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PRIORITISING SIGNIFICANT CHARACTERISTICS OF GREEN ROOF SYSTEMS IN MALAYSIA URBAN AREA

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ABSTRACT

Green roof systems are a type of sustainable construction that involves planting vegetation on the roofs of buildings. They have multiple benefits for the environment, such as reducing stormwater runoff, improving air quality, mitigating urban heat island effect, and enhancing biodiversity. However, they also pose some challenges and risks, such as increased structural load, fire hazard, water leakage, and maintenance cost. Therefore, it is important to identify and evaluate the significant characteristics of green roof systems that affect their sustainable, durability, and life cycle. These characteristics include the type and depth of growing medium, the selection of vegetation, the drainage layer and irrigation system, the protective layer, and the structural support. The survey is conducted by using questionnaire distributed to 118 contractors in Kuala Lumpur and Putrajaya. The data collection of 49 out of 118 questionnaires was tabulated, interpreted, and analysed using Statistical Packages for Social Science (SSPS) version 26. As a result, there are six significant characteristics of green roof systems are identified and ranked. The results showed that the most significant maintenance criteria of the green roof are structural support, followed by drainage system, waterproofing membrane, vegetation or plant selection, irrigation system, and lightweight growth medium. The findings of the study can serve as added value to existing practice. Therefore, it will also help to improve current green roof implementation in the Malaysia urban areas.

Keywords: *"Significant Characteristics", "Green Roof", "Malaysia", "Urban Area"*

INTRODUCTION

Environmental sustainability is the commitment to conserve natural resources and protect global ecosystems for current and future health and well-being. This is supported by Sustainable Development Goals from United Nations stated that one of the goals is to make cities and human settlements inclusive, safe, resilient, and sustainable. The 12th Malaysia Plan (RMK 12) also come out with the theme of Advancing Sustainability in improving the environment.

The heating and cooling of residential buildings are responsible for most of the energy used in the modern world. As a result, there has been a drastic increase in the development of sustainable energy sources, particularly in residential buildings, intending to lower the amount of energy consumed within buildings. One of the best ways to save energy is with a comprehensive green roof system. This has a positive impact on people's health and the appearance of their homes in addition to reducing the impact that living things have on their surroundings. A green roof system is an extension of an existing building's roof to grow greenery. The plants may be modular or have drainage layers, depending on the style of green roof installation. This is supported by Tabatabaee et al., (2019), the built environment's increased energy and resource consumption has prompted a global shift to sustainable building practices. As a result, many countries have begun to explore green roof (GR) systems, which are more environmentally friendly than traditional roofs. Vegetated roofs (GRs) are characterized as roofs with various layers, including vegetation, soil, a filter layer, a drainage layer, a waterproofing layer, and a structural deck. Various studies have been carried out in various climates to assess the benefits and costs of GR installation, aside from energy conservation, drainage systems, and noise reduction.

According to Cirrincione et al., (2021), building energy demand contributes to 36% of global energy consumption (and 39% of total energy-related CO2 emissions), at the European level, the construction sector accounts for 25–40% of total energy demand (about 35% of total CO2 emissions in Europe). Given recent events (the Covid-19 pandemic), which caused a huge number of individuals to spend considerably more time inside their residences, these figures (i.e., the percentage values connected to building energy demand, especially residential buildings) are estimated to rise. This shows us that buildings can consume a lot of energy and may affect many things.

The green roof system has many advantages but there are also disadvantages or problems with this type of roofing system. This paper aims to identify significant characteristics of green roof systems in Malaysia. Thus, this research is important in order to enhance the implementation for green roof systems in Malaysia.

LITERATURE REVIEW

Overview of Green Roof

A green roof system is an extension of an existing building's roof designed to grow plants. The plants may be modular or have drainage layers depending on the kind of green roof installation. To maintain the building secure and undamaged, green roofs must include a few crucial components, such as waterproofing and root repellant. The green roof is one of the new architectural approaches that incorporate the concept of sustainable development. It produces flora that is compatible with the environment on building roofs in the form of many layers that have a positive impact on both the environment and the economy.

