Driving Innovations for Green Infrastructure Components

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ABSTRACT

Hong Kong Housing Authority is responsible for producing and managing one of the world's largest public rental housing programmes, helping low-income families gain access to adequate and affordable quality housing. Over the decades, we have been planning, designing and building to drive and deliver a long term green and sustainable development for public housing in Hong Kong.

To drive innovations for green infrastructure components, we focused our research effort on maximizing greening opportunities and water conservation in landscape irrigation. This Paper focuses on the following research topics:

- Sustainable planting system for roof greening
- Cost effective vertical greening system
- Rain water harvesting system with bio-retention mechanism
- Root zone irrigation system for ground cover and shrubs
- Zero irrigation system (ZIS) for ground cover, shrubs and small trees

We have put on trial the above research topics in some pilot projects with encouraging results, particularly for ZIS, which is a self-sustained and passive design to deliver water to the vegetation and minimize topsoil evaporation through capillary action. It aims at harvesting the rainwater directly underneath the planting areas for irrigating purpose. It also provides a sustainable urban drainage system by reducing and deferring the volume of storm water entering the sewer system and to restore the natural hydrologic cycle. ZIS is also found more efficient in water conservation and less mechanical part for maintenance when compared with Rainwater Harvesting System or Root Zone Irrigation System. In the trial project, the water consumption of planter with ZIS was monitored over 24 months and no potable manual watering was required.

With the fruitful and promising research result in hand, our ultimate goal is to share the knowledge for the benefit of the society so as to achieve a sustainable green infrastructure, improve living environment, enhance human comfort and contribute to management of natural resources.

Keywords: *water conservation, zero irrigation system, affordable quality housing*

1. INTRODUCTION

Hong Kong Housing Authority aims at providing affordable quality housing in a proactive and caring manner, by using public resources effectively. Over the decades, we have been planning, designing and building to drive and deliver a long term green and sustainable development for public housing in Hong Kong.

To drive innovations for green infrastructure components (Greening, Landscape & Tree Management Section, Development Bureau, 2016), we pioneer in conducting studies on "Green Infrastructure Components" since 2008. We have been working on different greening studies to achieve a more sustainable and cost effective ways for maintenance of green roofs and vertical greening systems.

Besides our greening efforts, as fresh and clean water is a limited and precious resource in the world, we also launched initiatives for water conservation by reusing or recycling water where possible. In recent years, we focused our research effort on water conservation in landscape irrigation. These include rainwater harvest system, root zone irrigation system and Zero Irrigation System (ZIS).

Researches conducting for various green infrastructure components include the followings (Yim, 2015):

- Sustainable planting system for roof greening
- Cost effective vertical greening system
- Rain water harvesting system with bio-retention mechanism
- Root zone irrigation system for ground cover and shrubs
- Zero irrigation system (ZIS) for ground cover, shrubs and small trees

2. SUSTAINABLE PLANTING SYSTEM FOR ROOF GREENING

Research was carried out to study the performance of different plants species on green roof in order to establish a low maintenance green roof. We aim to compare the growth performance of two commonly used plant species (Sedum mexicanum and Arachis pintoi) and to test the performance of the system.

The results showed that the growth performance of Arachis pintoi is better than Sedum mexicanum. Arachis pintoi is a fast growing species which is able to provide greening impact quickly. It also has higher Nitrogen-fixing capability and is relatively free from pests and diseases. Therefore, it is easier to maintain. Moreover, it is observed to have a better heat reduction impact compared to Sedum mexicanum (Figure 1). (Hong Kong Housing Authority and C.Y. JIM, 2013)

