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A Review on the Development and Challenges of Green Roof Systems in Malaysia

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***Abstract*—**Green roof system is considered a relatively new concept in Malaysia even though it has been implemented widely in the developed countries. Generally, green roofs provide many benefits such as enhancing aesthetical quality of the built environment, reduce urban heat island effect, reduce energy consumption, improve stormwater attenuation, and reduce noise pollution. A better understanding on the implementation of green roof system in Malaysia is crucial, as Malaysia's climate is different if compared with the climate in temperate countries where most of the green roof studies have been conducted. This study has concentrated on the technical aspect of green roof system which focuses on i) types of plants and method of planting; ii) engineering design for green roof system; iii) its hydrological performance on reducing stormwater runoff; and iv) benefits of green roofs with respect to energy. Literature review has been conducted to identify the development and obstacles associated with green roofs systems in Malaysia. The study had identified the challenges and potentials of green roofs development in Malaysia. This study also provided the recommendations on standard design and strategies on the implementation of green roofs in Malaysia in the near future.

***Keywords*—**Engineering design, green roof, sustainable development, tropical countries.

I. Introduction

DEPLETING natural resources has appealed to sustainable developments at many countries around the world in the recent decades. Technologies or innovations which conserve the environment are gradually emerging as alternatives to mitigate consequences of climate change and rapid urbanizations. In the recent years, Malaysia is moving rapidly towards high income nation. In 2012, a study showed that Kuala Lumpur's green areas have been reduced to 59.4% or 14,386 hectare from its original 24,222 hectare of city area [1]. The level of urbanization is rising and expected to reach 83% in 2030 [2]. This showed that the urbanization process had affected the Kuala Lumpur's green areas, thus creating many environmental problems and creating high demand for its urban green spaces [3].

Development entity such as street, driveways, as well as building have been replacing forests, grassland, tree and others that will cause increasing volume of storm water runoff, diminishing ground water recharge, river erosion as well as enhancing stream channel [4]. As additional impervious surface are created, there is an increase in storm water runoff and anthropogenic pollutant that are responsible for urban aquatic environmental problems [5]. Quantity and quality control at source in urban is one of main approach in storm water management [6].

In urban, a space is limited and fully occupied with building and infrastructures. In recent development, vegetated or green roofs that used engineered growing media, area drought-tolerant plants and specialized roofing material are developed to be installed on existing or new structure [5]. These roofs not only become a mitigation strategy of storm water runoff but it also gives other various benefits [7]. However, many consider storm water runoff mitigation to be the primary benefits of green roofs due to prevalence of impervious surface in urban and commercial areas and failing storm water management infrastructure [8].

II. Green Roof Concept

Green roofs are made of a system of manufactured layers deliberately placed over roofing structures which support growing medium and vegetation. Green roof can be divided to two types which are extensive and intensive systems. The differences between extensive and intensive green roof systems are summarized in Table I. Extensive green roofs are light and covered by a thin layer of vegetation meanwhile intensive green roof which is heavier and can support small trees and shrubs. In addition, intensive green roofs normally known as roof garden that can be built on the roofs of building that are strong enough to support additional load. Extensive green roofs consist of a substrate layer with a maximum depth of about 150mm which including vegetable and plant [9]. Fig. 1 shows the structure of a green roof system.

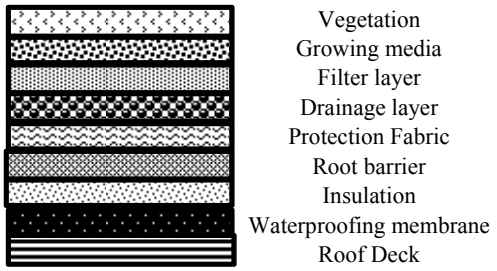


Fig. 1 Structure of green roof system

The vegetation in the green roofs can generate evapotranspiration, and the resultant humidification and air cooling will, in turn, reduce the heat island effect. In urban areas, this effect increase night temperature in the heart of city [11]. Heat island occur due to various factor for example increased number of paved, built over and hard surfaces areas, the reduction of evaporating surfaces, the insufficient of

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vegetation cover and less cooling due to shelter from building. The heat island effect will increase the energy consumption for air conditioners and also increase the production rate of air pollutant. Unlike building materials such as concrete and asphalt which raises the local temperature by reflecting the radiated solar energy, green roofs can reduce the amount of radiated heat by absorbing and deflecting the solar radiation Therefore, green roofs are considered as an effective measure to mitigate urban island effect in cities without using up valuable space [12].

