APPLICATION OF COCONUT WASTE AS GREEN ROOF MATERIALS FOR THE REDUCTION OF URBAN HEAT ISLAND (UHI)

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Thesis submitted in fulfillment of the requirements
for the award of the Diploma in Civil Engineering

Faculty of Civil Engineering Technology

UNIVERSITI MALAYSIA PAHANG

FEBRUARY 2023

ACKNOWLEDGEMENTS

Thanks to Allah the Almighty and Alhamdulillah for His blessing for giving me inspirations and patience to carry out this study as well as providing me with tremendous strength towards the end. My appreciation was dedicated to all parties who have contributed to the success of this study.

I would like to express my sincere gratitude to my advisor Dr. Noor Suraya Romali who had been guided me from the very beginning of my research, encourage me to do better and helped me in all the time of the study. Her generous contribution and great support throughout the period are very much appreciated.

I thank my fellow teammates Nur Atiqah Dasrul and Nazrul Aizad for their support in helping me to accomplish this research as we manage to finish it together through various hardships and challenges. Sincere thanks to Universiti Malaysia Pahang for providing me a good facility and an environment for me to conduct the experiment and tests. Last but not least, thankful are extended to my significant other, Muhamad Amin who kindly encourage me throughout my journey in my research and give me support from every corner.

ABSTRAK

Kesan alam sekitar urbanisasi kebanyakannya disebabkan oleh pencemaran, perubahan atmosfera dan litupan tanah. Kesan ini mewujudkan Pulau Haba Bandar (UHI). UHI menyumbang kepada kesan rumah hijau, yang menyebabkan pemanasan global. Disebabkan oleh pembandaran dan perindustrian, UHI merupakan bahaya besar bagi manusia pada abad ke-21. Pulau Haba Bandar ialah bandar atau kawasan berpenduduk padat yang jauh lebih panas daripada kawasan sekitarnya. Suhu yang lebih tinggi adalah terutamanya hasil daripada infrastruktur bandar dan aktiviti manusia. Pembandaran yang pantas dan tidak terancang menjejaskan kualiti persekitaran terma di negara sederhana, tetapi penyelidikan di kawasan tropika rendah, terutamanya yang kuantitatif, adalah terhad. Strategi teknologi yang hebat mesti diperkenalkan untuk mengurangkan kesan Pulau Haba Bandar. Salah satu kaedah untuk menyelesaikan masalah ini ialah penerapan sistem bumbung hijau pada bangunan. Objektif utama kajian ini adalah untuk membina sistem bumbung hijau yang meluas yang dapat mengurangkan kesan Pulau Haba Bandar menggunakan sisa kelapa sebagai bahan bumbung hijau serta menilai prestasi bumbung hijau dalam mengurangkan suhu permukaan bumbung dan udara sekeliling. Reka bentuk bumbung hijau adalah berdasarkan garis panduan bumbung hijau. Ia terdiri daripada lapisan vegetatif, lapisan substrat, lapisan penapis, lapisan saliran dan lapisan kalis air. Terdapat tiga jenis model prototaip yang dinilai berdasarkan pengurangan haba iaitu bumbung konvensional sebagai model kawalan, bumbung hijau komersial dan bumbung hijau sisa kitar semula. Fokus utama bumbung hijau kitar semula ialah penggantian bahan komersial untuk lapisan penapis dan lapisan saliran yang masing-masing diganti dengan sabut kelapa dan saliran kelapa. Hasil kajian ini telah menunjukkan bahawa bumbung hijau sisa kitar semula menunjukkan prestasi terbaik dari segi penurunan suhu berbanding bumbung komersial di mana suhu menurun daripada 33°C kepada 30.5°C. Ini menunjukkan bahawa bahan kitar semula telah memberi impak yang ketara terhadap prestasi pengurangan haba serta mengurangkan kesan Pulau Haba Bandar dan membawa kepada pencapaian bandar dan komuniti yang mampan.

ABSTRACT

Urbanization's environmental repercussions are mostly due to pollution, atmospheric changes, and soil cover. These effects create the Urban Heat Island (UHI). UHIs contribute to the greenhouse effect, which causes global warming. Due to urbanization and industrialization, UHI is a huge hazard for humans in the 21st century. An Urban Heat Island is a densely populated city or area that is substantially warmer than the surrounding region. The higher temperatures are mainly a result of urban infrastructure and human activity. Rapid and unplanned urbanization affects thermal environment quality in temperate countries, but research in the low tropics, especially quantitative ones, is scarce. A great technology strategy must be introduced to reduce the impact of Urban Heat Island. One of the methods to solve these problems is the application of a green roof system on buildings. The main objective of this study is to construct an extensive green roof system that can reduce the impact of Urban Heat Island using coconut waste as green roof materials as well as to evaluate the performance of green roof in reducing the temperatures of the roof surface and the surrounding air. The design of green roof is based on green roof guidelines. It consists of vegetative layer, substrate layer, filter layer, drainage layer and waterproofing layer. There are three types of prototype model that were evaluated based on thermal reduction which are conventional roof as a control model, commercial green roof and recycled waste green roof. The main focus on recycled green roof is the replacement of commercial material for filter layer and drainage layer which is replaced with coconut fiber and coconut drainage respectively. The outcome of this study has shown that the recycled waste green roof shows the best performance in terms of temperature reduction compared to commercial roof where the temperature decrease from 33°C to 30.5°C. This shows that recycled materials have given a significant impact on the performance of thermal reduction as well as reducing the effect of Urban Heat Island and leading to achieving a sustainable city and communities.

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LIST OF SYMBOLS

%	Percentage
m	Meter
mm	Millimeter
cm	Centimeter
T	Temperature
kg/m^2	Kilogram per Square meter
m/s	Meter per Second
L/m^2	Liter per Square Meter
°C	Degree Celcius
Ibs. per sq. ft.	Pounds per Square Foot

LIST OF ABBREVIATIONS

UMP	Universiti Malaysia Pahang
SDG 11	Sustainable Development Goal 11
UHI	Urban Heat Island
3R	Reduce, Reuse, Recycle

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Urbanization's environmental repercussions are mostly due to pollution, atmospheric changes, and soil cover. These effects create the Urban Heat Island (UHI). UHIs contribute to the greenhouse effect, which causes global warming. Due to urbanisation and industrialization, UHI is a huge hazard for humans in the 21st century (Liu & Bass, 2005). Rapid and unplanned urbanisation affects thermal environment quality in temperate countries, but research in the low tropics, especially quantitative ones, are scarce. According to a recent study, the intensity of UHI in Kuala Lumpur ranges from 3.9 to 5.5°C, which is a recognised value when human health and comfort are at stake (Elsayed, 2012). Klang and Kuala Lumpur are frequently several degrees warmer than the surrounding countryside. The typical annual temperature difference between the city and the airport was 1 to 2°C, but on calm, clear nights, it may reach 6 to 7°C (Elsayed, 2012).

UHI-related investigations have produced new urban surface finishing materials. Vegetation on rooftops is one of the most efficient passive strategies (green roof). Green roofs increase urban evapotranspiration by adding substrate and vegetation and directing energy to heat transfer. A green roof has vegetation on its uppermost layer. Extensive (depth less than 150 mm) and intensive green roofs were common (depth greater than 150 mm). Green roofs can improve urban areas' aesthetics, structural value, stormwater runoff mitigation, stormwater quality, noise, and UHI impacts (Razzaghmanesh et al. 2014).

1.2 Problem Statement

Urban growth is one factor that has led to rapid development in rural areas, which in turn has an effect on the peak of the thermal energy. This takes place when there is no void in the process of heat transfer. Because of these issues, the locals living in the area are experiencing a great deal of discomfort. Another environmental issue that needs to be addressed right now is urban heat islands (UHI), which are linked to climate change. The urban heat island effect (UHI) lowers the quality of both the air and the water by preventing the escape of toxins such as ozone.

According to the above perspective and considering that rapid and huge population growth is expected in the near future, it becomes increasingly important to apply UHI mitigation strategies in order to reduce its impact and improve the quality of life with focusing on energy consumption (Kloss et al., 2011).

A great technology strategy must be introduced to reduce the impact of Urban Heat Island (UHI). One of the methods to solve these problems is the application of green roof system on the buildings. Green roofs have been applied in many advanced countries such as Germany, Japan and so forth and it found could provide a numerous of benefit towards to the environment, building and also the users. Although that green roofs are deemed as the most suitable technology to be applied in Malaysia to improve the environment, however, the implementation of green roof in Malaysia is still low and considers it is a fairly new concept to Malaysia' Construction Industry. A research has found that the slow implementation rate of green roof systems in Malaysia is due to the nine factors, which are catered in lack of knowledge and awareness, lack of incentive, cost-based barriers and technical issue and uncertainty of green roof systems. Then, the research result shows that the cost-based barriers and the lack of incentive and initiative from the Government are the main challenges to the adoption of green roof systems in Malaysia. Hence, more efforts are required to encourage the construction practitioners to the implementation of green roof systems (Mahdzir et al., 2020).

Each component in green roof has the crucial roles in ensuring the system can be operating smoothly especially the components that able to influence the load applied on the entire building. Based on the urban stormwater structural design, the most important aspect in ensuring the performance of green roof are the selection of material used for each layer (Asman et al., 2017).

Furthermore, recycled waste materials are highly recommended to be used in promoting a sustainable and low-cost green roof system when compared to conventional green roof. In order to have a green roof that can reduce the effect of Urban Heat Island (UHI), the recycled waste materials must have the required characteristics.

As a result, concerns have been raised that call into question the validity of the green roof system's performance using recycled waste material that is readily available in Malaysia. In order to address the difficulties of high cost and choosing an appropriate green roof material, it is important to conduct research on the capabilities of recycled green roofs.

1.3 Objectives

The main objectives of this study are:

I. To construct an extensive green roof system that can reduce the impact of Urban Heat Island (UHI) using coconut waste as green roof materials.
II. To evaluate the performance of green roof in reducing the temperatures of the roof surface and the surrounding air.

1.4 Scope of Study

The scope of study focused on the evaluation of green roofs in terms of temperature of the roof surface and the surrounding air as well as reduction of impact of Urban Heat Island (UHI). The experiment was done on a lab-scale basis, with a model replacing the actual building. A thermometer is used for data collection. Experiment was conducted at Hydraulics and Hydrology Laboratory, Faculty of Civil Engineering Technology, University Malaysia Pahang, Gambang. A non-vegetated roof (control), a green roof with recycled waste materials as layers (Coconut shells, coconut fibre), and a green roof with commercial materials as layers were all built as prototype models (drainage cells, geotextiles). Both of them are utilizing Philippine grass as a vegetation layer. The two green roofs' performance in terms of improving thermal quantity was compared (commercial and recycled waste materials). The study includes a collection of the changes of thermal differences data taken at morning, afternoon and at night for 2 consecutive weeks.

1.5 Significance of Study

The green roof system delivers greater sustainable development benefits in the context of green building. Additionally, the application of recycled waste material in green roof systems is able to reduce landfill trash (Shahid et. al., 2016). The type of materials has a significant impact on the performance of the green roof in terms of environmental friendliness. As a result, the study highlighting the performance of recycled waste material for green roof systems is essential for addressing the effects of urban heat island.

