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RESEARCH ARTICLE

DESIGNING A GUIDELINE FOR GREEN ROOF SYSTEM IN MALAYSIA

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ABSTRACT

Green roof system is widely implemented because of its environmental and economic benefits and aesthetic value to a building. There are numerous successful green roof projects, both extensive and intensive in Malaysia. However, there is no specific technical guideline for the planning, design and construction of green roof system catered to the climate and background of Malaysia. The aim of the research is to propose and develop a technical guideline of extensive green roof system in Malaysia on the planning, design and construction aspects of vegetation, substrate, filter, drainage and root penetration barrier. Comparative literature review of guidelines from Hong Kong, Singapore and Sydney were leveraged upon to propose an appropriate guideline for Malaysia's market. In-depth interviews were carried out with green roof experts to collect feedbacks on the proposed guideline in the validation stage. The output from this research will conceptualise a framework for a technical guideline for future implementation of green roof systems in Malaysia.

KEYWORDS

Green roof system, guideline, construction, Malaysia

1. INTRODUCTION

The urgency of global warming has prompted a global movement to adopt sustainability as a focus in urban development. In 2009, in the UN Climate Change Conference in Copenhagen, Prime Minister Najib Razak announced that Malaysia will be working towards achieving a reduction of 40% in carbon emissions by the year 2020 [1]. Due to the increase in population and economic activities, greenery in the cities were rapidly replaced by the mushrooming of high rise building in Malaysia. Over the years of urban development, urban heat island effect and flash floods have become serious issues in the cities. Efforts are carried out as well as regulations to restore greenery in the cities but due to the limited spaces in the cities, rooftop greenery has become a popular solution in many countries.

Green roof systems are classified as two types, extensive and intensive. Intensive green roofs are roofs with substrate depth of more than 200mm whereas extensive green roofs have substrate depth of less than 200mm. Generally, intensive green roofs are harder to maintain and cost more as it requires higher structural loading support and the high substrate depth allow more varieties of plant selection like trees, shrubs and grass. Extensive roofs are easier to maintain and requires less maintenance as the plants selected usually has higher survivability and requires less attention to maintain. This research focus on extensive systems as they would be a good start for Malaysia to adopt green roof systems due to the low overall cost and easy implementation compared to intensive systems [2].

Green roof systems offer a more sustainable solution compared to conventional roof systems [3]. However, most of the green roof systems in Malaysia uses conventional materials like polymers in the filter and drainage layer. There are a lot of possible waste and recycled materials that can replace the conventional materials in green roof. Considerations need to be taken to incorporate waste and recycled materials in the design of the extensive green roof so that it is more beneficial from the environmental and economic aspect. However, there is a lack of research in Malaysia on the area of using waste and recycled materials for extensive green roof systems. Thus, there is a need to discover how the abundant unused waste in Malaysia can contribute to the implementation of green roofs.

There are several successful green roof systems applied in Malaysian buildings such as Putrajaya International Convention Centre, Sime Darby Oasis, Kl Sentral Park @ Platinum and many more [4]. However, there is no standard technical guideline for the implementation of green roof in Malaysia [5]. The Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau, FLL 2008 Green Roofing Guidelines from Germany which is the pioneer of the field serve as a standard that many European countries adhere to for green roof projects [6]. However, due to the different climate, the German FLL is not relevant to Malaysia's tropical climate, which is hot and humid all year. Countries that are similar to Malaysia's climate like Hong Kong and Singapore have successfully developed their own guideline for green roof system. The University of Hong Kong published the first guideline named Technical Guidelines for Green Roof Systems in Hong Kong in 2011 whereas Singapore published their own green roof technical guideline from Centre for Urban Greenery and Ecology, CUGE since 2010 [6].

Hence, the aim of this research is to develop a guideline for extensive green roof system in Malaysia. The area of focus includes the vegetation layer, substrate layer, filter layer, drainage layer and root penetration barrier layer. The guideline will provide information on each layer in the green roof systems regarding the planning, design and construction considerations.

The proposed guideline will address the following:

i. The perception issue of the barrier in green roof implementation in Malaysia due to the lack of guidelines on green roofs [4].

ii. The research gap of the absence of a guideline for green roof system in

Malaysia [5].

iii. To encourage adoption of green roof through accessible guidelines.

iv. To provide alternatives for the construction each layer using waste and recycled materials.