TABLE I
DIFFERENCES BETWEEN EXTENSIVE AND INTENSIVE GREEN ROOFS [10]

Intensive Green Roof	Extensive Green Roof
• Require intensive maintenance	• Require extensive maintenance
• Accessible	• Inaccessible
• Require deeper substrate (min 15 cm)	• Require shallow substrate (only 2-15 cm)
• Heavy weight (saturated weight between 200 to 500 kg/m^2)	• Low weight (saturated weight between 60-150 kg/m^2)
• High cost	• Low cost

Green roof is a living plant ecosystem of lightweight soil and self-sustaining plants. It is biologically alive and as such provides a protective cover on the building by using the natural of sun, wind, and rain to sustain itself [13]. Green roof is the combination of several elements which are plant, geotextile filter layer, drainage cell as well as water proofing membrane. Each element has its own specified function. Selection of plants or vegetation can be mosses, fern, sedums, grass, and ground cover [14]. The significant of green roof is to retain the storm water and reduce the total volume runoff. Studies have shown that green roof can retain almost 50% runoff volume during rainy period. Therefore, green roof is slightly different compare to convention roof where storm water is immediately discharge. Due to the reduction of storm water volume, quality of storm water will be improved simultaneously [15].

The selection of plants that to be planted on the roofs depends on the final plant height required, their flowering period and the type of soil that needed by these particular plant. This finding was strongly supported by [16]. The research found that foliage height was strongly influenced by transpiration levels and related to the shading of the soil surface. The shorter of the foliage height, the stronger of the thermal connection is between them. However, on the days of continuously high temperature, the high foliage still contributes to the removal of thermal loads from the building interiors. Substrate or growing media is also playing an important role on the plant establishment and performance under various conditions. Different factors of substrate such as type, slope, irrigation and slope can give different performance of green roof. The green roof medium must be substantially lighter, less rich and more porous than soil used for ground level garden. The medium or substrate chosen for green roof should be evaluated by its organic content, pH and nutrient level, weight, porosity and water retention capacity.

III. BENEFITS OF GREEN ROOF

A. Stormwater Management

Green roofs are among the most ideal approaches to address flooding problems in urban regions with high-density development. It can act as a site-level stormwater management plan. They can develop the measure of time it takes for water to go out from a site by over to 3 hours and decrease the rate of overflow by 65%. Extensive green roofs capture and hold the first ½ to ¾ inch of precipitation, keeping it from perpetually getting to be spill over. Introducing a moderately thin (3-inch-thick top) green roof on a wide enough territory could decrease the amount of combine sewer overflow case throughout a summer [17].

B. Biodiversity and Habitat

Flora and fauna could have new living spaces in city places. There are three most essential components in empowering biodiversity in green roof that are growing medium profundity, vegetation sort, and variety in plant tallness and spacing. Research proposes that the deepness, geology, plant content, age of a green roof and the neighborhood scene, can influence a top's capacity to improve biodiversity [17].

C. Save Energy

Green roofs can lessen the consumption of energy in a building for warming in the winter and cooling in summer. Green roofs can protect structures, giving high temperature retention in the winter and lessen total warming from the sunlight based radiation a building encounters in summer. [18], [19].

D. Air Quality

Plants have been utilized long time ago as a part of the urban environment to evacuate air toxins and nursery gasses like particulate matter, carbon dioxide, nitrogen dioxide, carbon monoxide and sulfur dioxide. Green roofs can decrease air contamination, contingent upon the soil deepness and the sorts of plants. A green roof can be utilized as a carbon sink in a cap-and-trade framework that gives a required cap on carbon emanations.

E. Aesthetics and Quality of Life

The green roof system can be used for beautifying the built environment and increasing the investment opportunity. Green roofs make an appealing space for occupants and inhabitants of neighbouring structures. At the point when open to occupants, they can likewise give a relaxation and recreation, in this manner release stress and relax the mind. Green roofs can likewise provide recreational space with an uplifted suspicion that all is well and good [17]

F. Increased Roof Membrane Durability

Installation of a green roof in roof system lessens the exposure of waterproofing membranes to high temperature fluctuations, which can cause micro-tearing, and ultraviolet radiation. This will prolong the lifespan of waterproofing membranes at the roof top level.

