THE APPLICATION OF COCONUT WASTE AS GREEN ROOF MATERIALS FOR STORMWATER QUALITY IMPROVEMENT

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Diploma in Civil Engineering

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ABSTRAK

Pembandaran meningkatkan kawasan yang tidak telap air dan mempelbagaikan amalan penggunaan tanah bandar dalam hidrologi dan alam sekitar. Selain itu, jumlah kotoran terkumpul di atas bumbung boleh menyebabkan pemendapan dan memberikan kualiti air ribut yang tidak baik. Apabila air ribut mengalir merentasi tapak pembinaan dan ladang yang tidak ditanam seperti atap bumbung, ia memungut kotoran lepas, menghasilkan lumpur, yang cepat dibawa ke dalam sungai yang menyebabkan pemendapan dan menyumbat saluran air, tasik dan takungan, yang boleh menyebabkan banjir, membunuh ikan dan haiwan akuatik. Oleh itu, kawasan kedap air seperti bumbung, jalan masuk, jalan raya, tempat letak kereta, dan laluan pejalan kaki mengurangkan kebolehtelapan tadahan yang mengakibatkan peningkatan larian aliran puncak, memberikan kualiti air ribut yang tidak baik dan meningkatkan suhu haba. Objektif kajian ini adalah untuk membina model bumbung hijau yang dapat meningkatkan kualiti air larian permukaan menggunakan sisa kelapa sebagai bahan bumbung hijau dan menilai prestasi bumbung hijau dalam meningkatkan kualiti air ribut. Bahan-bahan yang digunakan untuk bumbung hijau untuk kajian ini ialah Rumput Filipina sebagai lapisan tumbuh-tumbuhan, tanah terbakar sebagai lapisan substrat, sabut kelapa sebagai lapisan penapis, tempurung kelapa hancur sebagai lapisan saliran, dan terakhir pengedap bitumen untuk lapisan kalis air. Parameter kualiti air yang diuji dalam kajian ini ialah Permintaan Oksigen Biokimia (BOD), Permintaan Oksigen Kimia (COD), dan Jumlah Pepejal Terampai (TSS). Hasil kajian menunjukkan sisa kitar semula bumbung hijau tidak begitu berkesan berbanding bumbung lain. Daripada graf tersebut menunjukkan kepekatan bagi sisa kitar semula bumbung hijau adalah nilai tertinggi dalam TSS dan COD iaitu 40.3 mg/L dan 410 mg/L, tetapi ia mempunyai kepekatan BOD yang rendah iaitu 23.7 mg/L. Puncanya mungkin kerana penyediaan bahan bumbung hijau tidak dilakukan dengan betul, yang mengakibatkan kepekatan air ribut yang tinggi dalam parameter kualiti air seperti COD. Untuk menambah baik sistem bumbung hijau, kepekatan boleh dikurangkan dengan menukar bahan lapisan saliran dengan tempurung kelapa mentah. Kesimpulannya, model bumbung hijau yang boleh meningkatkan kualiti air larian permukaan menggunakan sisa kelapa kerana bahan bumbung hijau telah dibina tetapi bumbung hijau tidak mampu meningkatkan kualiti kepekatan bahan pencemar dalam air ribut.

ABSTRACT

The urbanization increases impervious areas and diversifies urban land use practices in hydrology and the environment. Moreover, the amount of accumulated dirt on the rooftop can cause sedimentation and give bad quality stormwater. When stormwater flows across construction sites and unplanted fields such as rooftops, it picks up loose dirt, creating mud, which is quickly carried into streams where it causes sedimentation and clogs the waterways, lakes, and reservoirs, which can cause floods, kills fish and aquatic animals. Hence, impervious areas such as rooftops, driveways, roads, parking lots, and footpaths lessen the catchment permeability resulting the increases of peak flow runoff, giving bad quality of the stormwater quality and increase the heat temperature. The objectives of this study are to construct a green roof model that can improve the surface runoff quality using coconut waste as the green roof materials and evaluate the performance of green roofs in improving stormwater quality. The materials that was used for the green roof for this study is the Philippines Grass as the vegetation layer, burnt soil as the substrate layer, coconut fiber as the filter layer, burnt crush coconut shell as the drainage layer, and lastly the bitumen sealant for the waterproofing layer. The water quality parameters that were tested in this study is Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Total Suspended Solids (TSS). The result shows that the green roof recycled waste is not very effective compared to the other roof. From the graph, it showed that the concentration for the green roof recycled waste is the highest value in TSS and COD which is 40.3 mg/L and 410 mg/L, but it has a low concentration in BOD which is 23.7 mg/L. The caused might be because of the preparation of the green roof material is not done properly, which resulting the high concentration of stormwater in water quality parameter such as COD. To improve the green roof system, the concentration can be reduced by change the material of the drainage layer with the raw coconut shell. As conclusion, the green roof model that can improve the surface runoff quality using coconut waste as the green roof materials has been constructed but the green roof is not capable to improve the quality of the concentration of pollutants in stormwater.