2. LITERATURE REVIEW

Regional materials are highly preferred as there will be lower carbon footprint in the logistics of the materials. According to Green Building Index (GBI), the use of recycled materials and regional materials can contribute to green building credits, thus contributes to the standard of a green building [7]. However, there is a need to identify such materials in Malaysia which are applicable in the construction of green roof. Each layer is investigated to find out what is the current practice in the market and what are the research done locally. The basic components of an extensive green roof are shown in Figure 1.

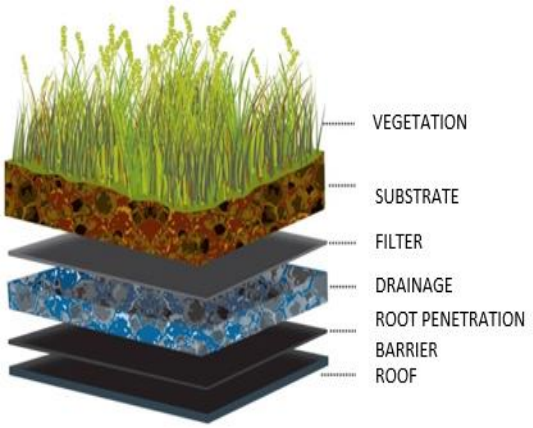


Figure 1: Components in extensive green roof system

Current use for green roof substrate according to German FLL standards is crushed recycled red bricks. Another replacement is combination that includes quarry fines, waste lay, paper ash and sewage sludge, which have the same properties as red bricks, which according to FLL standards are conforming to the level of quality as red bricks [8]. It is also common that in the substrate layer, the soil from Peninsular Malaysia e.g. Kuantan, Munchong, Rengam and Bungor were mixed in the substrate. The thermal properties of these soil were compiled in Table 3 [9].

There is a gap in the research of the usage of waste and recycled materials as filter layers. Current practice in the industry for filter layers involve the use of geotextiles in the form of non-woven fabrics [10]. According to Singh and Bouazza, its thermal performance also depends on the water content, time of immersion in water and surface treatment [11].

Rubber crumbs are also suitable as green roof drainage layer due to its water retaining function, good filtration while promising good drainage and aeration of the substrate and roots [12]. It is also able to reduce the Total Suspended Solid and Chemical Oxygen Demand value in the storm water runoff [13]. Polyfoam with palm oil fibre or coconut fibre was suggested as an alternative material for drainage too. However, the outflow water of the green roof with the suggested material should not be reused for potable consumption [13]. Besides, the Sydney City Council Green Roof Resource Manual suggested expanded shale, foamed glass and gravel for the drainage layer which also possess good thermal properties (see Table 3) [10].

Table 1: Contents of Guidelines

	G1	G2	G3
Technical requirements for each layer	No technical specification provided on each layer	In-depth technical specification provided for all layers.	Technical specification on soil composition, and loading design for substrate, drainage and plants
Planning	Considerations on the structural loading of the building and accessibility and site conditions of roof.	No planning consideration.	Considerations on the structural loading.
Design	Considerations on landscape, irrigation and drainage, wind design, plant selection, roof slope, sustainable technologies and agriculture.	Consideration on material choices for each layers and plant selections.	Considerations on loading design, materials choices for substrate and drainage layer, plant selections, agriculture, irrigation, water technologies, sustainable technologies and architectural design.
Construction	Consideration on safety issues, fire precautions, planting methods, gardening aspects and inspection and testing upon construction.	Consideration on installation instructions, testing, erosion issues.	No construction consideration.

G1 – Technical Guidelines for Green Roof Systems in Hong Kong
G2 – Singapore CUGE Standards
G3 – Sydney City Council Green Roof Resource Manual

G1 presents a detailed maintenance, procedures and requirements which includes plant and waterproofing membrane maintenance, leak detection and membrane replacement. There is also a clear and concise guide on planting options and planting methods covering also irrigation and fertilization. G1 also advises on the project management aspects of the green roof installations which includes the roles of professionals in green roofing, contractual matters, costs and regulatory measures and policies. Checklists for green roof planning, maintenance and preliminary considerations that were adopted from International Green Roof Association and Toronto Green Roof Construction Standard and the Supplementary Guidelines were also included in the G1. Some case studies done in Hong Kong regarding green roof projects were also included so that users of the guideline can refer to the existing projects for further study.

In Tan & Sia's study,76 selections of plants for green roofs that has been tested through controlled experiments were presented in this handbook, including a set of considerations for the selection of plants for green roofs in tropics [14]. Besides, the guidelines provide details on each layer with in depth technical requirements and construction considerations. However, G2 does not include a section about Green Building Credits.