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G.Noise Reduction

Noise problem could be reduced by using green roofs system, particularly for low recurrence sounds. An intensive green roof can lessen sound by 46-50 decibels while extensive can lessen sound from outside by 40 decibels.

H.Providing New Amenity Spaces

Green roofs help to achieve the standards of brilliant development and emphatically influence the urban environment by expanding comfort and green space and lessening group imperviousness to infill ventures. Green tops can serve various capacities and utilization, such as community gardens, commercial space and recreational space [20].

IV. Green Roof Implementation in Malaysia

For the past 15 years, only a few buildings in Malaysia have adopted green roof as a main green feature element. From past research, industries were very cautious about having rooftop gardens due to the unknown risk on maintenance aspects. Although nowadays many commercial buildings have green garden on their roof top level as a recreational podium, the type of green roof were mostly extensive rather than intensive. Table II summarized the buildings that have implemented green roof system in Malaysia since 1998.

TABLE II
Implementation of Green Roofs in Malaysia [21]

Building	Type of green roof	Year of Completion
Rice garden museum (Laman Padi), Langkawi	Intensive	1998
Ministry of Finance, Putrajaya	Extensive and Intensive	2002
Putrajaya International Convention Centre (PICC), Putrajaya	Extensive and Intensive	2003
Putrajaya City Hall, Putrajaya	Extensive	2004
Malaysian Design Technology Centre (MDTC), Cyberjaya	Extensive	2004
Serdang Hospital	Intensive	2005
Faculty of Social Sciences and Humanities, Universiti Kebangsaan Malaysia	Retrofit Extensive	2007
Sime Darby Oasis, Damansara	Extensive	2009
KL Sentral Park	Intensive	2009
Newcastle University Medicine Malaysia, Nusajaya	Extensive	2011
Laman PKNS, Shah Alam	Intensive	2013
Heriot-Watt university, Putrajaya	Extensive	2014
Tun Razak Exchange (TRX)	Intensive	2016

V. Green Roof Research in Malaysia

Though there are buildings with green roofs in Malaysia, their performances are not monitored and scientifically proved in local environment. Only limited studies/works had been done on green roof system in Malaysia [22]-[25].

Kok et al. [26] had carried out a study to evaluate the hydrological (quantity and quality) and thermal performance of an extensive green roof system in HTC, Malaysia. Findings showed that the performances of extensive green roof system are promising under local tropical climate. Simulations conducted in this study indicated that the extensive green roof system could reduce the peak discharge up to 47% for design storms and 26% for actual storm when compared to concrete tile roof. However, its reduction ability decreased for storms with intense rainfall. The water quality of the outflow produced by the green roof was generally good and achieved high WQI (Class I). However, the studied green roof was a source of PO_4 and acted as a buffer zone to neutralize the precipitation. Substrates of the green roof could be the essential factor in affecting the quality of the outflow. Cooler environment was created inside the green roof building since reduction of indoor temperature up to around 5% was observed after installation of the green roof system.

Reference [27] showed that green roof can lower the ambient air temperature as high as 1.5°C throughout a day and slightly pronounced during non-rainy day (1.6°C) as compared to rainy day (<1.5°C). Their results also showed that the rainfall volume of less than 9.8 mm was totally intercepted by the soil layer. Therefore, with the green roof area of about 645 m^2 and the soil depth of about 15 cm, the total rainfall of 8.9 mm is considered as a threshold value at which the green roof can store rain water. However, the significant of extensive green roofs to reduce ambient air temperature and retain the stormwater runoff is much dependent on the type and characteristics of the vegetation, soil structure and thickness and management of the area.

Musa et al. [28] had carried out a study to assess the effectiveness of the vegetated roof in reducing the quantity of storm water runoff. One vegetated roof (Pearl grass) and one non-vegetated roof were built in a small scale model. The model size is 1m x 0.75 m and surface area is 0.75 m^2 with slope of 6% for both models. Non-vegetated model depth was 50 mm while vegetated model was 200 mm depth which including 80mm vegetated layer. Their results showed that the vegetated roof model retained 17% to 48% storm water runoff from rainfall. The results also showed that higher rainfall intensity will lower the retention capacity capability of the vegetated model. Meanwhile, [29] in their study reported that a similarly configured green roof in a Malaysian climate could reduce runoff by 84% on a per-event basis and achieved a 51% overall volumetric retention.