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LIST OF SYMBOLS

%	Percentage
mm	Millimetres
m	Meter
cm	Centimetres
°C	Celsius
DO_i	Dissolved oxygen at initial
DO t	Dissolved oxygen at 5 days
P	Dilution factor
kg	Kilograms
g	Gram
mL	Millilitres
Mg/L	Concentrations

LIST OF ABBREVIATIONS

UMP	Universiti Malaysia Pahang
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
TSS	Total Suspended Solids
SDG	Sustainable Development Goals
MSMA SME	Manual Saliran Mesra Alam Small and Medium Enterprise

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Due to the up-growth development and industrial revolution, urbanization increases impervious areas and diversifies urban land use practices in hydrology and the environment. Impervious areas such as rooftops, driveways, roads, parking lots, and footpaths lessen the catchment permeability resulting the changes in surface types thus decreasing the amount of water flowing into the subsurface. Floods, temperature rise, and pollution of water are the major issues related to the hydrological changes in urbanized regions (Chow and Abu Bakar, 2016).

The problem that came from the rapid urbanization is the increase of impervious areas such as rooftops, which can lessen the catchment permeability resulting in a decrease in the amount of water flowing into the subsurface and it will hold a lot of dirt. When it comes to impervious surface of land coupled with heavy rainfall during rainstorm events, it will affect the stormwater runoff volume which it can be the factor in the flash flood because of the volume of runoff that cannot be controlled. Stormwater runoff consequences such as increasing in flood rate and erosion directly result from changes in the surface runoff amount caused by increases in impermeable surface cover associated with urbanization. Moreover, the amount of accumulated dirt on the rooftop can cause sedimentation and give bad quality stormwater. When stormwater flows across construction sites and unplanted fields such as rooftops, it picks up loose dirt, creating mud, which is quickly carried into streams where it causes sedimentation and clogs the waterways, lakes, and reservoirs, which can cause floods, kills fish and aquatic animals. The absorption of solar radiation by municipal structures, the emission of human factor energy, a diminished rapid transport of thermal from within roadways, as well as the shortage of water and greenery, which decreases evapotranspiration, all contribute to the urban heat island (UHI). Furthermore, it doesn’t have any heat exchange, hence it cannot balance the heat in a room temperature and cause discomfort to people (Chow and Abu Bakar, 2016).

To reduce a lot of consequences of urbanization, one sustainability solution has been introduced which is a green roof system. The purpose of green roof construction is to compare the efficiency with conventional roof system in terms of the material that been used in green roof system which is the waste and recycled material. Other than that, green roof can also help towards sustainable development of cities and reduces the issues that came from the urbanization. Pertubuhan Arkitek Malaysia (APM) and Association of Consulting Engineers Malaysia (ACEM) have launched a grading system in 2009 for environmentally friendly building which is called Green Building Index (GBI). The Green Building Index is Malaysia’s first comprehensive rating system for evaluating the environment design and performance of Malaysian buildings. The assessment criteria are energy efficiency, indoor environmental quality, sustainable site planning and management, material and resources, water efficiency, and innovation. Under the GBI assessment framework, points will be awarded for achieving and incorporating environment-friendly features in buildings. Green roof is one of the environment-friendly features which can improve energy consumption of a building by minimizing solar heat gain through the building through the process of evapotranspiration of vegetation, and it also contributes to water efficiency by producing less surface runoff and harvesting rainwater by incorporating with other MSMA SME components (Mohamad Roseli et al., 2014). Hence, the study on green roof is essential to provide a better environment for Malaysia.