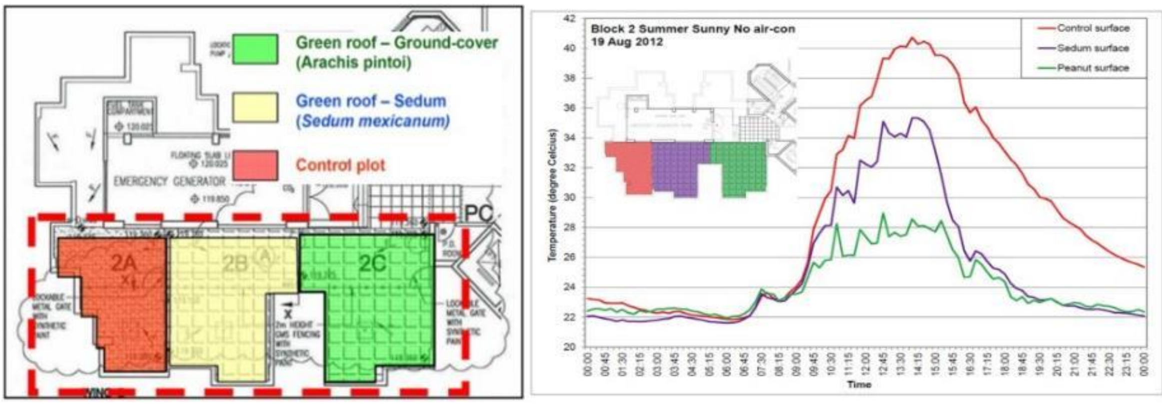

Figure 1: Roof temperature graph

3. COST EFFECTIVE VERTICAL GREENING SYSTEM

In 2010, we carried out a research on heat reduction capacity of vertical greening system and a cost effective way to maintain vertical greening system. The vertical greening system applied in the study is a green panel system. A maximum of 16°C temperature reduction was recorded for a vegetated wall surface.

Research results indicated that the substrate moisture content should be maintained at between 25% to 35% and liquid fertilizers should be applied regularly for duration of six weeks each year, preferably at spring time. From the research, we also found that seven out of nine species tested are suitable for vertical planting. They include Zoysia japonica, Alternanthera versicolor, Axonopus compressus, Cynodon dactylon, Arachis duranensis and Sansevieria trifasciata .

4. RAINWATER HARVESTING SYSTEM WITH BIO-RETENTION MECHANISM

We also studied various landscape irrigation systems for reduction in water consumption. The rainwater harvesting system is developed to collect rainwater and treat rainwater to an acceptable quality for landscape irrigation. Bio-retention treatment measures were selected for water treatment. Bio-retention acts as a self-sufficient system which provides both physical (sedimentation and filtration) and biological (pollutant degradation) treatment. The illustration of bio-retention treatment pond is at Figure 2.

A study was carried out at public housing estate at Shui Cheun O. Five species of plants, namely Pennisetum alopecuroldes, Cyperus papyrus, Miscanthus sinenesis, Tradescantia albiflora and Pteris ensiformis were identified to be suitable for bio-retention. (AECOM, 2014)

Rainwater collected passing through the bio-filtration and physical filtration. The quality of filtered rainwater generally complied with the standard stipulated by the Hong Kong Water Services Department (WSD) except the results on turbidity and colour. The results in the mock up (Figure 3) also indicated that E.coli removal rate was above 97%. Further study would be pursued.

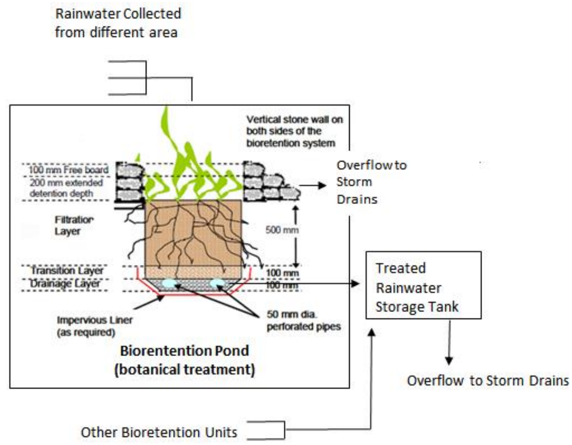

Figure 2: Bio-retention pond

Figure 3: The mock up system

5. ROOT ZONE IRRIGATION SYSTEM FOR GROUND COVER AND SHRUBS

Root zone irrigation system is one of the water conservation irrigation methods we studied recently. Based the pilot scheme of a public housing project in Kai Tak area, this system is able to achieve water saving up to 38% .