G3 possesses a set of considerations on design load for substrate, drainage and plants which were helpful to estimate the design loads of the total green roof system. Moreover, special features in G3 are (1) the inclusion of architectural design considerations for intensive green roof (2) water

technologies such as water collection, storage and filtration for grey water and black water uses, (3) the application of solar and wind energy technologies on the rooftop. Various case studies on both extensive and intensive green roofs were also included in G3.

3. METHODOLOGY

The first stage of the research is to propose a guideline from the literature review conducted among the selected guidelines. A range of literature that were written on green roof systems were selected and reviewed especially those produced from Malaysia. This is carried out to understand the application of this technology in the context of the local climate and background. From the comparative study of G1, G2 and G3, the relevant items were reviewed and identified for the proposed guideline appropriate for Malaysia.

The second stage involves validation process conducted via in-depth interviews. A range of experts in Malaysia from different backgrounds related to green roof were interviewed. The process was conducted in March 2018 for a period of two weeks upon sending out the invitation. The proposed guideline was then presented to the experts and a series of topics were discussed to collect data namely (1) sufficiency of features in the guideline, (2) relevancy of green building credits, (3) adaptation to local industrial practice, (4) improvements or redundancy in guideline, and (5) expectations and perceptions of the guideline.

The third stage was to process the data and improvise on the proposed guideline. The following section will detail the sections of the final validated guideline.

4. RESULTS & DISCUSSION

The first section will discuss the proposed guideline based on the comparative literature review done. Then, the second section will explain the results obtain through the in-depth interview with the experts. The improvements based on the data collected will be discussed in the third section. Finally, the contents of the finalized guideline after consolidation will be presented to conclude the research output.

4.1 Literature review

From the literature review done in Table 1, the contents of each section were identified, and the number of the main items discussed in the guidelines were listed in Table 2.

Table 2: Comparison on the items in the guidelines

	G1	G2	G3	G4 (Proposed)
Layers	**No. of plant selections**			
Vegetation	0	76	30	14
	No. of technical requirements			
Substrate	0	12	2	13
Filter	0	8	0	8
Drainage	0	8	1	9
Root Penetration Barrier	0	8	0	8
Topics in the Guidelines	**No. of topics discussed**			
Green Building Credits Section	1	0	0	1
Planning	2	0	1	2
Design	7	2	8	4
Construction	5	1	0	3

Table 2 shows the total number of technical requirements and topics discussed in each of the guideline.

G4, the proposed guideline is then formed by selecting the appropriate items to be customized as a guideline for Malaysia. The composition of G4 are as follow. For the vegetation layer, 14 plants were selected from G2 which fits the characteristics as mentioned in G1. Whereas for the substrate, filter, drainage and root penetration barrier, a total of 38 technical requirements for each layer were compiled from G2 and G3. As for the green building credit section, it is customized according to the green building rating tools in Malaysia. Next, the two planning considerations included in G4 were accessibility and site condition selected from G1 and structural capabilities selected from G3. Additionally, the four design considerations taken were types and materials, plant selections, wind design and design loading. Finally, the three construction considerations selected were installation methods in G2, planting method and option and leak detection from G1. The selection of the items was based on the focus to provide design and construction considerations for all five layers in the green roof.

The proposed guideline is outlined in the following sections, (1) Introduction, (2) Root Penetration Barrier, (3) Drainage, (4) Filter, (5) Substrate, (6) Vegetation. Due to space limitation, do refer to the long report for the detailed proposed guideline.

4.2 Validation inputs from the experts

Five experts in the industry that participated were identified as E1, E2, E3, E4, E5. The results of the interview on the five topics discussed based on the proposed guideline, G4 are shown below:

4.2.1 Sufficiency of design features in the guideline

All experts agreed that the design features in the guideline proposed are sufficient. According to E1, the common issue faced in the industry was flooded vegetation due to the clogged drainage system. Therefore, E1 emphasized on the importance of drainage layer to have sufficient design and construction considerations to make sure storm water runoff can discharge to the building drainage system.

4.2.2 Relevancy of green building credits

All experts were satisfied with the inclusion of green building credits in the guideline. E2 suggested green roof to be qualified to obtain credit on advanced energy efficiency performance due to the outstanding thermal performance of green roof. E3 suggested the application of green roof systems to be more relevant for green building projects on schools, hospitals and shop lots so that the thermal performance is more significant due to higher roof to façade ratio. E4 suggested to generalize the green building credits so that they are relevant to all green building rating tools in Malaysia.