It is totally vital to do a study on green roofs in order to provide support in the management of energy consumption, in particular for the aim of improving thermal performance. In addition to this, it seeks to foster the development of green roof structures in Malaysia, where there is currently a restricted amount of applicability for such systems. In point of fact, the rapid development that is taking place in Malaysia at the present moment is one of the benefits that can be acquired by making use of the green roof. This is one of the advantages that can be gained. This is due to the presence of a large number of buildings with flat roofs. In spite of this, the idea of a green roof in Malaysia is still considered to be a rather fresh one, and only a select few structures have adopted it at this time. The study will contribute to the Green Technology Master Plan of 2017 to 2030, the purpose of which is to increase the number of environmentally friendly buildings in Malaysia. In addition, the study will also contribute to the Sustainable Development Goal 11 (SDG 11).

When compared to conventional roof systems, green roof construction aims to be more efficient. This is because the material that is used in green roof systems, which includes waste and recycled material, is more efficient than the material that is used in traditional roof systems. A green roof, in addition to its other potential benefits, is one way to contribute to the long-term viability of metropolitan areas by mitigating the negative effects of urbanisation. Reduce, reuse, and recycle are the three components of the "3R" method, which stands for "reduce, reuse, and recycle." If we want to have a healthy environment, we need to reduce the amount of waste that we throw away, and one of the methods that we can use instead of just throwing things away is the "3R" method. As a result, application of a green roof can be one of the measures taken to maintain a healthy environment by using waste products that have been recycled, such as coconut husks, as the material in the roof's layers.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The phenomena whereby urban regions are hotter than surrounding rural areas is known as Urban Heat Islands (UHI) (Silza et al., 2018). This situation is primarily attributable to urbanization and rural-to-urban migration. Due to the presence of a high concentration of pollutants in heavy rainfall, this circumstance generates impermeable surfaces that represent a severe problem (Suszanowicz and Kolasa-Wicek, 2019). In addition, the rise of porous soil caused by human and industrial activity is degrading groundwater quality, despite the fact that the soil removes contaminants and functions as a filter for water passing through it (Rubaba, 2016). Furthermore, changes in the volume of surface runoff due to increases in impermeable surface cover associated with urbanization create effects including increased flood rate and erosion (Moore et al., 2017). Figure 2.1 shows the development of urbanization in Malaysia.

Figure 2.1 Kuala Lumpur city, Malaysia

Source: Department of Statistics Malaysia (2020)

2.2 Urban Heat Island Effect

An Urban Heat Island (UHI) is a densely populated city or area that is substantially warmer than the surrounding region. The heat that is emitted from vehicles, power plants, air conditioners, and other complex urban buildings are the primary contributors to the Urban Heat Island (UHI) effect. The thermal and surface radiative qualities of building materials like concrete and asphalt are notably different from those of natural landscape, which can absorb energy from the sun and convert it to perceptible heat. Building materials like concrete and asphalt are used in construction. In addition, the UHI can be influenced by a number of different factors, such as the scarcity of green places and water. The urban environment is susceptible to the UHI phenomena not only during the day but also during the night. This is due to the fact that the absorbed heat is radiated back to the surrounding environment throughout the evening. (Odli et al, 2016). This phenomenon is illustrated in Figure 2.2.

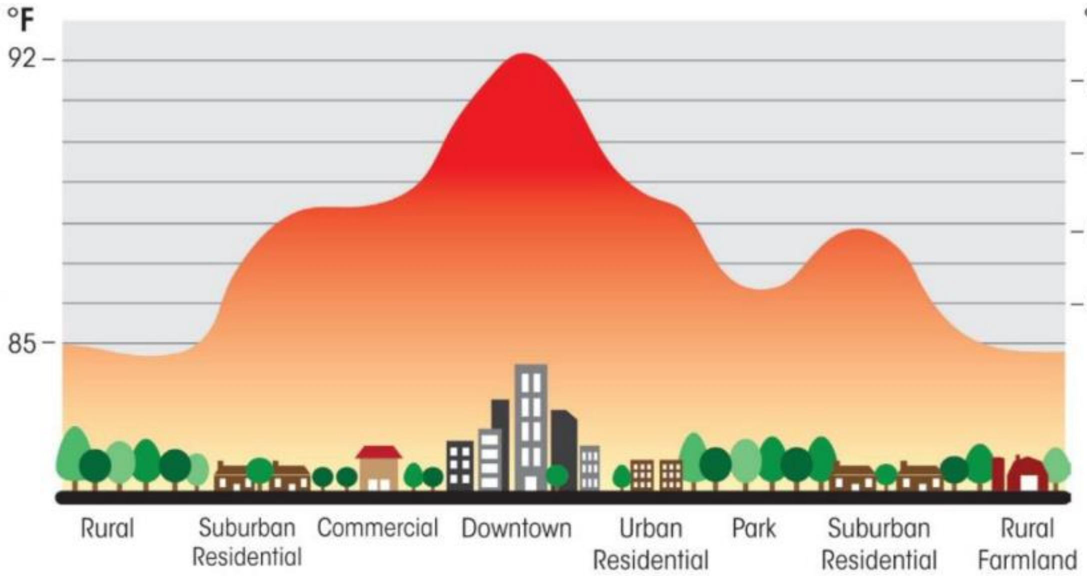

Figure 2.2 Urban Heat Island profile

Source: Odli et al (2016)

2.3 Green Roof

Green roofs can be defined as vegetated layer on top of a roof structure that has certain components and depth. (Ismail et al., 2018). A green roof is an innovative form of roofing. The green roof is a system that used growing medium and vegetation on the top of the building roof (Creswell, 2007). Most green roof installations in Malaysia are found on residential buildings and are of the intensive type. (Ismail et al., 2018). Figure 2.3 shows the implementation of green roof in Malaysia.

Figure 2.3 Application of Green Roofs at Bandar Rimbayu, Shah Alam

Source: Ismail et al (2018)

2.3.1 Benefits of Green Roof

There are many benefits to having a green roof. Having a green space among so many constructed facades is a unique aesthetic rarely seen in the "concrete jungle". Having a vibrant, living green roof not only looks great, but also has a whole host of benefits. Green roofs can be used for storm-water management, providing water to the new plants, which then return the water into the atmosphere through evaporation. A green roof can hold a certain amount of water, which delays storm-water runoff and lightens the load of sewer systems at a time when it is truly needed.

A green roof in an urban environment moderates the Urban Heat Island effect (where urban environments absorb and trap heat), improves air quality, and captures airborne pollutants, all of which contributes to a better, cleaner environment. In addition, they also reduce outside noise by 40 decibels, which can make a loud truck into a minor annoyance.

Green roofs also contribute to energy efficiency. They add greater insulation, which can reduce the amount of energy used to moderate building temperature.

Researchers have found that an extensive green roof (15-50 lbs. per sq. ft.) can reduce daily energy demand from air conditioning by 75%. A green roof can also be used to grow food, which can not only reduce someone's carbon footprint, but also create a local food system. A green roof can also contribute to better water quality, increased biodiversity, and a better sense of community. Building a green roof is worthwhile for anyone looking for a project that's not only rewarding but also environmentally-friendly.

2.3.2 Type of Green Roof

Many experts confirm that green roof can be classified into two types of systems which are intensive and extensive (Long et al., 2006, Pushkar, 2019, Creswell, 2007, Castleton et al., 2010).

2.3.2.1 An Intensive Green Roof

An intensive green roof which can be seen from Figure 2.4 is a living roof capable of supporting much larger, more complex plant structures and designs than their extensive counterparts. Most commercial or larger scale residential projects are intensive. Intensive system is more like a roof garden supporting large tree and shrubs, but require deep substrates and regular maintenance. Therefore, it is generally heavy and requires a specific support from the building (Pushkar, 2019, Creswell, 2007).

Figure 2.4 Intensive Green Roofs at Acappella Residence, Shah Alam

Source: Ismail et al (2018)

2.3.2.2 An Extensive Green Roof

In order to create a functional roof with the green roof system that simply required minimal maintenance, an enormous green roof is constructed. A substantial green roof is constructed using a substrate with a depth of 7 to 12 cm and a weight of 150 kg/m^2 (Petrovic et al., 2017). Due to the shallow depth of the substrate, sedums, succulents, and other drought-tolerant plants were frequently used to cover the system. Benefit-wise, an extended green roof can totally cover the roof with surface plants while requiring little maintenance and placing a small stress on the building structure. The system's qualities make it easier to replace and do not require an irrigation system for the plant that is used. One of the enormous green roof systems installed at the Heriot-Watt University in Malaysia is depicted in Figure 2.5.

Figure 2.5 Extensive Green Roofs at Heriot-Watt University, Malaysia

Source: Ismail et al (2018)

2.4 Layers of Green Roof

Each layer of a green roof serves a distinct purpose, allowing the roof as a whole to perform its many functions. Vegetation, a growing medium, a filter sheet, a drainage layer, and a waterproofing layer make up the bulk of a green roof's multiple layers. Green roofs can be either extensive or intensive, with the latter having a clearer distinction between its layers and structure as shown in Figure 2.6. Leak detection systems, irrigation, and thermal insulation are just some of the additional features that can be incorporated into the green roof's various layers depending on the budget. In order to achieve a sustainable design and satisfy client needs, it is critical to pick the right green roof materials (Vijayaraghavan, 2016). Therefore, the layer's inclusion in the green roof system is context and necessity dependent.

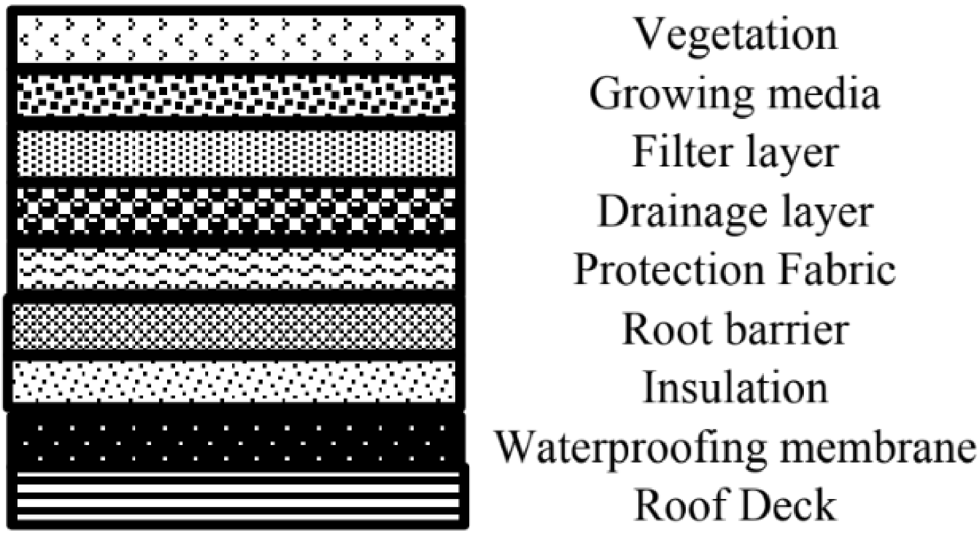

Figure 2.6 Structure of green roof system

Source: Chow and Abu Bakar (2016)

2.4.1 Vegetation Layer

Vegetation is the most significant aspect of a green roof. Green roof plant choices is heavily influenced by climate. Vegetation has an important function in the urban environment, boosting evapotranspiration, decreasing the urban heat island effect, increasing biodiversity, and achieving attractive views and recreational goals (Palla et al., 2018). However, vegetation used for green roofs must be able to withstand drought, flourish in low-nutrient conditions, offer ground cover with little roots growth, and require minimal upkeep (Vijayaraghavan, 2016).