In addition, Ismail et. al, (2018) stated that green roofs are a component of an urban greening plan for coping with climate change. It offers a practical approach to resolving environmental issues, an innovative response to the problem of space shortage in urban centers, and an improvement in the standard of living for people. In Malaysia, which is now experiencing fast urbanization and the loss of green space in most of its urban areas, green roofs are extremely significant. For instance, the urban area of Kuala Lumpur reduced the amount of green space per person from 9 square meters as needed by the World Health Organization in 2010 to 8.5 square meters in 2014. In Kuala Lumpur, 150,000 square meters of vacant rooftop space have been identified as a potential location for green roof installation. Besides, buildings such as residential, commercial, industrial, educational, and public ones, as well as private residences and other kinds of structures suitable for green roofs.

Furthermore, through evapotranspiration, the plant on a green roof cools the surface and absorbs heat from the air. The temperature of the roof surface and the surrounding air is lowered by these two actions. While a conventional roof may raise the ambient temperature by almost 50°C, a green roof can keep an area cooler than the surrounding air. In addition to having a good effect on the structure itself, having more roofs beneath the plants can contribute to reducing "urban heat islands," which are frequent in highly populated areas.

Types of Green Roof

A green roof is made up of a variety of elements, including vegetation, a drainage layer to remove any excess moisture, a substrate that provides nutrients for the plant's roots, and a water supply system. Generally, a green roof provides an atmosphere that is suitable for supporting vegetal development. This is supported by Abass et. al, (2020), the three varieties of green roofs are generally implemented on building roofs based on desired functions and cost which compares and classifies

them. The comparison differs depending on the installation cost, plant types, plant species, and structural system.

An extensive green roof is an example of a naturally present, mostly self-sustaining type of plant. Certainly, reducing stormwater runoff from buildings at the source is the most economical and environmentally friendly infrastructure. Extensive green roofs are the most effective and natural, even if they only partially reduce a building's environmental impact. According to Bentsen et. al, (2010), extensive green roofs require less maintenance because they are made with an ecological purpose rather than aesthetics in consideration. An extensive green roof's plants require little in the way of specialist treatment, and people rarely or never interact with it. This is because extensive green roofs are only suitable for small plants and limited choices. This is also supported by Walters and Karen, (2018) the plant selection for extensive green roofs is often restricted to ground covers and smaller growing plants, and the depth of the growing medium is limited to a shallower level (15 cm). Although extensive roofs often require little maintenance, the only plant species allowed on them are herbs, grasses, mosses, and drought-tolerant succulents like sedum because of the shallower medium depth.

A semi-intensive green roof is an improved natural type of vegetation, frequently self-sustaining and developing, as stated by Stella and Personne (2021). Certainly, reducing stormwater runoff from buildings still makes financial sense and benefits from a bio-diverse natural infrastructure. Semi-intensive Green Roofs are also frequently used to reduce a building's environmental impact because they are known to have good stormwater retention and biodiversity. For instance, the aesthetic and ecological impact is increased when semi-intensive green roofs are partially situated over extensive green roofs. On the other hand, semi-intense regions on an intensive green roof will cost less and provide a visual transition.

According to Balvedi et, al. (2023) unlimited plant and design variations are included in an intensive green roof or roof garden. Similar rules apply to open space planning, which enables any kind of plant. Perennials, grasses, bulbs, summer flowers, shrubs, and huge trees may all be a part of intensive greening. A lawn is regarded as an intensive green roof because of its high care needs. However, intensive green roofs without lawns require less general maintenance than most people would anticipate. In addition, due to the high level of management required by their design to operate more like a traditional terrestrial garden with a variety of plants that each need special care, intensive green roofs are more expensive to construct. Based on that research, intensive green roofs are likely known for their multiple plantations on the roof. This is also supported by Walters and Karen, (2018) intensive green roofs may enable the planting of shrubs, trees, walkways, and different landscape elements, such as benches because they have growth medium depths of more than 15 cm. Figure 1 (a) and (b) presents buildings designed with intensive and extensive green roof in Malaysia.