4.2.3 Adaptation to local industrial practice

Both E1 and E4 suggested including a wider range of practice as the green roof technology is still new and yet to be enforced. Therefore, contractors have more options to implement green roof systems.

4.2.4 Improvements or redundancy in guideline

E1 suggested the inclusion of the guidelines on irrigation system, rainwater harvesting system and incorporation of solar panels on the rooftop. Both E2 and E3 suggested the introduction of K-values for each component in the green roofs as a guide for the energy calculation for green building consultants. Besides, E2 suggested the consideration on leaf area index on plant selection. While E4 suggested less focus on vegetation as it belongs to the area of horticultural experts whereas E5 suggested the inclusion of waterproofing and structural loading.

4.2.5 Expectations and perceptions of the guideline

Each expert perceived the guideline to cover different function. For example, E1 agreed that the guideline is complete for the areas covered and further research should be conducted to cover other aspects of green roofing such as irrigation and maintenance. While both E2 and E3 perceived the guideline as useful if it works also as a guide for consultants to obtain information for green roof energy performance. E4 agreed that the guideline will be able to address the perception on the barriers in green roof implementation. Additionally, E5 agreed on the comprehensiveness on the guideline but expects waterproofing to be included in the guideline.

From the validation, many improvements could be considered in the final guideline. However, the selected improvements identified crucial in this research were the thermal performance guide, building drainage considerations, updated green building credits and structural loading. Other improvements that were not excluded were leaf area index in plant selection, waterproofing, irrigation, rainwater harvesting, sustainable technologies and maintenance aspects of the green roof. This is due to the focus of the research is mainly on the planning, design and construction of the green roof layers.

4.3 Improvisation upon validation with experts

Therefore, the following improvisation elements, (1) thermal performance guide, (2) building drainage considerations, (3) updated green building credits and (4) structural loading are included in the final guideline. The thermal performance guide is shown in Table 3 with the introduction of K-value for the possible material that can be adopted in green roof.

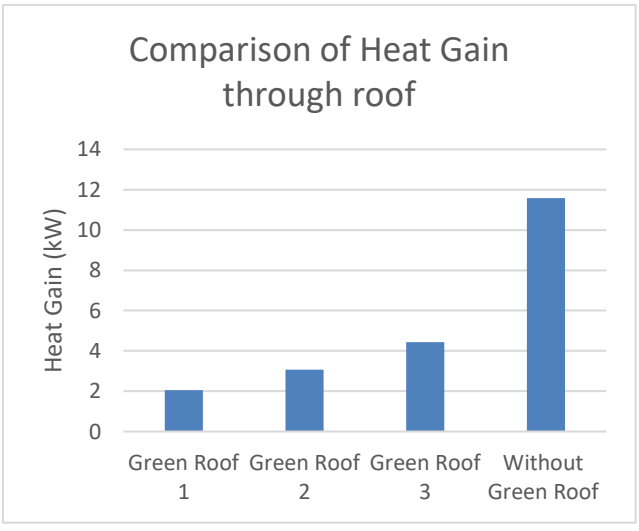
Table 3: K-values of waste, natural and recycled materials in green roof

No.	Materials	K-Value (W/mK)	Reference
Substrate			
1.	Kuantan soil	0.11-0.73	[9]
2.	Munchong soil	0.10-0.18	[9]
3.	Rengam soil	0.111-0.978	[9]
4.	Bungor soil	0.141-0.866	[9]
5.	Coconut husk	0.074	[15]
6.	Oil palm fibre	0.020	[16]
7.	Bricks	1.154	[17]
8.	Clay roof tiles	0.836	[17]
Filter layer			
1.	Non-woven polyester geotextile	0.07-0.83	[11]
Drainage			
1.	Rubber, soft	0.100	[18]
2.	Rubber, hard	0.160	[18]
3.	Gravel	0.33-1.1	[19]
4.	Foamed glass	0.058	[20]
5.	Expanded shale	0.611	[20]

Table 4: Comparison of green roofs with materials drawn from Table 3 and concrete slab without green roof.