The climate in Malaysia is hot and rainy, which might damage rooftop vegetation. The best vegetation for wide green roofs includes sedum, grasses, non-woody plants, and mosses (Isa et al., 2020). Wet or dry climates should not affect the extensive green roof plants. Because green roofs improve climate, plant kinds should withstand severe temperatures and wind. Otherwise, vegetation protects substrate and arthropods and birds. Species improve water, air, and thermal performance on green roofs. Additionally, ground-covering vegetation is best for sloped roofs because it reduces runoff and improves evapotranspiration. Zoysia japonica (Japan grass) was employed by Kok et al. (2016) because of its ability to cover the ground, and the green roof reduced peak flow by 47.3%.

The best plant for green roof systems is Sedum, including Sedum Spectabile and Radix Ophiopogonis, which retains 31.3% of runoff (Liu et al., 2019).

Malaysian native plants were used in Chow et al. (2018)'s green roof retention experiment. Axonopus Compressus performs worse than Portulaca Grandiflora, a sedum species (Cow Grass). Silva et al. (2019) tested bromeliads' stormwater retention in Rio de Janeiro. Limited plant types must meet severe plant selection requirements. Succulents, tall forbs, dwarf shrubs, creeping forbs, and graminoids can be used as green roof vegetation. Functional diversity and variety of growth forms can improve the resilience and performance of green roof systems (Thuring & Dunnett, 2019). Succulents and other sedum species are chosen for green roofs because they can survive without irrigation and tolerate substrate moisture shortages (Rayner et al., 2016).

2.4.2 Substrate Layer

The substrate's chemical and physical qualities support plant growth. The substrate must be permeable to allow water to move into the drainage layer and not exceed the structural building's capacity load (Eksi & Rowe, 2016). Water quality, peak runoff, sound, and thermal insulation are affected by substrate. Green roof substrate selection must reflect the system's purpose (Vijayaraghavan, 2016). Nagase (2020) found that commercial green roof substrate flora was nearly dead compared to cocopeat substrate. Each substrate's physical properties vary, affecting its ability to retain water. The vegetation selected determines the substrate depth for extensive and intensive green roofs. Since intensive green roof vegetation is greater, the substrate layer must be deeper and more nutrient-rich. Smaller vegetation can grow in low substrate thickness on the broad green roof.

2.4.3 Filter Layer

The filter layer prevents substrate and silt from clogging the drainage system by letting water pass through. Unwanted debris in drainage layers will stimulate weed growth and obstruct the system. Granular and geotextile filter layers are available. Non-geotextile materials are used as filters because they are lightweight and can support the upper layers while acting as a root barrier membrane for vegetation. Cascone (2019) found that granular material as pumice, expanded clay, and crushed bricks has water permeability greater than 0.3 m/s and non-woven geotextiles absorb 1.5 L/m^2.

2.4.4 Drainage Layer

The drainage layer in a green roof system balances air and water. The drainage layer drains extra substrate water to maintain an aerobic substrate environment. In addition, it protects waterproof membranes and improves system thermal characteristics. The commercial materials are modular layers of high-strength plastic (polyethylene or polystyrene) with sections to retain water and evacuate surplus water. The HDPE membrane may store water in cavities or cups. Pozzolana, pumice, and lapilli will be employed in the drainage layer and as water storage for granular materials. The right drainage layer depends on the location's rainfall, building needs, structural requirements, costs, green roof size, roof slope, discharge quantity and velocity, and plant type (Cascone, 2019).

2.4.5 Waterproofing Layer

The layer of a grassy roof comes first for maintaining the structural envelope. Water has changed throughout time into one of the most harmful natural resources. Naturally, the main water-holding systems on the rooftops cannot be constructed without covering the roof with a membrane that is waterproof. All green roofs have layers, but the thick waterproofing barrier layer is the most important one. Regardless of how significant it is, a leaky green roof is still a broken one. It is possible to twist, apply fluid, or insert sealant membranes into pre-formed sheets, among other forms and application techniques. When evaluating waterproofing membranes, flexibility and resilience are key criteria.

2.5 Green Roof Guidelines

The design and associated green roof test were based on FLL recommendations taken from Losken et al. (2008). Due to the lack of particular green roof guidelines for Malaysia, the technical requirements given by the FLL guidelines were utilized in the construction and evaluation of the green roof system in this study. The guidelines for the planning, construction, and maintenance of green roofs include the legislative framework condition, types of green roof and forms of vegetation, as well as the operational and impacts of green roofs. In addition, the guideline specifies requirements for construction and building materials. Figure 2.7 shows the typical cross-section of green roof system.

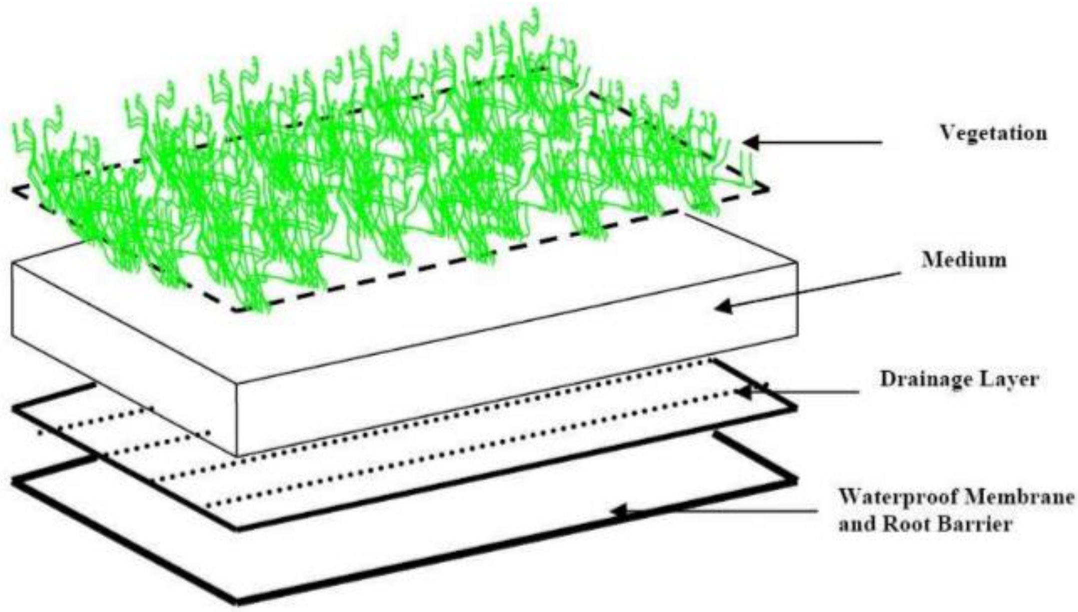

Figure 2.7 Typical cross-section of green roof system

Source: Berghage et al. (2009)

2.6 Recycled Waste Material for Green Roof

Recycled or natural materials boost sustainability. To eliminate commercial materials in green roof layers, several materials were examined. Oil palm fibre and crumbled bricks can substitute commercial substrate in substrate layers, whereas rubber crumbs work well as green roof drainage layers (Siew et al., 2019). Recent research included repurposed bricks, concrete, and sawdust. Due to its coarser texture, crushed concrete boosted root aeration and drainage but failed to meet water retention and weight limits (Eksi et al., 2020). Cocopeat, which is lightweight and easy to care, has also been used in green roof substrate layers. Cocopeat outperformed conventional green roof substrate. Cocopeat-grown turf survived whereas commercial green roof substrate turf died (Nagase, 2020).

To enhance water absorption and better the quality of stormwater runoff, a filter layer was replaced with recovered waste material. The ideal filter replacement material would allow water to pass through but stop dust and other tiny particles from entering the drainage layer. In addition, the filter layer's elements need to be robust enough to withstand the pressures of installation without failing prematurely.

When comparing the hydraulic performance of green roof systems, Carrera et al. (2022) use three distinct filter layer types, including black woven geotextile, reused non-woven geotextiles, and geofoam. They decided that non-woven geotextiles that have already been used once are the best option because of their ability to filter stormwater runoff. According to earlier research (Asman et al., 2017), using natural fibres like coconut fibre and palm oil fibre in the filter layer is preferable than using sugarcane fibre. The results of the experiment indicated that the combination of coconut fibre and palm oil has the ability to reduce the levels of turbidity, chemical oxygen demand (COD), and total suspended solids (TSS). The coconut fibre has the highest pH-lowering ability (about 7.38%) and the palm oil fibre has the lowest (roughly 7.08%) of any natural fibre.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter provides an overview of the methods that were implemented in order to achieve the goals of the study. These methods include the design of the lab-scale prototype model, the selection of plants and materials for each layer, and the evaluation of the system's performance in terms of reduction of Urban Heat Island by observing the thermal performance between a common roof without vegetation and a vegetated green roof system.

3.2 Methodology of study

Figure 3.1 depicts the research approach that was taken for the study. The design of a green roof is based on an objective scope that is able to collect data for the purpose of measuring temperature. The structure and design are made up of two primary components, namely the roof component and the building component. The material that would be used to replace the material of the commercial roof green roof was then determined. Before the raw material can be used, it must first go through some preparation and then go through a few processes. Philippine Grass was decided upon as the species of plant life to be used in the green roof system. Coconut shells take the place of the modular panels in the drainage layer, and coconut fibres take the place of the geotextile fabric that was used in the filter layer. The data collection process involved the utilisation of three distinct models. The effect of the urban heat island can be seen by observing the trend of change in temperature. The experiment was carried out with the aid of a thermometer, and data regarding the interior and exterior temperatures of the structure were gathered each morning, afternoon, and night for a period of two weeks in a row.