The root zone irrigation system consists of polyethylene dripping tubes wrapped with specially designed fleece, which is sewed into two further layers of non-woven fabric to form the Root Zone Irrigation Mat.

The function of the mat is to secure an even distribution of water as well as to prevent sand and other materials from clogging the drip pipes. Irrigation is then performed by the water saturation effect of the mat and resulting capillary action, guiding the water towards the drier part of the soil. The roots of most plants can grow through the mats without changing the irrigation performance of the mat. The irrigation mats are usually installed about 100 to 200 mm below soil surface and can irrigate lawn areas, flower beds and small shrubs.

5.1 The trial study at public housing estate at Kai Tak

A trial system was set up at Kai Tak public housing site to compare the performance of conventional irrigation method (sprinkler system) with that of the root zone irrigation system in terms of water consumption and the growth performance of the plants in 2011.

Two planters of similar sizes were constructed. Six types of vegetation which were commonly adopted in HA's projects were planted. The conditions of the two planters at around the beginning and end of the study are shown in Figure 4 respectively. Planter no. 1 (on left side) was irrigated by the root zone system while planter no. 2 (on right side) served as the control was irrigated manually via a sprinkler system.

Figure 4: Photo of mock up planters taken on 2 Feb 2011 and 5 Jun 2012

Water consumption of the two irrigation methods were logged on a weekly basis from March 2011 to March 2012. The health condition of the plant species was also checked on monthly basis by comparing the conditions of the root growth of the plants in the two planters.

5.2 Findings

5.2.1 Performance of plants growth

A comparison of water consumption and the performance of the plant species were recorded as in Figure 5. No significant difference is observed regarding the performance of the plant species in both planters.

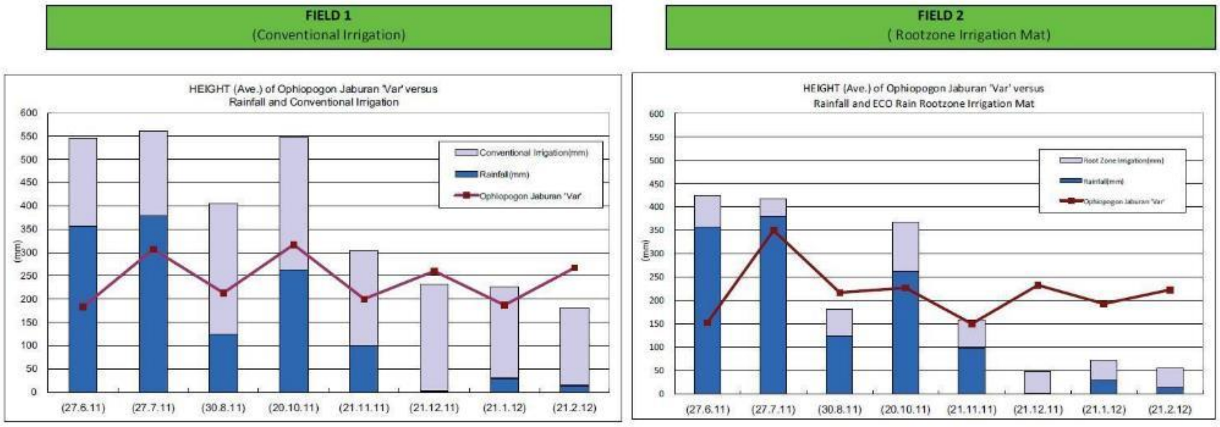

Figure 5: Plant growth monitoring graph

5.2.2 Irrigation water consumption

The average water consumption rates of the planters from 12 May 2011 to 31 March 2012 were 1.54 and 5.7 litre/m^2/day respectively. By comparing with HKHA's latest standard manual irrigation rate of 2.5 litre/m^2/day, root zone irrigation system can maintain the plant growth to the same extent with a water saving potential of approximately 38%.