1.2 Problem Statement

The urbanization process has significantly increased the stormwater runoff and pollutant build-up at the catchment surface area. There is increasing recognition in developed countries that stormwater management needs to be undertaken in a safer and more ecologically sustainable manner. Stormwater should be regarded as an asset and a resource to be valued, rather than the traditional attitude of regarding it as a nuisance to be disposed as quickly as possible. When stormwater flows across construction sites and unplanted fields, its pickup loose dirt, creating mud, which is quickly carried into streams where it causes sedimentation pollution. These are readily carried by storm and flood waters, causing excessive build-up or sedimentation. Many rivers, lakes, and coastal waters are currently degraded by urban stormwater due to excessive flows, poor water quality, removal of riparian vegetation, and the destruction of aquatic habitats. This has resulted fundamentally from a primary focus on a rapid disposal or conveyance-oriented approach to stormwater management. Stormwater management practices need to be broadened to consider environmental issues such as water quality, aquatic habitats, and riparian vegetation, and social issues such as aesthetics, recreation, and economics. Other than that, Malaysia is also known for the waste of materials that are thrown away the most in the world such as unused coconut shells. The waste will be burned, and it can cause air pollution and it will pollute the water if it is dumped into the water (Chow and Abu Bakar, 2016).

1.3 Objectives of Study

The objectives of this study are;

1. To construct a green roof model that can improve the surface runoff quality using coconut waste as the green roof materials.

2. To evaluate the performance of green roofs in improving stormwater quality.

1.4 Scope of Study

The study was constructed at Hydraulic and Hydrology Lab, Universiti Malaysia Pahang (UMP) and Environmental Lab, Universiti Malaysia Pahang where the main objective is to construct the lab scale prototype model that is used to imitate a green roof system. The observation will be made by the production of the recycled green roof model with substantial wastes such as coconut fibre and coconut shell as filter and drainage layer. The tested water quality parameters were limited to Biochemical Oxygen Demand (BOD) Test, Chemical Oxygen Demand (COD) Test, and Total Suspended Solids (TSS) Test.

The scope of the study is also to realize the use of green roofs in terms of hydrological performance and environment quality such as improving the stormwater quality by reducing the concentration in the stormwater. The experiment event is based on lab-scale, but the sample of the experiment is based on actual rainwater. The lab-scale experiment was conducted at Hydraulics and Hydrology Laboratory, Faculty of Civil Engineering Technology, Universiti Malaysia Pahang, Gambang using rainfall simulator. Three comparisons were constructed between three prototype models which are non-vegetated roof or common roof, commercial roof and lastly green roof with recycled waste materials which is the of coconut waste.

1.5 Significance of Study

This study aims to show the how green roof can help towards sustainable development of cities and reduces the issues that came from the urbanization. Pertubuhan Arkitek Malaysia (APM) and Association of Consulting Engineers Malaysia (ACEM) have launched a grading system in 2009 for environmentally friendly building which is called Green Building Index (GBI). The Green Building Index is Malaysia’s first comprehensive rating system for evaluating the environment design and performance of Malaysian buildings. The assessment criteria are energy efficiency, indoor environmental quality, sustainable site planning & management, material and resources, water efficiency, and innovation. Under the GBI assessment framework, points will be awarded for achieving and incorporating environment-friendly features in buildings. Related to the SDG 11, green roof is one of the environment-friendly features which can improve energy consumption of a building by minimizing solar heat gain through the building through the process of evapotranspiration of vegetation, and it is also contributes to water efficiency by decreasing the surface runoff and harvesting rainwater by incorporating with other Manual Saliran Mesra Alam Small And Medium Enterprise (MSMA SME) components (Mohamad Roseli et al., 2014). Green roof can also change the quality of the stormwater by its layer, hence green roof can be applied as one of the systems that can develop a sustainability city and communities.

The benefits of studying the green roof system is to give people knowledge about what they can do with the un-used waste such as coconut waste instead of throwing it away. It is also applicable to all people since Malaysia has many buildings with flat roofs. Hence, they can build the model for their own importance, and also for other life benefits such as a green roof can be the house for the animal such as squirrels, and also can be lived by any plant on top of it. As a result, Malaysia can be viewed as the country with implementation of a prototype that can reduce the waste and at the same time it gives benefits to flora and fauna. This study will also contribute to the Green Technology Master Plan of 2017 to 2030 which is the target is to increase the number of green roof applications in Malaysia (*Green-Technology-Master-Plan-Malaysia-2017-2030*, n.d.).