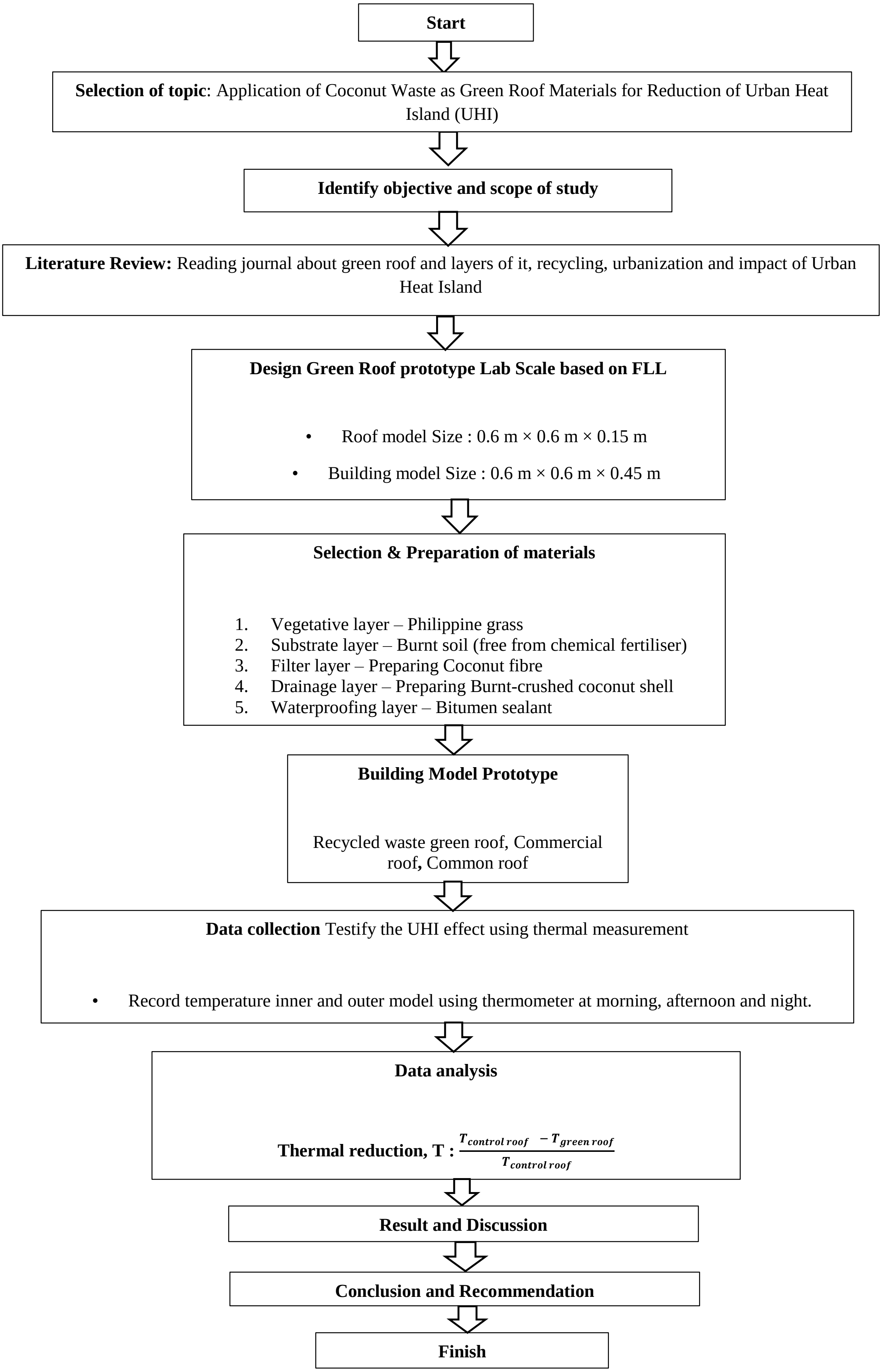

Figure 3.1 Flowchart of study methodology

3.3 Design of Green Roof Prototype Model and Layers

The prototype model is composed of two sections which divide the place to put the green roof system on the top and the bottom section to support the load applied. The dimension of the full prototype model is illustrated in Figure 3.2. and Figure 3.3. The wall of the prototype model is made of gypsum board and the corner is attached with pipe to collect the water runoff. The properties of gypsum board able to hold the load of the green roof layers applied. The thermometer is placed at inside and surrounding model of the green roof structure to mimic the real building structure. Figure 3.2 and Figure 3.3 show the dimensions of the two components.

Specifically, the study focused on the role of vegetation architecture and species composition on runoff quality and quantity and was based upon observations that interception of rainfall in grasslands varies with species composition, and that the percentage of annual rainfall lost through interception by grasses can vary with species and with vegetation height. A system of ‘microcosms’ (small, self-contained artificial plant communities) and lysimeters (apparatus for collecting run-off) was constructed, consisting of trays with dimension 600×600×150 mm deep from black polypropylene plastic as suggested by Dunnet et. al (2008). The preparation of the model also based on FLL Green Roof Guidelines by Losken et. al (2018).

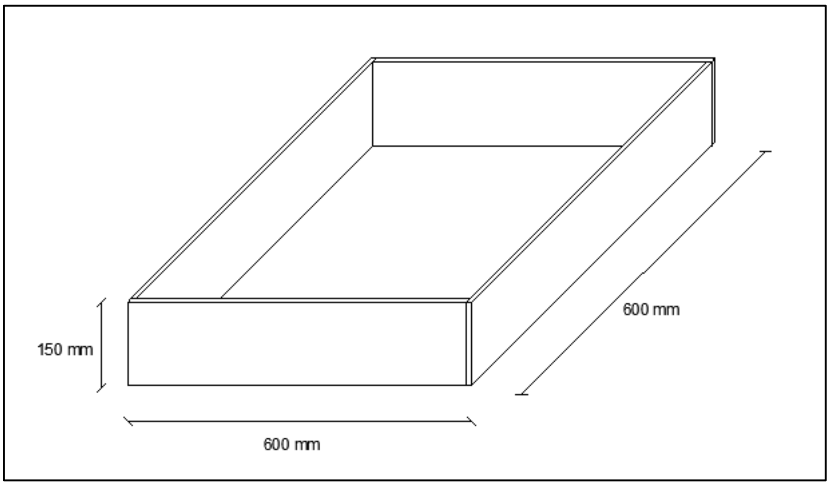

Figure 3.2 The Dimension of Roof Model

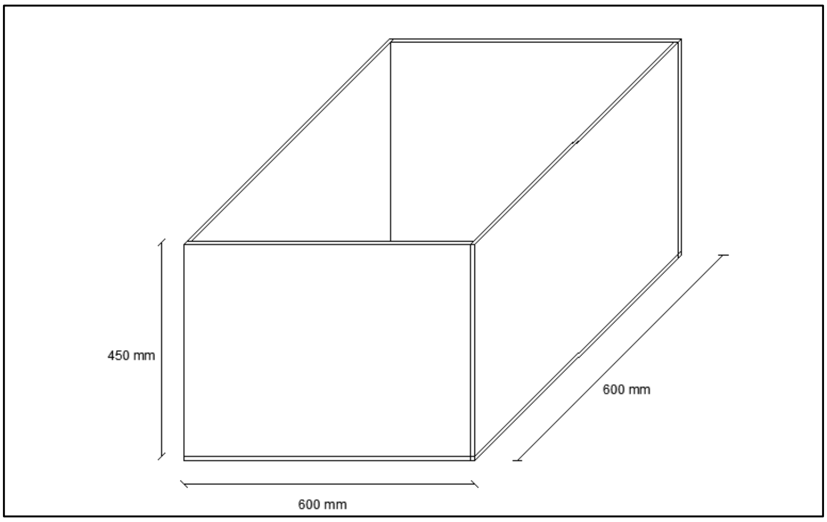

Figure 3.3 The Dimension of Building Model

For the purpose of this project, the material and dimension that will be used to make the model of the green roof have been selected and decided upon. In order to ensure that the objectives of this study are satisfied, the selection of both of the factors is absolutely essential. The dimension layers for recycled waste and commercial roof are displayed in Figure 3.4 and Figure 3.5 respectively. 100mm are devoted to the substrate layer, 20mm are devoted to the filter layer, and 35mm are allocated to the drainage layer.

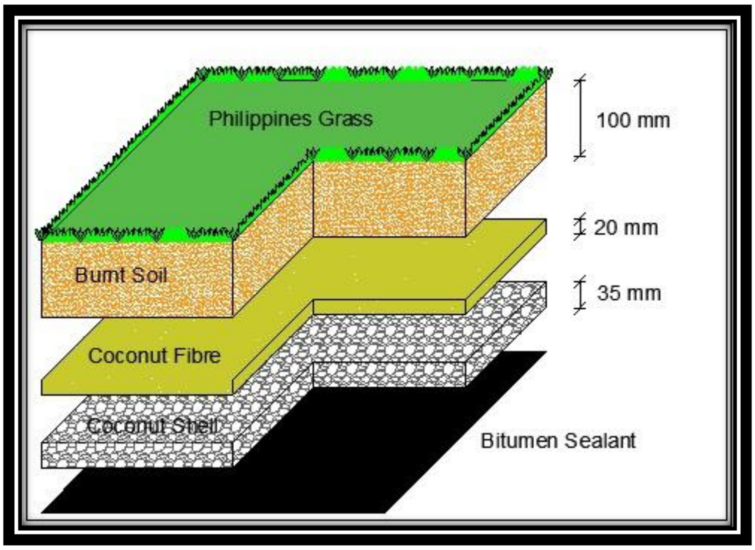

Figure 3.4 Layers Dimension of Recycled Waste Green Roof

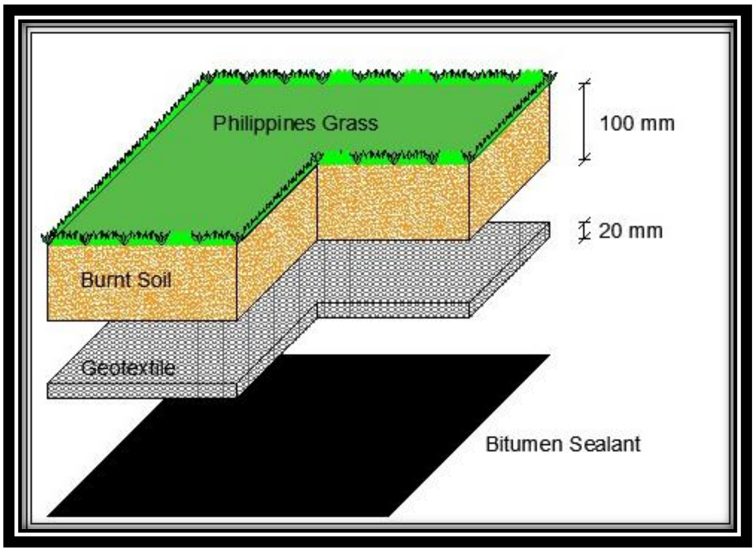

Figure 3.5 Layers Dimension of Commercial Green Roof

3.4 Preparation of Prototype Model

Gypsum board is used as the structural component of the model and construction sealant is used to attach the gypsum board. The vegetated model consists of five major layers which include vegetation layer, substrate layer, filter layer, drainage layer, and waterproofing layer. The preparation of roof and building model and producing the layer of vegetated prototype model, from top to bottom, is shown in Figure 3.6 to Figure 3.14. The process started with cutting the gypsum board according to the exact dimension. Then, attached the gypsum board using the construction sealant. Next is making a hole to insert pipe outlet. Then, apply the bitumen sealant. After applying the bitumen sealant, the model needs to be rest for a while until the bitumen sealant is completely dry. Next, pour the burnt-crushed coconut shell into the roof model. After that, put the coconut fibre on top of the burnt-crushed coconut shell. Consequently, place and level the burnt soil into the prototype model and lastly plant the vegetation, Philippine grass. The final product of the prototype model is shown in Figure 3.15.