6. ZERO IRRIGATION SYSTEM (ZIS) FOR GROUND COVER, SHRUBS AND SMALL TREES

Another pioneering study on sub-irrigation method is the Zero Irrigation System (ZIS). There are two design objectives of ZIS. First, it aims to harvest the rainwater directly underneath the planting areas for irrigating purpose so as to minimize the manual irrigation operation and maintenance cost. Second, as it uptakes the storm water, it reduces the storm water run-off and groundwater recharge.

The ultimate goal of ZIS is to achieve zero portable water consumption for irrigation. ZIS offers great potentials for water conservation in landscape irrigation. We have therefore conducted pioneering studies on ZIS with a view to fully realizing such potentials in our new public housing estates. The pioneering studies comprise two separate trials on ZIS, conducted at the public housing estates at Tuen Mun Area 18 in 2013 and Homantin site in 2014 respectively.

6.1 Components of zero irrigation system (ZIS)

ZIS is a sub-irrigation method that water is delivered to the plant root zone from below the soil surface and absorbed upwards through capillary action.

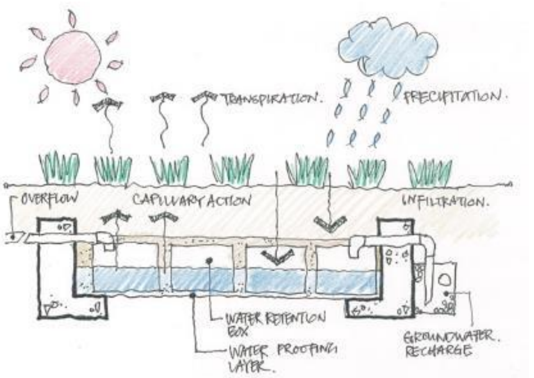

Figure 6: Illustration of zero irrigation system (ZIS)

Figure 7: Construction of ZIS at trial planter

The illustration in Figure 6 indicates how ZIS functions in practice. After rain falls, water is then absorbed into the soil; any excess is collected in special retention boxes under the ground. When the soil above becomes dry, capillary action draws up water from the retention boxes to irrigate the plants in a self-sustaining cycle. In general, as ZIS has less mechanical parts, it operates at lower capital and management costs than other sub-irrigation systems, and can collect and re-use storm water without any hygiene concerns.

6.2 The trial study of ZIS at public housing estate at Tuen Mun Area 18

The objectives of the trial study were focused on the performance of plants growth, the effectiveness of capillary action and water consumption of ZIS. After installation, the trial system was monitored for 24 months since November 2013. The construction of ZIS was illustrated in Figure 7.

6.2.1 Findings

6.2.1.1 Plant growth condition

During the monitoring period, only general horticultural maintenance was carried out; no manual watering was applied. Six types of shrubs which are commonly adopted in HA's project were planted in the trial and they were found well established. No die-back or replacement was recorded.

6.2.1.2 Irrigation water consumption

After an initial infill of water to the system, no further manual watering was applied since 11/2013. The average water consumption was 2.2 litre/m^2/day. The system collected, stored rainwater and delivered the water by itself. The lowest water depth during the driest period was about half of the maximum holding capacity. The record of water level in ZIS planter was in Figure 8.

