Hong Kong’s weather condition. This is a DSD’s breakthrough! With coloured photos, the species for green roof could be identified quickly and precisely. Also, as the scientific names of the species (written in Latin) are quite difficult to remember, the common name and the chinese name of the species will be cited together to facilitate communication.



紅莧草
Alternanthera
paronychioides
'Picta'
(Red Smooth
Joyweed)



綠莧草
Alternanthera
paronychioides
(Smooth Joyweed)



花葉沿階草
Ophiopogon jaburan
(Jaburan Lily-turf)



腎蕨
Nephrolepis auriculata
(Sword Fern)

Figure 6 : Proposed “Coloured” Standard Drawing – Green Roof Common Species

Knowledge Sharing

Over the years, DSD has been actively promoting the advanced greening knowledge to the practicing engineers and academics alike. This is demonstrated by DSD’s enthusiasm in delivering technical presentations to the engineering professionals on the innovative greening technology including green roofs at various occasions, such as New Horizon in Greening Seminar at Central Library on 10 December 2010, Green Groups Forum at Sha Tin Sewage

Treatment Works on 10 November 2011, Skyrise Greenery Seminar at Science Museum on 8 May 2012, HKIE Technical Seminar at HKIE Headquarters Seminar Room on 26 July 2012, etc.



Figure 7 : Knowledge Sharing at Central Library, Sha Tin Sewage Treatment Works, Science Museum and HKIE Headquarters Seminar Room

CONCLUSION

“Bank of Green Roofs” equips engineers, academics and the general public’s knowledge towards the technical details and cost data of green roofs in DSD. Together with the 10 keys for implementation of green roofs, the proposed DSD Standard Drawings will facilitate wider application of green roofs. The cost data bank is simple and easy to use! It could serve as a reference to those who are interested in carrying out green roofs. Supporting sustainable development, DSD is devoted to carrying out more greening works to its drainage and sewerage facilities. When more and more green roofs are implemented in a highly congested city like Hong Kong, the urban heat island effect will be alleviated and the quality of our living environment will be enhanced!

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