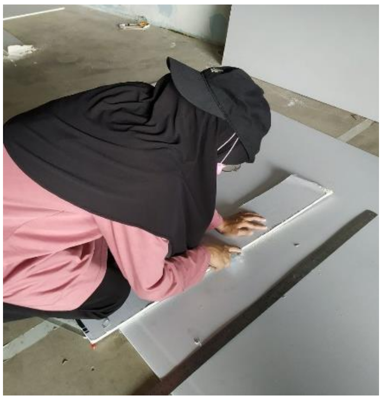

Figure 3.6   Process of cutting gypsum board

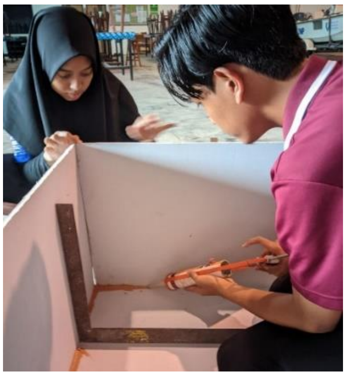

Figure 3.7 Process of placing the sealant

Figure 3.8 Let the construction sealant completely dry

Figure 3.9 Process of drilling a hole to insert pipe

Figure 3.10 Process of applying the bitumen sealant at the bottom of the structure

Figure 3.11 Drainage layer of the green roof (coconut shell)

Figure 3.12 Filter layer of the green roof (coconut fibre)

Figure 3.13 Substrate layer of the green roof (Burnt soil)

Figure 3.14 Vegetation layer of the green roof (Philippine Grass)

Figure 3.15 Final product of Geen Roof Prototype Model

3.4.1 Vegetation

The flora layer's biodiversity and photosynthesis helped regulate the building's temperature. Photosynthesis converts extra carbon dioxide into oxygen, cooling the environment. The plants on huge green dorm roofs should rejuvenate and adapt to the local environment and harsh roof weather. As illustrated in Figure 3.16, Philippine grass is employed as plant layer in this investigation. Since it grows in any conditions, Philippine grass is easy to find. Its grassy area helps prevent flooding and erosion by retaining rainwater. The flora layer's biodiversity and photosynthesis helped regulate the building's temperature. Photosynthesis converts extra carbon dioxide into oxygen, cooling the environment. Evapotranspiration, where water from the soil travels up to the leaf through its roots and stem and evaporates through the stomata, can also raise humidity.

Figure 3.16 Vegetation layer of green roof model

3.4.2 Substrate layer

The substrate layer components are depicted in Figure 3.17. The upper 2 to 8 inches of soil, known as burnt-soil, contain the vast bulk of the ground's remaining nutrients and fertility. Both green roof versions have a sufficient 100 mm of substrate depth, so the Philippine grass can thrive there. The substrate layer should be composed of low-maintenance soil that has an optimal nutritional composition. The green roof's effectiveness can be affected by the substrate's permeability to water, its capacity to hold water, and its moisture content. As a result, the soil that has been burned is employed in the substrate layer because it can absorb water more effectively. Because of its low density, this soil can be used on the massive green roof, reducing the stress on the underlying structure (Eksi & Rowe, 2016).

Figure 3.17 Substrate layer of green roof model

3.4.3 Filter layer

The commercial material, non-woven geotextile, is being substituted in this study with the coconut fibre depicted in Figure 3.18. Coir, or coconut fibre, is the dense fibrous material found in the coconut's flesh that also happens to be incredibly lightweight. Incorporating coconut fibre into a green roof system merely adds a mild load that won't compromise the integrity of the building as a whole. The waste materials, like coconut fibre and coconut shell, are abundant and cheap to source in Malaysia. Coconut fibre has a high lignin content, which gives it excellent strength, durability, resistance to decay, water absorption, and thermal properties (Shravan Kumar et al., 2021). Coconut fibre was chosen as the substrate because of its ability to filter out larger particles while allowing water of higher quality to get through to the lower layer. Peak discharge can be mitigated by the incorporation of coconut fibre, which absorbs precipitation (Alias et al., 2020).

Figure 3.18 Filter layer of the recycled waste green roof

The procedure of preparing raw material for the filter is illustrated in Figure 3.19. The coconut fibre that serves as the filter layer is made from recovered waste materials. To get the process underway, the raw materials were amassed and brought together. In order to separate the component of the fibre that is made from the coconut, the coconut fibre is separated from the husk. The next step is the cleaning and washing process for the coconut fibre. After the material has been cleaned, it is next dried in the open air by being subjected to direct sunshine for a period of time before being shredded. Shredded coconut fibre is equally distributed throughout the prototype after being prepared in this manner.

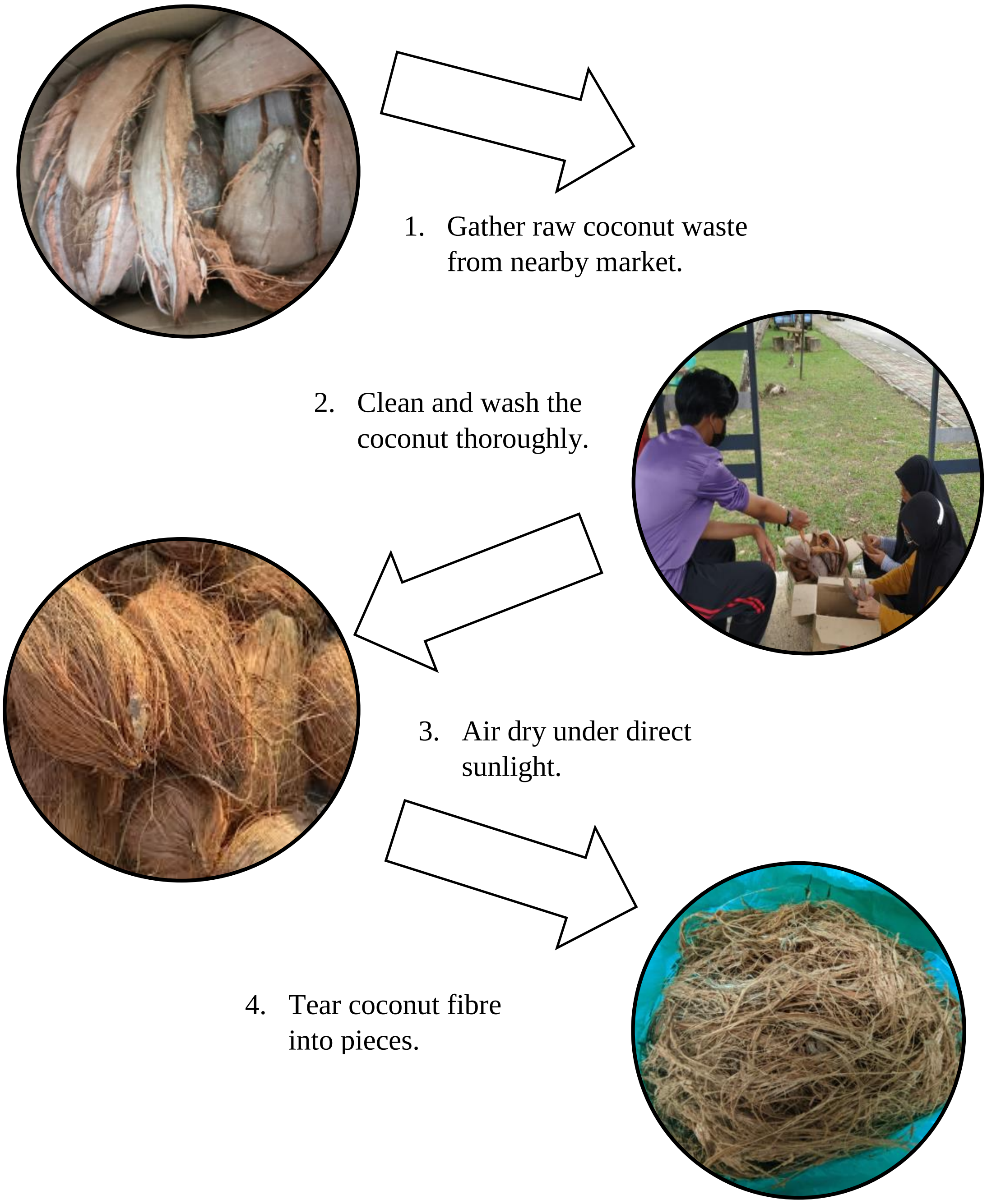

Figure 3.19 The process of preparing the coconut fibre

3.4.4 Drainage Layer

The drainage layer plays the important roles in the overall system of the green roofs. The drainage layers provide a good aeration of the plants roots as the drainage layer allows excess water to drain away. The material used for these drainage layers is coconut shell depicted at Figure 3.20. Figure 3.21 depicts the procedure that must be followed in order to prepare the coconut shell. The procuring of the raw supplies took place at the neighbourhood market. After removing the husk, you will be left with the coconut shell. The method of heating and activating the coconut was preceded by a drying procedure in which the coconut shell was exposed to direct sunlight. During the activation process, additional porosity is generated, which results in an increase in both the surface area and the diameters. When compared to the state in which the coconut shell has not been activated, this property of the coconut shell enables it to have a greater capacity for the absorption of water.