Figure 1: (a) Intensive and (b) Extensive Green Roofs

(Source: Ismail, 2018)

Green Roof Projects in Malaysia

Due to its advantages for the environment, economy, and aesthetic value of a building, green roof systems are widely used. In Malaysia, multiple extensive and intensive green roof initiatives have been effectively implemented. According to Isa et. al, (2020) from 24,222 hectares of the city area to just roughly 59.4% of the entire area or 14,386 hectares, Kuala Lumpur's region saw a decrease in its green spaces. After this decrease, Kuala Lumpur provides a clear demonstration of the country's adverse effects of urbanization and the urgent need to create sustainable strategies that may preserve greenery alongside modern development. In addition, green roofs have the ability to expand the amount of green area on unused roofs in urban locations. Most Malaysian professionals, academics, and people with practical perspectives are interested in the green roof system due to the depletion and deterioration of the country's environmental resources, such as soil, water, and air.

Several buildings in Malaysia already implement green roofs such as Heriot-Watt University, Platinum Sentral Malaysia, Bandar Rimbayu Shah Alam, and many more as shown in table 1.

Table 1: Several Green Roof Building in Malaysia

Buildings	Building Type	Green Roof Type	Completion Year
Ministry of Finance, Putrajaya	Office Building	Intensive	2002
Putrajaya International Convention Centre (PICC)	Public Building	Intensive And Extensive	2003
Riana Green East, Kuala Lumpur	Residential - Condominium	Intensive	2009
Kl Sentral Park @ Platinum	Office Building	Intensive	2011

Newcastle University Of Medicine Malaysia	Institutional	Extensive	2011
Swiss Garden Residences, Kuala Lumpur	Residential - Condominium	Intensive	2011
Kiara 9, Mont Kiara, Kuala Lumpur	Residential - Condominium	Intensive	2011
Heriot-Watt University, Malaysia	Institutional	Extensive	2014
Sime Darby Oasis, Damansara	Office Building	Extensive	2015
PJ Midtown – Petaling Jaya	Residential - Condominium	Intensive	2019
Bukit Bintang City Centre – Kuala Lumpur	Public Building	Intensive	2020
The Tropika – Bukit Jalil	Office Building	Extensive	2023
Southplace Residences, Tropicana Metropark	Residential - Condominium	Intensive	Expected to complete in 2024
Bandar Rimbayu Township	Residential	Intensive	Expected to complete in 2026

Significant Characteristics of Green Roof

Vegetation

According to Ismail et, al. (2020) in order to intercept, absorb, and evapo-transpire rainwater, green roofs rely on vegetation like sedums/succulents, grasses, herbs, wildflowers, and for extensive green roofs, shrubs and trees. Plantings need to be prepared for the extreme weather that prevails on roofs, such as little soil depth, seasonal drought, strong gusts, and direct sunlight. On intensive green roofs, a greater range of plant species may be employed, although they often require more upkeep. Plantings require frequent irrigation throughout the first two months of establishment.

Growing Medium

According to Tariku and Hagos, (2022) the green roof surface is either flat or gradually sloping, and it is made up of a filter bed or growth medium area that is covered in a variety of flora. Depending on the green roof system or product used, the growing medium will vary, but it is typically made to be permeable, light, and to have sufficient fertility and drainage capacity to sustain plant development and allow for water absorption and penetration as stated by Isa et, al. (2020). In order to avoid surface erosion from wind or rain scours while plantings are being established, growing medium may be coated with matting or another erosion control device. Within a few hours of a storm ending, green roofs are made to drain any extra water. The

presence of standing water in the filter bed must be frequently monitored. It is necessary to clear the typical bed filtering. Periodic repairs may also be required for animal burrows, damage from foot activity, wind scour, or elevation.

Irrigation

Many green roofs will require recurrent watering, particularly in the first two months of development. The irrigation system should be frequently inspected and tested to make sure it is operating correctly. The irrigation systems must be turned off before the winter and then emptied and reconnected to the water supply in the spring, as stated by Paraskevopoulou et, al. (2021).

Protective Layer (Filter, Roof Barrier, Waterproofing)

According to Ismail et, al. (2018) a water-proofing membrane layer and a root barrier layer that guards the water-proofing membrane against root penetration and degradation are two common layers found on green roofs that are intended to protect the roof deck and insulation from water damage via microbial activity, or by a single barrier that serves as both. Checking for any areas of the green roof where protective layers are visible and hence at danger of harm is part of the inspection process.

