# A State-of-the-Art Review on Green Roof Implementation

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**Abstract.** Green roofs are known as an effective and sustainable design tool to mitigate urban heat island (UHI) effects. Generally, green roofs can be categorized as intensive and extensive roofs based on their purpose, design and characteristics. Green roofs built with several different layers and thicknesses depending on the roof type, the aim of the design and/or weather conditions. This paper will review the application of green roof in Malaysia that can reduce indoor heat problem and promotes the energy saving among the public. Challenge towards the application, obstacles of the green roof technology, and future recommendations are also discussed. There is numerous study on the impact of thermal heat, which show that the green roof helps in reducing indoor temperature. However, from past research, most of the studies focused on commercial building and office building. Therefore, the idea of extending the use of green roof to Rest and Relaxation (R&R) building in Malaysia is suggested as it is known to be a massive public area which is suitable to introduce the benefit of the green roof.

**Keywords:** Green roof · Rest and relaxation area · Green technology

## 1 Introduction

The green roof of a building is known for planting a medium size of plant and vegetation on top of the building. A layer of soil or a growing layer will be prepared to plant the vegetation [1]. In a general study, there are two types of green roofs; extensive and intensive. As a common practice, the intensive green roof is recognized as a roof garden. The number of an intensive roof garden in Malaysia is higher than the extensive green roof, and the construction of this roof garden (intensive roof) was mainly found and accessible in the urban residential and commercial area [2]. However, the application of this green roof as a green technology in a public area such as Rest & Relaxation (R&R) Service Area has not been carried out yet.


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There are several effects of climate change that caused global environmental issues such as including higher atmospheric temperature, intense precipitation, increase greenhouse gaseous emission, and create discomfort of the indoor condition [1]. Thus, the benefit of green roofs can help to solve the global warming phenomena by implementing this technology to R&R is recommended. The implementation of an extensive green roof type to the existing or new R&R building is viable.

This paper presents the state-of-the-art knowledge on the green roof, including the material and installation method, advantages, and its application in a tabular form. A discussion which includes challenge and obstacle with future research on a green roof is also presented. To expose the public about green roof technology, the R&R could be an excellent place to initiate for the awareness of this knowledge and simultaneously could provide as a rest area for the drivers.

## 2 Material and Method

### 2.1 Green Roof Installation

In the construction of green roof, type of roof and climate condition in the area are the factors that need to be considered as to determine the thickness and type of layer to use. From the bottom to the top layer of green roof systems typically, consist of a root barrier, drainage, filter, growing medium, and vegetation layer. Each of these layers designed to operate primarily based on its function and to protect the structure beneath. As a result, each of the layers contributes to several environmental and operational advantages of vegetated roofs [3].

Figure 1 shows the typical layers of a green roof system. The first layer is a root barrier followed by a drainage layer to allows excess water to drain away, and the filter layer is installed on top of the roof to provide a waterproofing layer for the roof. Then the water retention layer is overlaid to keep and manipulate water runoff to maintain the moisture of the soil. By having this layer will ensure that the plant will get sufficient water to grow. The type of green roof, vegetation, previous soil saturation, building's roofing assembly and weather conditions will decide the retention capacity [4]. Last and foremost, the growing medium layer to provide an area for the vegetation to develop and the determination of this developing medium layer is essential as the material used is different from the ordinary material for residence plants or gardens. Usually, the type and mixture of growing medium material rely on the plant selected for the green roof. Plants selection must refer to the type of roof, surrounding climate, and circumstance of the building.

Most of the roof truss structure in Malaysia are in sloping shape due to the fact of the high intensity of rain. Installation of the green roof on this type of roof is complicated, and generally, most of the green roof constructed on the flat roof surface. The green roof construction starts through applying the diagonal piece of green roof layer from the lowest point with a waterproof membrane layer to avoid building from leakages, an isolation mattress, and a shielding one to prevent losses from the penetration of roots or other structural movements [5].

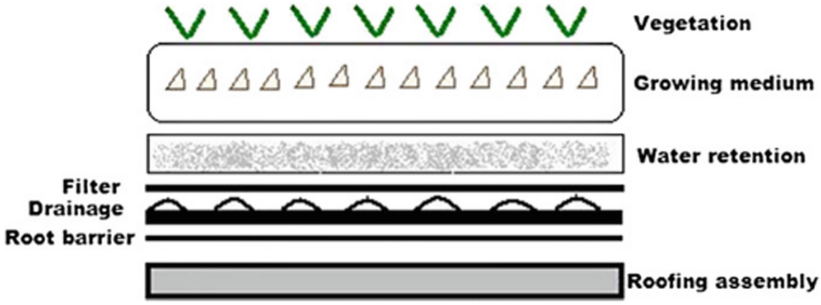


**Fig. 1.** Cross-section of green roof layers [3]

## 2.2 Types of Plant

Numerous types of plants are suitable for an extensive green roof. From the past research, several types of plant had been tested to match with the climate in Malaysia. For an example, four testbeds were vegetated with monocultures planting of native plants, Axonopus compressus (cow grass), Zoysia matrella (Manila grass), Nephrolepis biserrata (fern) and portulaca Grandiflora cultivars (sedum). Native plants such as Fern, grass, and sedum are the category of native plants that are suitable to grow in Malaysia [6].