Figure 3.20 Drainage layer of recycled waste green roof

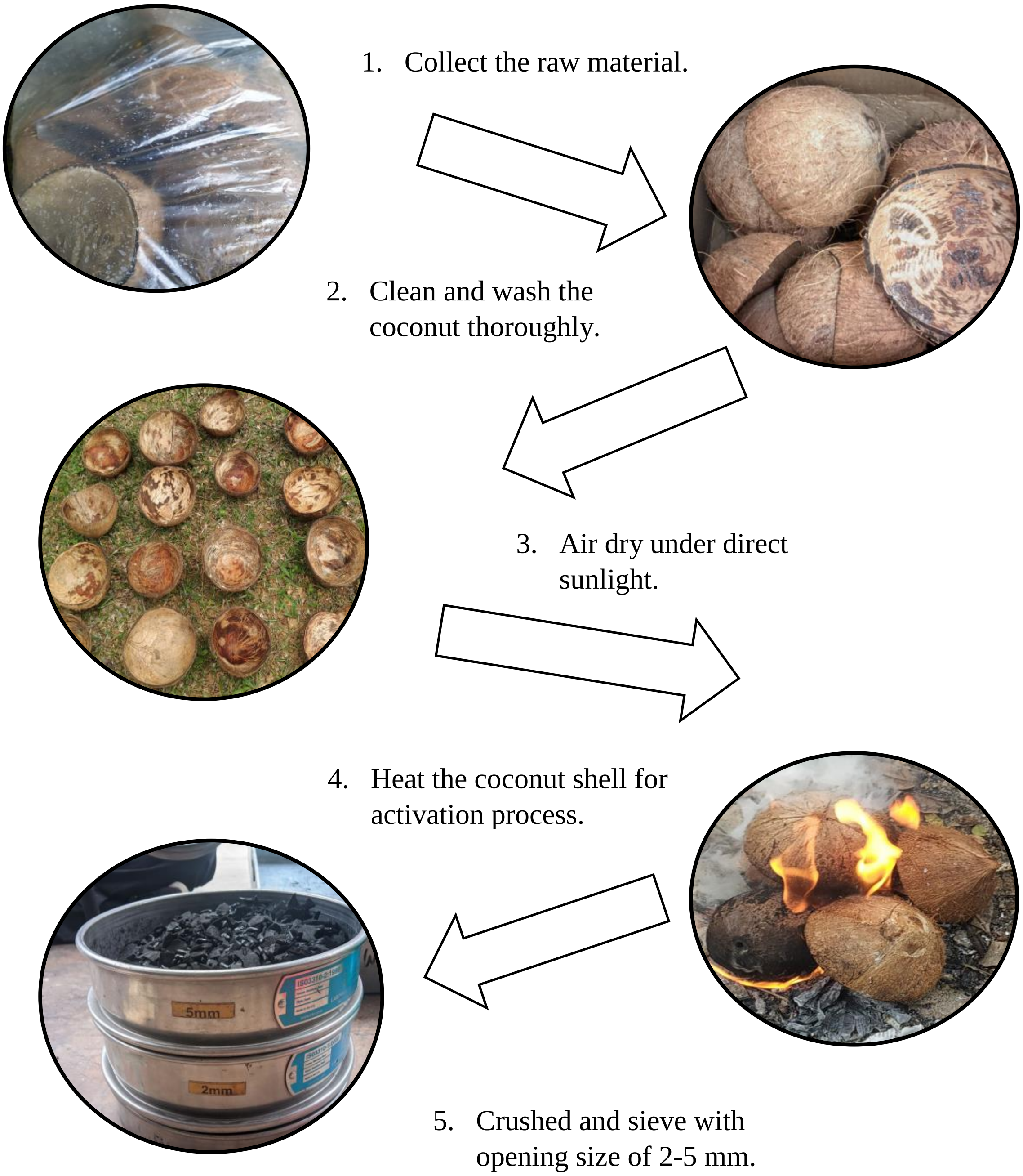

Figure 3.21 The process of preparing the coconut shell

3.4.5 Water proofing layer

The existence of a water proofing layer is essential to the success of a green roof system because it prevents the entire structure from being damaged by water infiltration. For the sake of preventing leaks in the green roof system, its installation is obligatory. When water seeps in through the roof, it can cause extensive damage that necessitates costly repairs. Therefore, a layer of waterproofing will prevent additional harm. This green roof system uses a bitumen sealant as its water-proof layer. The liquid is poured to the base layer to prevent the green roof system's moisture from seeping through. The bitumen sealant is applied to the base of the building, as shown in Figure 3.22.

Figure 3.22 Application of bitumen sealant

3.5 Tested Parameter

The performance of the green roof system in reducing effect of Urban Heat Islands was observed for two weeks. Each data was collected every day at morning, afternoon and night. The experiment was done at the same time for three prototype models, non-vegetated prototype model (control), commercial green roof, and recycled waste green roof as shown in Table 3.1. The expected outcome from the experiment should be that the recycled waste green roof shows the depiction in thermal compared to the commercial roof and control roof.

This study only focus on thermal reduction since there is no fluid involved and the scope only refers to thermal performance without involving any heat transfer, heat flux, electromagnetic waves, giving convection and radiation heat transfer out of calculation. By the end of the study, the total of the two weeks data will be calculated and discussed using Equation 3.1, which only involved the thermal reduction of the prototypes.

$$\textbf{Thermal reduction } (°C) = \frac{T_{contol\,roof} - T_{green\,roof}}{T_{control\,roof}} \qquad \textbf{3 .1}$$

Thermometer is placed and hold tightly by the holder. Observe the level of mercury in the thermometer of surrounding air of the prototype model and note down the reading. Then, put the thermometer inside the prototype building. Observe the change in the mercury level and note down the reading. The testing is conducted simultaneously for the three prototype model every morning, noon and night for two weeks.

Table 3.1 Tested Parameter

Duration	**Evaluation**	**Point of Observation**
Two Weeks	Common Roof	Inside prototype building
	Commercial Roof	
	Recycled waste Roof	Roof surface

3.6 Evaluation of Thermal Reduction

The performance of the green roof system in reduction of Urban Heat Island was observed based on the thermal changes recorded from the inner and outer of prototype building. The thermal changes for the non-vegetated roof (control) was observed, followed by the thermal changes for vegetated roof (commercial and recycled waste). The temperature data is collected for two week. The graph i.e., Thermal Reduction was plotted against the Time for all roof type. Then, the percentage of thermal reduction was calculated by using the Equation 3.2:

$$\textbf{Thermal reduction } (\%) = \frac{T_{contol\,roof} - T_{green\,roof}}{T_{control\,roof}} \times \mathbf{100\%} \qquad \textbf{3 .2}$$

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This study aims to evaluate the effectiveness of green roofs as a method for decreasing the impact of Urban Heat Islands (UHI). In terms of system parameters, vegetation utilized, and material choice for each layer, a green roof at a lab scale was built. The effectiveness of the green roof system was evaluated in terms of decreased change in temperature. In accordance with the study objectives, this part presents the research outcome.

4.2 Temperature of Inner and Outer Buildings within Two Weeks

Figures 4.1, 4.2, 4.3, and 4.4 compare the effectiveness of green roofs in mitigating the effects of Urban Heat Island by depicting temperature data plotted against time for the exterior and interior of the building over the course of two weeks. The peak temperatures of conventional roofs, commercial green roofs, and recycled waste green roofs were all found to be different. Green roofs that incorporate recycled materials have greater potential for heat reduction than commercial green roofs, according to the study's findings. At midday on January 13, the control model registered a maximum temperature of 31.5°C for inner building. The temperature on commercial roofs has dropped to 30°C, and on the same day, 29.5°C was recorded in recycled waste. Figure 4.1 and Figure 4.2 show, for the inside of the building, that the trend of decreasing temperatures for recycled waste is more consistent than it is for commercial and common roofs. The same pattern of results is also seen for the outer of the structure as shown in Figure 4.3 and Figure 4.4. On 3 January at noon, the peak temperature is recorded for control roof which is 33°C followed with commercial roof (32°C) and the lowest is recycled waste (31.5°C). Overall, it can be concluded that the recycled waste green roof manage to reduce the building temperature compared to the commercial and control green roof.