Drainage Layer

An HDPE (high density polyethylene) membrane that stores water in cups for use by plants when they need it serves as the typical green roof drainage layer. When surplus rainfall drains through holes positioned between storage cups. This is supported by Abass et, al. (2020) the amount a drainage layer can hold ultimately depends on the size of the cup, although extensive green roof drainage layers typically have a storage capacity of 1.5 to 5.5 l/m2. For large living roofs, a 12mm layer storing 1.5l/m2 is typically sufficient. And still, it goes without saying that a larger drainage system and storage capacity are needed the more complex the roof.

Structural Support

According to Alkhrdaji, (2012) the choice of the roof strengthening system is frequently dictated by the ability of the system to increase strength as needed without impairing the structure's functionality, appearance, or use. Based on the structural study of the current roof system as well as constructability, cost, and strength increase concerns, the structural engineer normally determines which type of strengthening system is most suited for the project. For example, the types of roof slab installed on the roof.

METHODOLOGY

The type of data collection used for this research is quantitative data while the type of sampling used is purposive sampling. The respondents of this research are among the contractor G7 in Kuala Lumpur and Putrajaya. This place has been chosen for this research because Kuala Lumpur and Putrajaya are among the urban areas where green roofs are being implemented as supported by Isa et al., (2020). There are 58 contractor companies which involved in green roof installation in Kuala Lumpur and Putrajaya (Lembaga Pembangunan Industri Pembinaan Malaysia (CIDB), 2023). It is estimated that there are 3% from each company involved in green roof as the sample size for the study, which is equivalent to 174 contactors. Based on Krejcie and Morgan (1970), the sample size for the population of 174 is 118 respondents. Therefore, 120 questionnaires have been distributed to the respondents through online survey by using Google Form. The study achieved 49 returned questionnaires which are 41% out of 120 questionnaires that have been distributed to the respondents. According to Nulty (2008), the acceptable online respond rate is 20% which means that in order to reach adequate data collection, the research must reach the minimum of 20% of respond rate. Therefore, this study achieved the minimum of 20% respond rate which is compulsory to achieve adequate data collection. The data are then analysed by using Statistical Package for Social Science (SSPS) Version 26 and the descriptive analysis are presented in the form of tables and charts.

The limitation for this research is time, respondent, and locations which it relies on questionnaire survey as the main data collection method. Questionnaire survey will only cover small sample size of professionals in Malaysia and also for small area. Moreover, the time to collect the data is also limited as it is to be done in a semester only. Hence, the study uses purposive sampling technique for the sample size in order to consider for the data collection.

FINDINGS

Demographic Information

The research found that out of 49 respondents, 23 respondents were below 5 years of working experience (46.9%), 12 respondents were 6 – 10 years (24.5%), 7 respondents were 11 to 15 years of working experience (14.3%) and 7 respondents with 16 years and above years of working experience (14.3%). Next, the highest percentage of respondents currently working company operating is 6 to 10 years with 36.7%. Then, 11 – 15 years current working company operating (28.6%), below 5 years with 22.4% and the lowest is 16 years and above with 12.2%. About 39 respondents from 49 are involved in green roof projects with 79.6% and 10

respondents were not involved in green roof projects (20.4%). As shown in the table, the highest percentage of respondent's number of involvement in green roof projects is less than 3 projects with 53.1%. Then, 4 – 6 projects (24.5%), 7 to 9 projects with 16.3% and the lowest is 10 projects and above with 6.1%. Finally, the percentage of respondent's agreement toward Malaysia Government in promoting green roof in Malaysia. About 35 respondents from 49 agree in their opinion with 71.4% and 14 respondents (28.6%) did not agree with the statements. Table 2 and Figure 2 shows the demographic information discussed above.