İn choosing plant species, it is an important aspect to recognize the type of plant to be planted in a different climate condition. For a herbaceous plant, graft planting or seed sowing in soil bed is usually applied. Meanwhile, graft rooted is applied to the plant in a specific arranged area of the soil bed. [5].

After considering all the conditions and function of the rooftops, there are several characteristics should consider in choosing the best vegetation that suitable for extensive green roofs type (Figs. 2, 3, 4 and 5):

- Able to resist different climate conditions
- Short and soft roots
- Regularly irrigated
- Easily available and cost-effective
- More evapotranspiration
- Less maintenance
- Ability to grow in fewer nutrients conditions
- Rapid multiplications
- Can reduce heat island phenomena

**Fig. 2.** Nephrolepis biserrata (fern)

**Fig. 3.** Nephrolepis biserrata (fern)

**Fig. 4.** Portulaca grandiflora cultivars (sedum)


**Fig. 5.** Zoysia matrella (Manila grass)

All the above characteristics explained the significant aspects that can be followed as a guideline for the selection of suitable plants in Malaysia [7]. Furthermore, further research on the proposed plant to be planted based on the above characters can be carried out to enhance the suitability of the plant with Malaysia's condition.

## 3 Advantages of Green Roof

To date, the application of green roof offers many advantages to the surroundings and the building itself. The advantages or impacts may vary and depend on the roof performance, which is control by the design and type of the roof system, climate, and region.

Generally, a green roof can enhance energy consumption by minimizing the heat gain to the building through evaporation of planted vegetation on the roof surface, and

this will simultaneously lead to enormous cost savings with less use of electricity. The green roof helped to increase the runoff water quality with less rubbish, improve the air quality and reduce the heat waves in the area [7]. Furthermore, the other benefits of green roofs can help to generate cool enclaves of different connectivity, shapes, orientations, and size on the roof. The tendency of related cooling effect to spread around depends on the size of the area of community [8] that could improve an environmentally friendly area. Green roofs showed to be effective in reducing surface temperatures of rooftops through measured temperatures, but the effects on ambient air temperature appear to be marginal. Substrate moisture strongly affected the reduction of temperature, and as the layer of green roofs is thin, thermal capacity can be decrease than a concrete roof [9].

Apart from these improvements, the green roof additionally gives beautiful views and can be developed for the leisure area. From past research, some researcher has proven that the green roof can reduce the surface temperature, an indoor temperature in a single-story building, and increasing the indoor humidity to give a better environment inside the building [10]. Due to the proven impact of the green roof for single storey buildings, thus the implementation of this technology to R&R along the highway (commonly consists of a single-story building) could help in reducing the heat inside the building.

## 4 Application of Green Roof

For the past 20 years, acknowledgement of green roofs increased throughout some parts of the world with the installation of this technology in a commercial building. Through this installation on buildings, the benefits are not only given a sustainable green surface, but it will also improve the microclimate for public and continuously contribute to biodiversity protection. [5]. The implementation of the green roof for Asian countries such as Malaysia, however, still in the starting phase. The application of green roof technology to existing or new buildings in Malaysia is still limited. To encourage more building practising of green roof in Malaysia, the advantage and its problem need to be tackled as well as the policy, incentives, and guidelines from the government [11].

Table 1 shows the compilation of literature studies from past research on the application of green roofs all over the world. Most of the green roof applications focused on developing the system to the office and residential building, and none has been applied to R&R. Many of the experimental studies have been carried out against the extensive green roof type, with the benefits proven, the implementation of a green roof to R&R will enhance the scenery and surrounding environment as well as a recreational area to the drivers when using the highways.

**Table 1.** Compilation of literature study from past research on the application of green roof

| Author | Research | Type of building |
|---|---|---|
| [12] | Green roofs in mitigating Urban Heat Island effects | University experimental building |
| [13] | Thermal and energy performance assessment of the extensive green roof | University experimental building |
| [14] | Thermal analysis of extensive green roofs combined with night ventilation | Office building |
| [15] | Indoor heat stress and cooling energy comparison between a green roof and non-green roof | University experimental building |
| [16] | Comprehensive Evaluation of Energy and Environmental Performances of an Extensive Green Roof | Residential building |
| [17] | An overview of green roof development in Malaysia and a way forward | Office building |
| [18] | Thermal performance of extensive green roofs | Residential building |
| [19] | A comprehensive study on green roof performance for retrofitting existing | Residential building |
| [20] | Construction and design requirements of green buildings' roofs | Office building |
| [21] | Green and cool roofs' urban heat island mitigation potential in the tropical climate | University experimental building |
| [22] | Extensive green roof outdoor spatio-temporal thermal performance | Office building |
| [23] | Thermal and energy performance of two distinct green roofs | One floor building |
| [24] | Experimental study of the thermal performance of an extensive green roof | Factory |
| [25] | Green roof cooling contributed by plant species | University experimental building |
| [26] | Long term experimental analysis of the thermal performance of extensive green roofs | İnstitutional building |