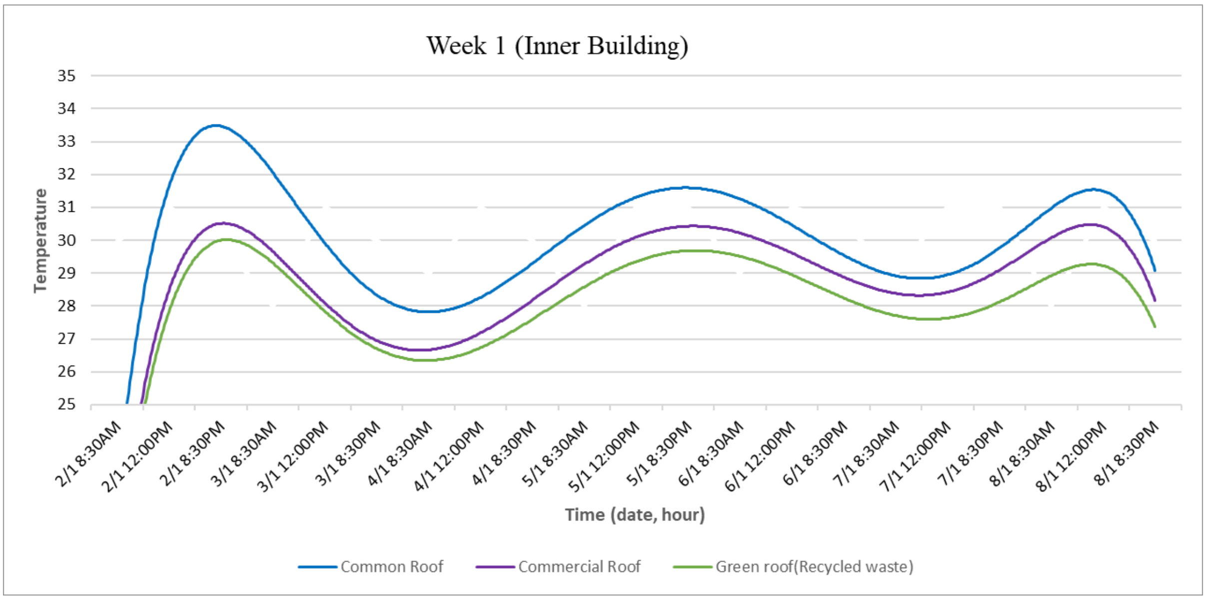

Figure 4.1 Temperature observation for inner building in first week

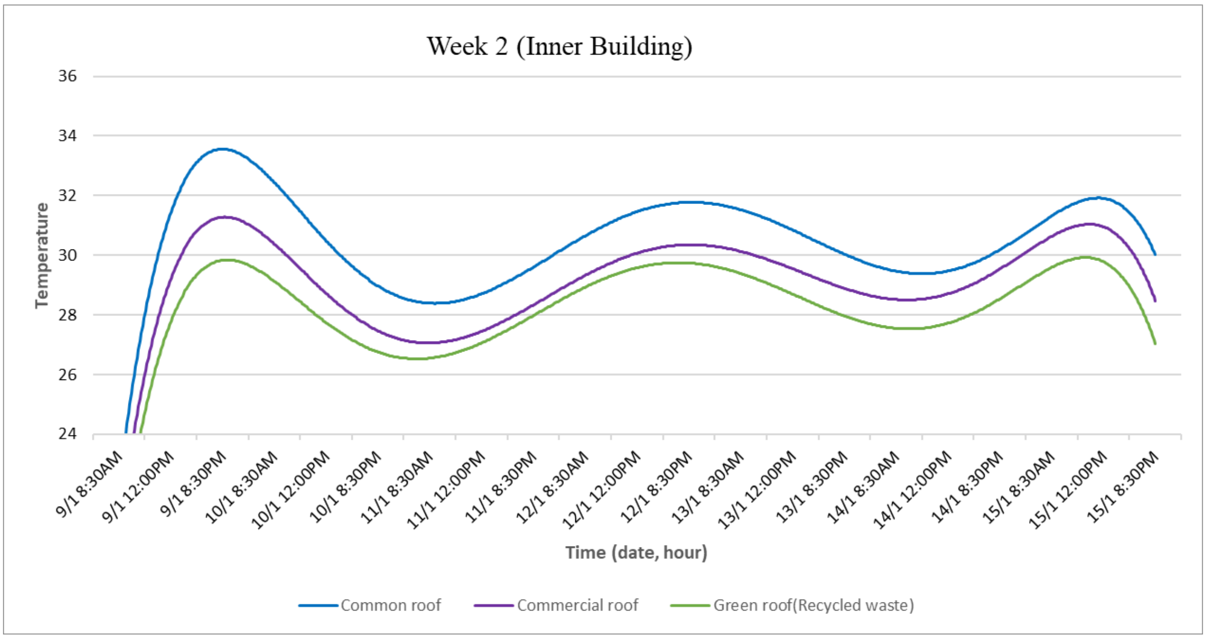

Figure 4.2 Temperature observation for inner building in second week

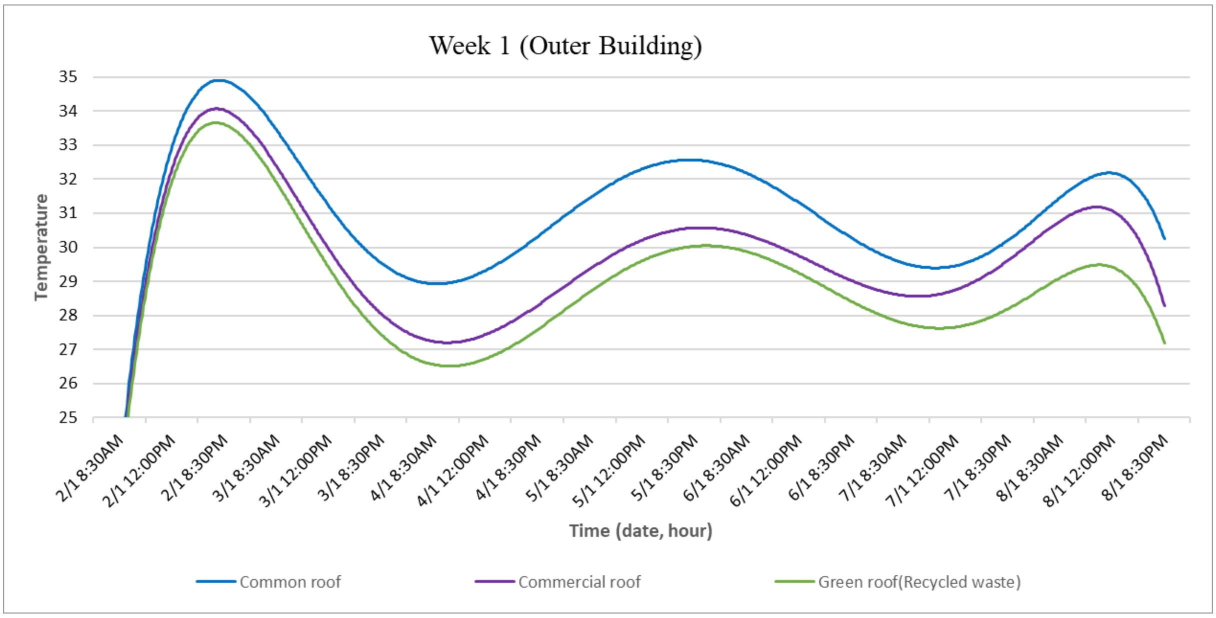

Figure 4.3 Temperature observation for outer building in first week

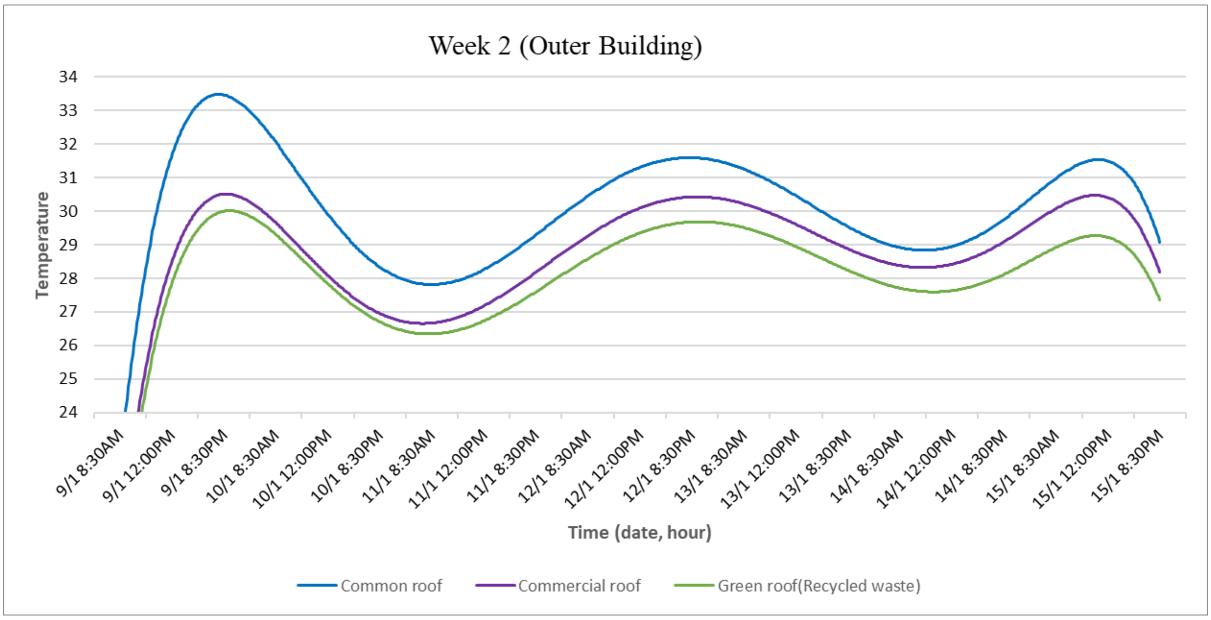

Figure 4.4 Temperature observation for outer building in second week

4.3 Thermal Reduction

Figures 4.5 and 4.6 show the temperature decrease percentage for each model at the inner and outer observation points, while Figures 4.7 and 4.8 show the inner and exterior building temperatures. The heat decrease achieved by commercial and recycled trash green roofs is compared in Table 4.1. Commercial green roofs were found to be effective in mitigating the effects of Urban Heat Island, with reductions of 6.45% and 11.48%, respectively, measured for the building's interior and exterior. A green roof made from recycled materials performs better from a thermal efficiency standpoint, reducing heating and cooling costs by 16.13% and 14.75%; respectively. The use of recycled waste material, such as coconut shell and coconut fibre, likely increased the green roof's capacity to reduce heat gain by a substantial margin.

Table 4.1 Percentage of thermal reduction for commercial roof and recycled waste green roof

	Commercial roof		Recycled waste	
Point of observation	Inner building	Outer building	Inner building	Outer building
Thermal Reduction (%)	6.45	11.48	16.13	14.75