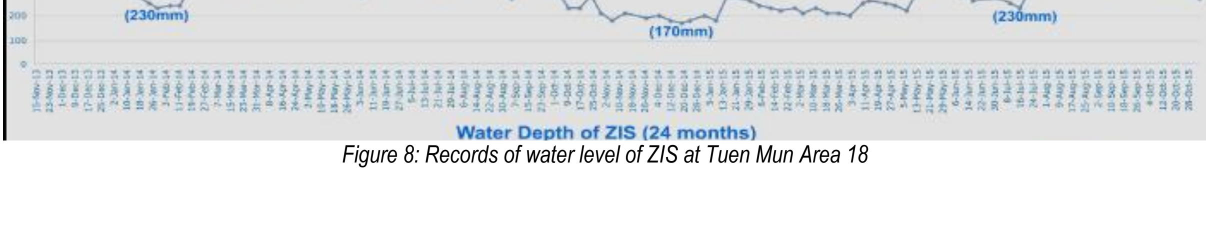

Figure 8: Records of water level of ZIS at Tuen Mun Area 18

6.3 The trial study at Homantin Site

With the success of the trial study at Tuen Mun Area 18, the system is further refined to support tree planting. Another trial ZIS planter with tree planting pit was constructed at Homantin Site. Two tree pits were constructed inside the ZIS planter. The trial system was then monitored for around 21 months since November 2014. The construction of ZIS with tree pits was illustrated in Figure 9.

Figure 9: Construction of ZIS at trial planter at Homantin Site

6.3.1 Findings

6.3.1.1 Plant growth condition

Same as the trial at Tuen Mun Area 18, no manual watering was applied after initial infill. However, one tree was found wilting after 8 months and needed replacement. This may be caused by planting the trees during winter dry season. We also considered that the tree roots required more time for establishment to take up water from the ZIS. Therefore, we recommended planting the tree during wet season and providing first month manual irrigation for the tree roots to establish.

6.3.1.2 Irrigation water consumption

In the trial study, the water consumption was 1.4 litre/m^2/day. Same as the trial at Tuen Mun Area 18, the lowest water depth during the driest period maintained at half of the maximum holding capacity (Figure 10).

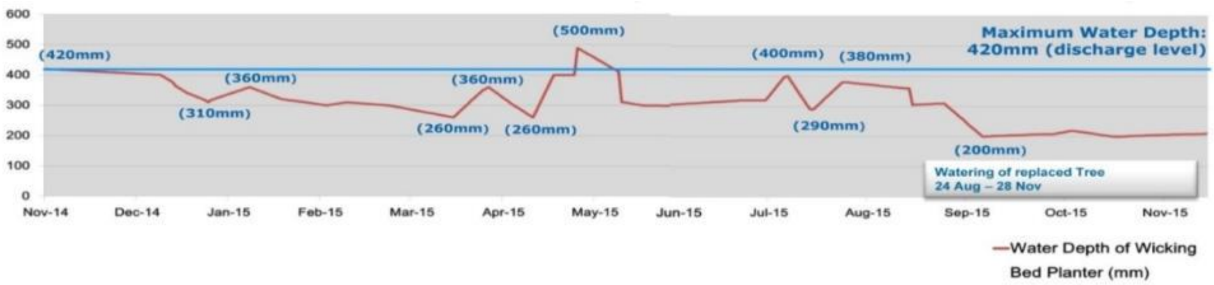

Figure 10: Records of water level of ZIS at Homantin Site

6.4 Benefits and limitations

ZIS is an effective, self-sustained sub-irrigation planting system. The evaporation rate of irrigation water is greatly reduced. No manual watering is required to supplement the water stored in the retention cells. The system also serves as an effective system in reducing storm water run-off. The water consumption records indicated the system performed satisfactorily under both wet and dry seasons.

However, the ZIS system is not suitable for planters on slopes or with complicated underground utilities as the retention boxes should be laid at same level for water storage.

7. CONCLUSION

The ultimate goal of this paper is to share our knowledge and experience in applying the innovations or initiatives on green infrastructure components for the benefit of the society so as to achieve sustainable green infrastructure, provide better living environment, enhance human comfort and contribute to management of natural resources. All these promising results of the pilot studies on green and water management provide a firm keystone for us to plan the green infrastructure and to provide a better and a more sustainable green environment.

Among the various innovative studies, the Zero Irrigation System is the most effective sub-irrigation system for water saving and storm water management. We have been very encouraged by the result of the ZIS trial, which has proved effective both in saving water and reducing the manpower resources required for maintenance. ZIS has great potential for extensive application in new estates, and we are now conducting further research study with the aim of refining the design and reducing construction time and costs through modularisation.

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