Table 2: Demographic Information

Questions	Frequency	Percentage (%)
Years of working experience in the industry		
Below 5 years	23	46.9
6 – 10 years	12	24.5
11 – 15 years	7	14.3
16 years and above	7	14.3
How long has the company you are working for now been operating?		
Below 5 years	11	22.4
6 – 10 years	18	36.7
11 – 15 years	14	28.6
16 years and above	6	12.2
Does your company involve in green roof projects?		
Yes	39	79.6
No	10	20.4
How many Green Roof projects have been involved in before?		
Less than 3 projects	26	53.1
4 – 6 projects	12	24.5
7 – 9 projects	8	16.3
10 projects and above	3	6.1
In your opinion, do you agree that the Malaysia government is doing a good job in promoting Green Roof concepts in Malaysia?		
Yes	35	71.4
No	14	28.6

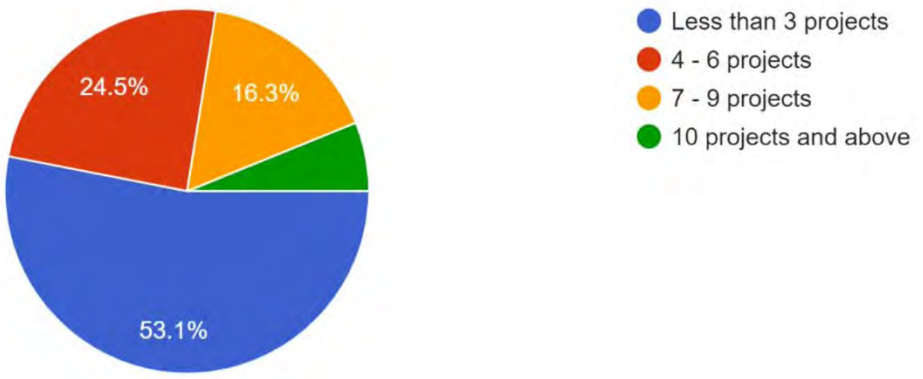

Figure 2: Percentage of Respondents Involve in Green Roof Projects (Sources: Fieldwork Survey, 2023)

Significant Characteristics of Green Roof Systems

The aim of this study is to identify the significant characteristics of green roof systems in Malaysia among contractors to acknowledge which characteristics of green roof systems need to be focused on. The significant characteristics of green roof systems in Malaysia are being analysed among contractors as shown in table 3. From table 3 below, “structural support” (mean=4.78) found as the most significant characteristic towards green roof systems. Next, “drainage system” (mean=4.76). Followed by “waterproofing membrane” and “vegetation/ plant selection” (mean=4.53). After that, “irrigation systems" (mean=4.37) and lastly “lightweight growth medium" (mean=4.35) has the lowest means score.

Table 3: Significant Characteristics of Green Roof Systems

The Critical characteristics of Green Roof Systems in Malaysia	Mean	Std. Deviation	Rank
Structural Support	4.78	.422	1
Drainage Systems	4.76	.434	2
Waterproofing Membrane	4.53	.649	3
Vegetation/ Plant selection	4.53	.649	4
Irrigation System	4.37	.727	5
Lightweight Growth Medium	4.35	.561	6

The aim of the study which is to identify the significant characteristic of green roof systems in Malaysia, has been achieved. The significant characteristic identified in

this research study were classified into nine significant characteristics which are waterproofing membrane, roof repellent systems, drainage systems, lightweight growth medium, roof's layers, irrigation system, vegetation/ plant selection, roof slab and structural support. The highest rank of significant characteristics is structural support. This is supported by Alkhrdaji, (2012) structural support is the most important characteristic because it is to support the weight of green roof systems and ability to increase strength of the medium itself. Meanwhile, the lowest rank is lightweight growth medium, which is also supported by Zhang and He, (2021) as it is important to maintain the maximum weight for certain green roofs.

CONCLUSION

In a nutshell, the significant characteristics of green roof system in Malaysia rank 1 is structural support, followed by drainage system, waterproofing membrane, vegetation/plant selection, irrigation system and lightweight growth medium. These are the main factors that affect the performance and sustainability of green roofs in the Malaysia urban areas. These critical characteristics need to be carefully designed and maintained to ensure the optimal benefits of green roofs such as reducing urban heat island effect, energy consumption, stormwater runoff, pollution and enhancing aesthetic value.

According to a review by Ismail et al. (2018), the current development of green roofs in Malaysia is still lagging behind other Asian countries due to some constraints such as lack of policies, incentives, guidelines, awareness and perception among the industry players and public. Therefore, more efforts are needed to promote and implement green roofs in the Malaysian built environment to contribute to a greener and more livable Malaysia.

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