Shahid et al. [30] had investigated the possibility of using palm oil clinker to replace the porous stone materials as drainage layer in green roof system. In order to assess the effects of replacing the drainage layer with palm oil clinker, a few experiment trays with 5 cm of substrate layer and 4 cm of drainage layer and three type of plant species were studied. Three different sizes of palm oil clinker were selected which are C-small (2 mm), C-medium (5 mm), C-big (10 mm) and punice (3-10 mm). Based on their results, the hydraulic conductivity of the palm oil clinker is proportionate to the size of clinker. It was found that palm oil clinker has a good ability to drain the excess water and there is no effect in term of plant development when the palm oil clinker is used as drainage layer.

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VI. Challenges of Implementing Green Roof System in Malaysia

The implementation of green roofs in Malaysia is still low whereby only few buildings in Malaysia have adopted green roofs. According to the survey done by [31], nine factors have been identified as contributors to the obstacles of the application of green roofs in Malaysia. These factors are including past failure, difficult and high cost, complicated and hard to maintain, limited local expertise, lack of scientific research, fear of unknown risk, higher cost of materials supply, no design standards and guidelines and believe that green roof is susceptible to fire. The results of survey were summarized in Table III. The top obstacle is the limitation of local expertise and inexperienced green roof professionals, which creates a challenge to implement green roofs in Malaysia. Reference [32] indicated that there are lack of experience among facilities manager and maintenance crew in reference with green roof that ultimately lead to poor maintenance. In case of Malaysia, it is difficult to get green roofs installer and specialist companies for green roofs system. Thus, due to the limitation of green roofs suppliers in Malaysia, it will result to high cost of installation and materials. Reference [33] stated that providing incentive is a successful strategy to promote green roofs to the industry players as what has done by Germany, Canada, Japan and Singapore. Many buildings in developed countries have used green roof as one of the solution to increase green area along with its benefits [33]. Around 14% of all flat roofs in Germany have adapted green roof and it became common because of the supportive government policies [34]. Another obstacle to adopt green roofs in Malaysia is because of no design standards and guidelines on green roofs. Reference [22] indicated that there are no design standards and guidelines in Malaysia on green roofs systems. This has creates the challenges for the building owner to install the green roofs in a proper and standardized way.

VII. Conclusions

Green roofs have been proven that it can produce many benefits such as reduce energy consumption by decreasing cooling and heating loads, provide amenity and aesthetic value, increase building values, improve stormwater runoff mitigation, lower air temperatures, enhance urban air quality, assist in urban stormwater pollutant removal, reduce noise in urban environments and mitigate urban heat island effects. Extensive literature review has been conducted to explore the practical approaches and problems associated with green roofs, perceived from facility management point of view in Malaysia. Green roof technologies are the integrated knowledge of plants biology, hydrology and architecture. Designing the green roof required a good knowledge of engineering as all the critical aspects of design must be included such as weight of the systems, suitability of proposed plants and the environmental aspect at the regions. The study had identified the challenges and sustainable development of green roof buildings in Malaysia. Other than that, this study also provides the guidelines and recommendations on planning and design intent at the early stage of green roof development in Malaysia context. More research and initiatives are required to be taken by both research institutes and government in order to promote the green roof system in Malaysia.

TABLE III
Obstacles in Adopting the Green Roof in Malaysia [30]

Obstacles	Percentage (%)					RII	Rank
	Strongly Disagree	Disagree	Slightly Agree	Agree	Strongly Agree		
Past failure of green roof	0	8	20	53	19	0.765	9
Difficult & High Cost	0	4	12	36	48	0.856	4
Complicated & Hard To Maintain	0	3	11	49	37	0.837	7
Limited Local Expertise and Inexperienced green roof professionals	0	0	13	34	53	0.891	1
Lack of Scientific Research	0	0	15	37	48	0.867	3
Fear of Unknown Risk	0	3	11	49	37	0.843	5
Higher Cost of Material Supply	0	4	16	33	47	0.880	2
Design Standards & Guidelines	0	0	13	34	53	0.840	6
Susceptible to Fire	0	7	13	33	47	0.832	8

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