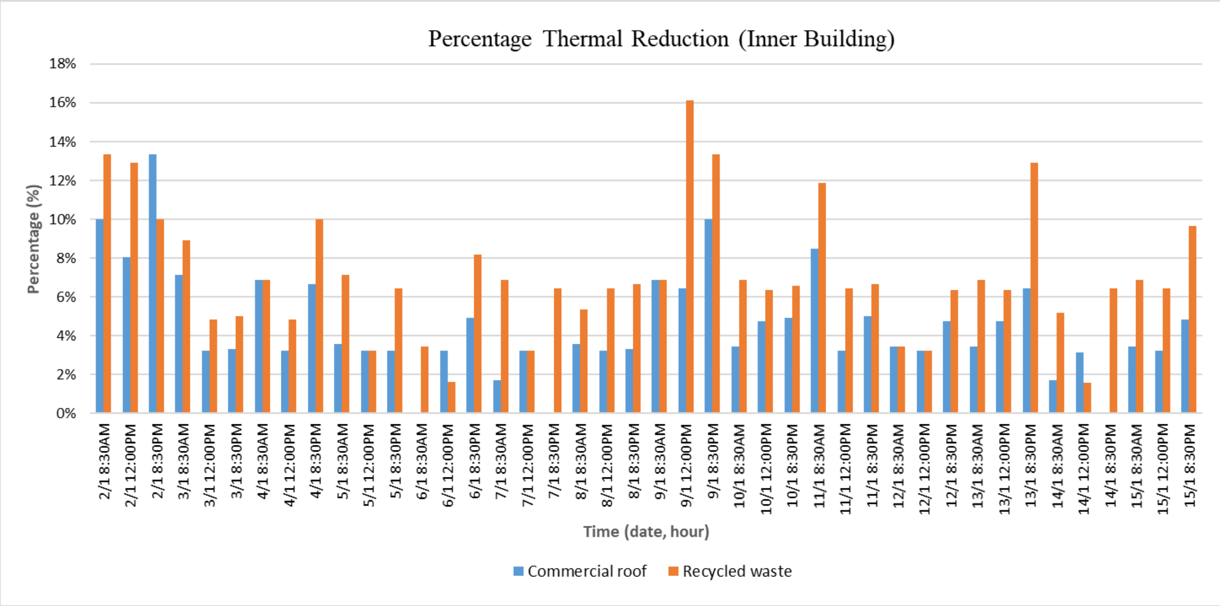

Figure 4.5 Percentage of Thermal Reduction for Inner Building

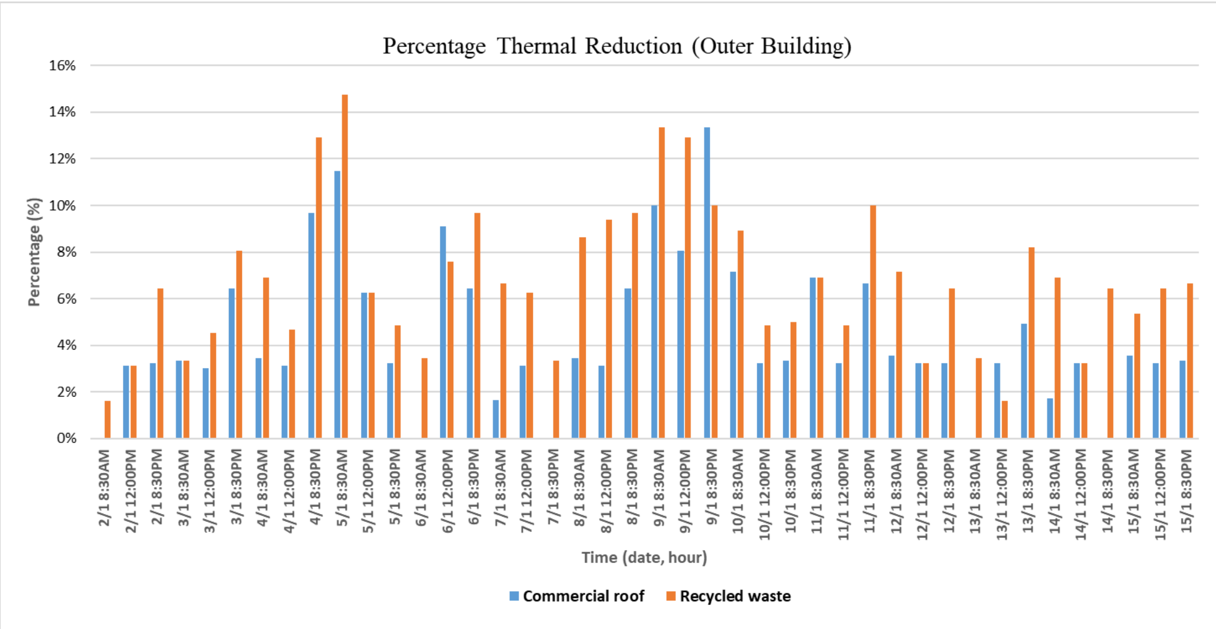

Figure 4.6 Percentage of Thermal Reduction for Outer Building

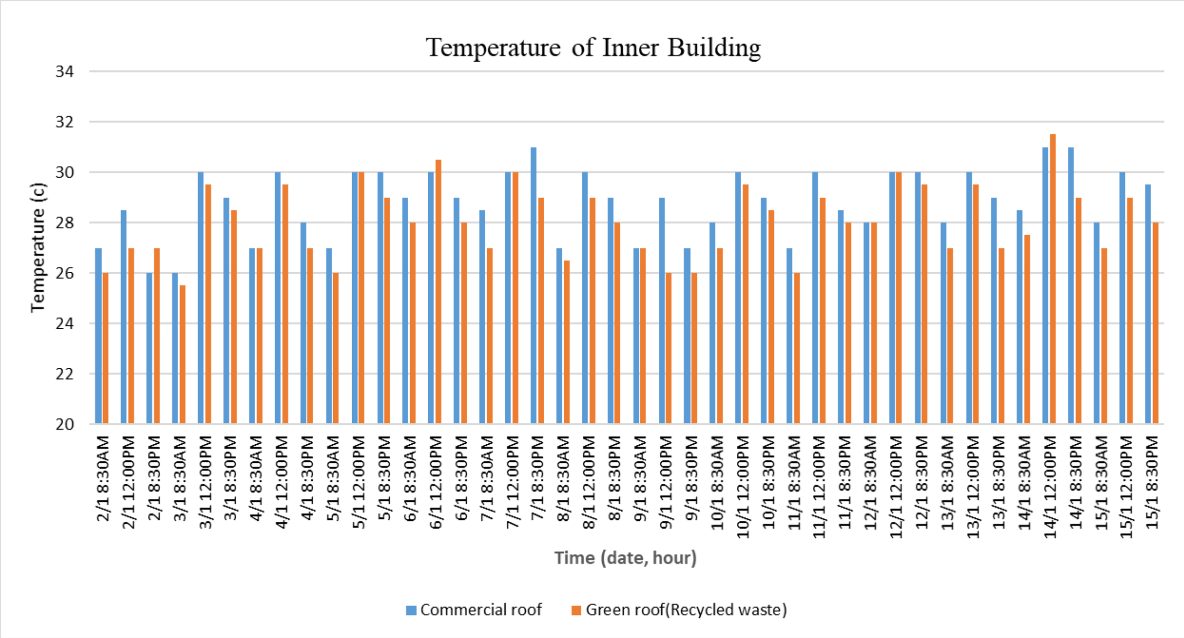

Figure 4.7 Temperature of Inner Building

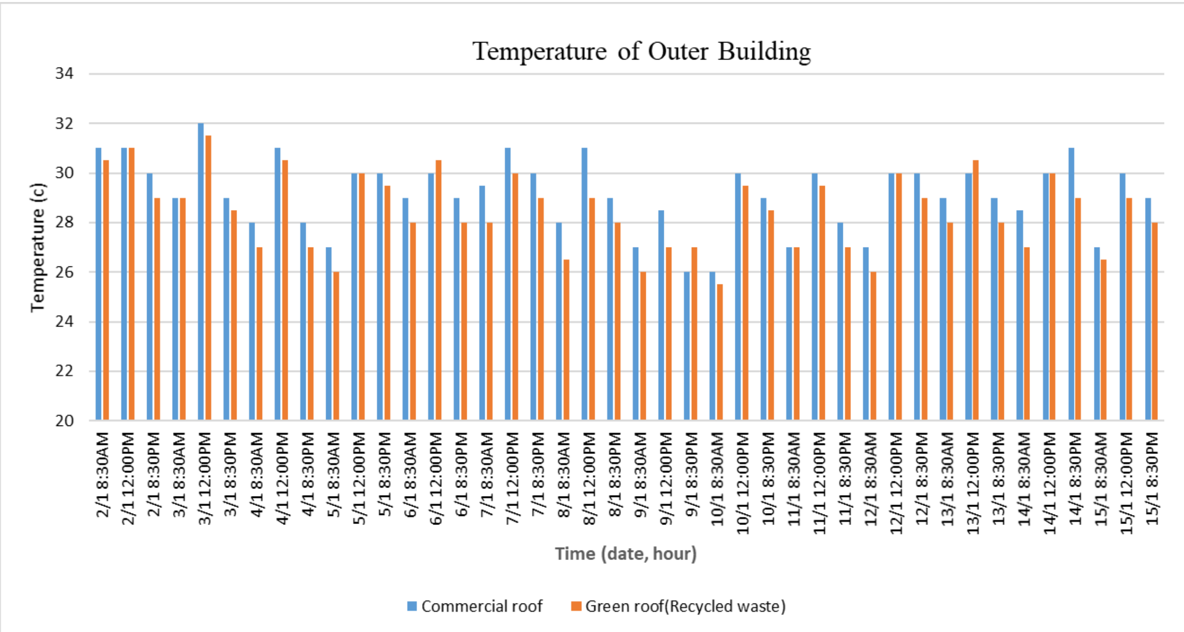

Figure 4.8 Temperature of Outer Building

CHAPTER 5

CONCLUSION

5.1 Introduction

The evaluation of the green roof system's potential to lower the temperature of the roof surface and the surrounding air as well as the impact of Urban Heat Island were the main objectives of this study. The lab scale green roof with the chosen plant and material for layers was used to achieve the major conclusions of this study.

The study shows that, when compared to commercial green roofs, recycled waste green roofs were most successful at lowering the temperature of the roof surface and the air around it. The green roof made of recyclable waste reduces temperature by 3% to 16%. As a result, using Philippine grass as the vegetation and substituting recycled waste, such as coconut fibre as the filter layer and coconut shell as the drainage layer, for commercial materials are suitable and show a promising outcome as follows;

I. The model of green roof that used recycled waste is capable of minimizing the impact of Urban Heat Island, with the best result being a 16.13% decrease in the temperature on 9 January 2023 at 12:00 PM.

II. When compared to the control roof, which had a temperature recorded of 33°C on January 6, 2023 at twelve in the afternoon, the recycled waste green roof model has the potential to make a significant improvement in terms of peak temperature, where it reduced to 30.5°C. This improvement could have a significant impact on the building's overall energy efficiency.

III. Compared to a commercial green roof, a green roof made from recycled materials can reduce inside temperatures by a larger margin. By as much as 16.3%, a green roof system made from recycled materials (coconut fibre and coconut shell) outperforms a green roof made from commercial materials.

IV. The Philippine grass has the ability to lessen the impact of Urban Heat Island, which would result in a decrease in temperature.

V. Results showed that when it rained, both the roof surface and the ambient air temperature dropped, suggesting that weather conditions have an impact on green roof performance.

5.2 Recommendation

There are a few recommendations that need to be considered for further study of the application of green roof for reduction of Urban Heat Island.

i. The prototype model's design must be well-planned and built to ensure the experiment runs well.
ii. Before the experiment, vegetation should be sown to grow naturally on the model's substrate.
iii. For long-term green roof performance and sustainability testing, continuous simulations are recommended.
iv. More research is needed to find a better material for prototype model.
v. Keep drains clear.
vi. Place the model at correct and suitable place.
vii. Using succulent or high-transpiration plants.
viii. Using substrate that can store a lot of water instead of dirt that dries out soon (soil medium or nutrient soil).
ix. Avoid using and mixing materials with high thermal co-efficiency.
x. Before doing a study, read and comprehend existing research.
xi. Measure layer depths correctly.
xii. Review each raw material processing procedure.

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APPENDICES

Appendix A: Progress of work

Prepare the coconut shell

Assemble the model

Cut the gypsum board

Crush the coconut shell

Appendix B: Data sample

Data of temperature

		Week 1 (Inner Building)			
Date/Time	Common	Commercia	Green roof(Recycled waste)		
2/1 8:30AM	30	27	26		
2/1 12:00PM	31	28.5	27		
2/1 8:30PM	30	26	27		
3/1 8:30AM	28	26	25.5		
3/1 12:00PM	31	30	29.5		
3/1 8:30PM	30	29	28.5		
4/1 8:30AM	29	27	27		
4/1 12:00PM	31	30	29.5		
4/1 8:30PM	30	28	27		
5/1 8:30AM	28	27	26		
5/1 12:00PM	31	30	30		
5/1 8:30PM	31	30	29		
6/1 8:30AM	29	29	28		
6/1 12:00PM	31	30	30.5		
6/1 8:30PM	30.5	29	28		
7/1 8:30AM	29	28.5	27		
7/1 12:00PM	31	30	30		
7/1 8:30PM	31	31	29		
8/1 8:30AM	28	27	26.5		
8/1 12:00PM	31	30	29		
8/1 8:30PM	30	29	28		

		Week 1 (Outer Building)			
Date/Time	Common	Commercial	Green roof(Recycled waste)		
2/1 8:30AM	31	31	30.5		
2/1 12:00PM	32	31	31		
2/1 8:30PM	31	30	29		
3/1 8:30AM	30	29	29		
3/1 12:00PM	33	32	31.5		
3/1 8:30PM	31	29	28.5		
4/1 8:30AM	29	28	27		
4/1 12:00PM	32	31	30.5		
4/1 8:30PM	31	28	27		
5/1 8:30AM	30.5	27	26		
5/1 12:00PM	32	30	30		
5/1 8:30PM	31	30	29.5		
6/1 8:30AM	29	29	28		
6/1 12:00PM	33	30	30.5		
6/1 8:30PM	31	29	28		
7/1 8:30AM	30	29.5	28		
7/1 12:00PM	32	31	30		
7/1 8:30PM	30	30	29		
8/1 8:30AM	29	28	26.5		
8/1 12:00PM	32	31	29		
8/1 8:30PM	31	29	28		

		Week 2 (Inner Building)			
Date/Time	Common	Commercial	Green roof(Recycled waste)		
9/1 8:30AM	29	27	27		
9/1 12:00PM	31	29	26		
9/1 8:30PM	30	27	26		
10/1 8:30AM	29	28	27		
10/1 12:00PM	31.5	30	29.5		
10/1 8:30PM	30.5	29	28.5		
11/1 8:30AM	29.5	27	26		
11/1 12:00PM	31	30	29		
11/1 8:30PM	30	28.5	28		
12/1 8:30AM	29	28	28		
12/1 12:00PM	31	30	30		
12/1 8:30PM	31.5	30	29.5		
13/1 8:30AM	29	28	27		
13/1 12:00PM	31.5	30	29.5		
13/1 8:30PM	31	29	27		
14/1 8:30AM	29	28.5	27.5		
14/1 12:00PM	32	31	31.5		
14/1 8:30PM	31	31	29		
15/1 8:30AM	29	28	27		
15/1 12:00PM	31	30	29		
15/1 8:30PM	31	29.5	28		

		Week 2 (Outer Building)			
Date/Time	Common r	Commercial r	Green roof(Recycled waste)		
9/1 8:30AM	30	27	26		
9/1 12:00PM	31	28.5	27		
9/1 8:30PM	30	26	27		
10/1 8:30AM	28	26	25.5		
10/1 12:00PM	31	30	29.5		
10/1 8:30PM	30	29	28.5		
11/1 8:30AM	29	27	27		
11/1 12:00PM	31	30	29.5		
11/1 8:30PM	30	28	27		
12/1 8:30AM	28	27	26		
12/1 12:00PM	31	30	30		
12/1 8:30PM	31	30	29		
13/1 8:30AM	29	29	28		
13/1 12:00PM	31	30	30.5		
13/1 8:30PM	30.5	29	28		
14/1 8:30AM	29	28.5	27		
14/1 12:00PM	31	30	30		
14/1 8:30PM	31	31	29		
15/1 8:30AM	28	27	26.5		
15/1 12:00PM	31	30	29		
15/1 8:30PM	30	29	28		