## 5 Discussion

### 5.1 Challenge and Obstacle

In Malaysia, there is only a few existing building has practised the green roof system; most of the practitioners are afraid of the unknown risk during the maintenance from the green roof. In order to encourage or incorporate more on green roof system for new and existing buildings, this problem needs to be addressed. The performance of the existing green roof needs to be monitored, maintained and scientifically proved in the local environment.

Figure 6 shows nine factors of obstacles in implementing the green roof in Malaysia in which the factors were obtained from the survey study [11]. Referring to the study based on data analyses of the important relative index (RII), the most factor of the obstacle was the limited local expertise, inexperienced green roof professional, higher cost of green roof materials, and lack of research. These are the type of obstacles that reduce the number of green roofs practised in Malaysia. When there is no local

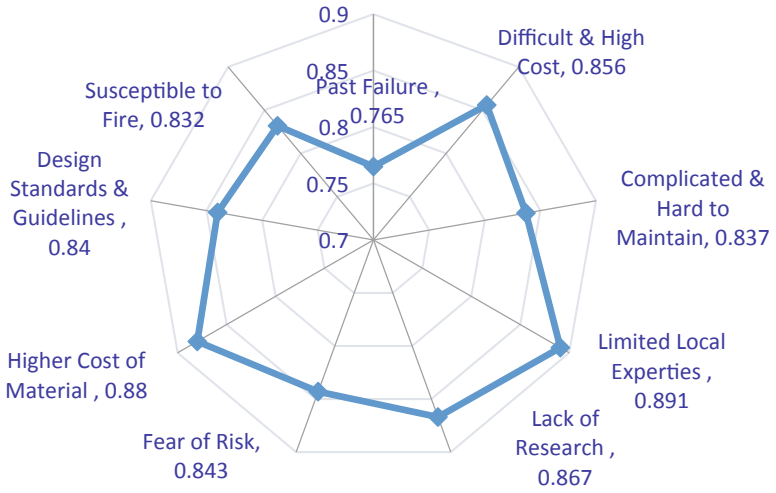


**Fig. 6.** Relative importance index [11]

expertise that has the knowledge and experience, it will be difficult for the consultant, developer, or owner of the building to implement green roofs in Malaysia. There are several past studies also indicated that the poor maintenance and unsolved problem from the green roof are caused by the lack of experience of the facilities manager and the maintenance team. This shows that having local expertise is very important to increase or improve the quality of the green roof system and specialize in solving the problem from installing to maintaining stage [2].

In terms of risk and maintenance aspects, the leakage problem has been the primary concern, and to solve this, new technologies were introduced. The leakage problem can be repaired through one of the methods by removing the growing medium and exposed the membrane to indicate the location of leaking. However, this method could be considered as a minimum expenditure cost to maintain the green roof compared to the whole life cost of the building. [6]. Another important factor which involves the role of government in promoting green roofs is through providing guidelines or standard as well as the incentive to the owner of the building. A full commitment and cooperation between the government, building practitioners, and owner of the building are needed to increase the use of green roofs.

### 5.2 Future Green Roof Study

Based on the previous study all over the world and specifically in Malaysia, green roof implementation has received greater acknowledge due to its advantage in solving the environmental problem. Therefore, there is a potential study to incorporate green roof technology either at existing or new R&R buildings. Although many studies have proved that green roofs can decrease energy consumption by reducing the cooling and heating load, lower air temperatures, improve stormwater runoff, and many others, the impact of a green roof to R&R has not yet tested. Therefore, the effectiveness study of

green roofs implementation in reducing energy consumption needs to be carried out in detail as R&R is an area that always been visited by the drivers. Besides that, a potential study on the impact of green roof with urban design factor on a specific height, coverage site area, and the existing road orientation is also recommended. These are the areas that should be explored in futures to obtain the actual impact on different types of building.

## 6 Conclusions

This review paper concentrates on the green roof materials and installation, suitable types of plant, advantages, and its application in Malaysia. Discussion on the challenge and obstacles as well as a future study of green roofs is also presented. From past research, there are many significant finding has been reported. However, there are still many factors such as construction cost and lack of expertise in green roof installation that need to be considered for improvement.

Without a doubt, the green roof in Malaysia is not entirely implemented yet into the construction industry and still requires in-depth studies to enhance its benefit. Due to the positive impact of a green roof to the environment, the importance of green roof as a sustainable option in the construction industry and society cannot be denied. Thus, cooperation from the government, such as enforcement, incentives, and policies, could contribute to the main factors in increasing the development of green roofs.

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