	Green Roof 1		Green Roof 2		Green Roof 3		Without Green Roof	
Layers	**Materials**	**λ (W/mK)**	**Materials**	**λ (W/mK)**	**Materials**	**λ (W/mK)**	**Materials**	**λ (W/mK)**
Substrate	Oil palm fibre	0.020	Oil palm fibre	0.020	Crushed bricks	1.154	N/A	
Filter	Geotextile	0.070	Geotextile	0.070	Geotextile	0.070		
Drainage	Foamed glass	0.058	Rubber	0.016	Rubber	0.016		
Root Penetration Barrier	N/A	0.170	N/A	0.170	N/A	0.170		
Concrete slab	Cement sand screed	0.533	Cement sand screed	0.533	Cement sand screed	0.533	Cement sand screed	0.533
	Reinforced concrete slab	1.442	Reinforced concrete slab	1.442	Reinforced concrete slab	1.442	Reinforced concrete slab	1.442
	Cement sand plaster	0.533	Cement sand plaster	0.533	Cement sand plaster	0.533	Cement sand plaster	0.533
U-value ($W/m^2 K$)	0.499		0.744		1.075		2.811	

The values in Table 3 serve as a guide for the calculation of the U-value of green roof in Table 4. The calculated U-value is translated to the heat gained through the roof as shown in the Graph 1.



Graph 1: Comparison of heat gained with and without green roof

Key layers that affect thermal performance are the drainage and substrate as they are the top two thickest layer in the green roof. Therefore, selection of materials for drainage and substrate is key to increase the thermal performance for green roof. Graph 1 shows that without green roof the heat gained through the roof was almost tripled. The thermal values and calculation here will be useful in the guideline to allow green roof designers to consider the material options to achieve the desired thermal performance.

The other improvements such as building drainage considerations, updated green building credits and structural loading is included in the finalised guideline. (Please refer long report for the finalised guideline). By leveraging the results from the validation process, the framework of the guideline is shown as below.

Table 5: Table of Contents for the Finalised Guideline

Contents
1. Introduction
2. Root Penetration Barrier
3. Drainage
4. Filter
5. Substrate
6. Vegetation
7. Green Building Credits
8. Thermal Performance Guide

Table 5 shows the contents of the final guideline after validation and improvisation on the inputs from experts. The following outlines the contents of the guidelines:

Introduction

• Defines extensive green roof and the function of each layer with specification of their performance characteristic

• Structural capabilities of roof

• Accessibility and site conditions

Root penetration barrier

• Types and materials available in the market

• Performance requirements

• Eight installation requirements

• Leak detection

Drainage

• Types of materials available in the market

• Performance requirements

• Total of nine technical requirements which are design loads, granulometric distribution of aggregates, structural and layer stability, behaviour under compression, water permeability, water storage capacity, pH values, carbon content and salt content

• Building drainage systems

Filter

• Types of materials available in the market

• Performance requirements

• Total of eight technical requirements which are design loads, density, width of aperture, susceptibility to root penetration and resistance to mechanical stress, weathering, micro-organisms and chemicals.

Substrate

• Types of materials available in the market

• Performance requirements

• Total of thirteen technical requirements which are design loads, granulometric distribution, organic content, structural and bedding stability and settlement of substrate, behaviour of substrate boards under compression, water permeability, water storage ability, air content, pH value, salt content, nutrient content, seed germination, proportion of foreign substances

• Erosion issues and wind design

Vegetation

• Fourteen Plant selection

• Planting method and option

• Plant characteristics

Green Building Credits

• Introduction on the green building credits based on Malaysia's green building rating tool.

Table 6: List of Green Building Credit

	Items
1.	Energy Efficiency Performance
2.	Advanced Energy Efficiency Performance
3.	Storm Water Design Quantity & Quality Control
4.	Greenery & Roof
5.	Recycled Content Materials
6.	Regional Content Materials
7.	Water Efficiency Irrigation & Landscaping

Thermal Performance Guide

• Table of K-values

• Example U-value calculation for green roof

5. CONCLUSION

The results of this research contribute to the future green roof projects in Malaysia by producing the first green roof guidelines catered for the market in Malaysia. With this guideline, it hopes to encourage the adoption of green roof in Malaysia at a larger scale by providing the planning, design and construction considerations on green roof. The guideline can also serve as a standard for green roof projects in the future when the technology is enforced on developments. Future works involved designing the guideline on the aspects of waterproofing, irrigation, rainwater harvesting for green roof, sustainable technologies and maintenance for green roof. Research to identify local waste and recycled materials and its thermal properties for the application in green roof would be needed too for a complete thermal performance guide.

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