The purpose of green roof construction is also more efficiency compared with conventional roof system in terms of the material that been used in green roof system which is the waste and recycled material. Other than that, green roof can also help towards sustainable development of cities and reduces the issues that came from the urbanization. It was estimated that 3–7% of the area of the temperate basin should be maintained as wetlands to provide sufficient flood control and water quality improvement functions (Mitsch and Gosselink, 2000). In order to achieve a good environment, we must reduce the disposal of waste material and one of the alternative methods that we can use other than throwing it away is by using 3R method which is Reduce, Reuse, and Recycle. Hence by constructing Green Roof, it can also be one of the efforts to sustain a good environment by recycled waste material such as coconut as the material in the layers (Li et al.,2021).

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Rainwater is very influential to the environment in such animals and plants live. If the quality of rainwater is not good, it will also affect human life in the field of fishing and agriculture. In addition, Malaysia is also known for the waste of materials that are thrown away the most in the world. One of the most famous examples of waste material is unused coconut shells. Hence, to overcome this problem, the recycled waste green roof system has been proposed to sustain the environment and reduce the stormwater pollutant. In this chapter, a complete description about the study is presented. The detail about green roof, the design criteria, and its evaluation in terms of water quality performance are described. However, the literature review is still limited for each scope of the project.

2.2 Green Roof System

Green roof system is a vegetated system where plants are planted on the roof using an engineered growing medium laid on certain layers of the system. A green roof system is composed of a protection and storage layer, a drainage layer, a root-permeable filter layer, a growing medium (substrate), and vegetation. Green roofs in Malaysia are becoming increasingly popular recently not just because of their aesthetic value but also due to them positive impact on environmental issues. The two major types of green roofs are intensive and extensive. An intensive green roof is also known as a roof garden in which the plants comprise trees and shrubs and need regular maintenance. Therefore, the system requires specific support from the building as it is generally heavy. However, this type of green roof is accessible. The extensive green roof is lighter compared to an intensive green roof in terms of loading. It is less expensive and requires low maintenance, but the selection of plants is rather limited than the intensive green roof. It offers limited accessibility as most of the time, it is only accessible for maintenance purposes. Green roof is one of the methods to sustain the environment. Previous research done on green roofs proved that green roofs had many economic, environmental, and social benefits. For example, by using the green roof system, we can increase the water quality because it filters pollutants from rainfall.

A green roof by broad definition can be defined as any planted open space that is detached from the earth by a building or other structure; they are a contained green space on top of a human made structure. The green roof system is considered as one of green technology products designed to provide not only panoramic view from the green pasture view, but also helps in terms of reduction in runoff and temperature to protect the environment in the long term. This system has been installed locally in various type of development such as hotel, luxurious residency area and roof top parking areas at some high-rise buildings (Mohamad Roseli et al., 2014).

Green roofs are an increasingly important component of water-sensitive urban design systems that can potentially improve the quality of urban runoff, reduce the energy consumption of buildings, and add aesthetic value to the environment. The components of a green roof are discussed, and the advantages and disadvantages of different types of green roofs are assessed. In addition, the origins and concentrations of the main pollutants are discussed, moreover environmental cost-benefits of green roofs are also considered. In addition, the main factors that affect the quality of green roof runoff water, e.g., plant species, fertilization, pH, growth media as well as how green roofs could reduce energy consumption are discussed. In most cases, the green roof strategy can be defined as an efficient plan that reduces flood water runoff, produces some oxygen, and eliminates some carbon dioxide. The burden on water treatment facilities can be reduced by increasing the quality of runoff water (Hashemi et al., 2015).

The moisture retained in the green roof mass slowly evaporates attracting dust particles to the damp surfaces of vegetation and substrate at the same time as reducing thermal activity above the roof. The plants absorb gaseous pollutants and during the natural process of photosynthesis convert carbon dioxide to oxygen which improves air quality even more. The basic components of a green roof system include plants, substrate layer, filter layer, drainage layer, water proofing layer, as well as protection layer. Water proofing layer is the most bottom part in green roof assembly which is normally laid directly above the structural deck in order to prevent moisture from entering the buildings. The following component is drainage layer. It is used to direct excess runoff to roof drains and gutters and store water for the plants. Sometimes a protection layer is inserted between the drainage layer and waterproofing membrane as well. A filter layer is installed between drainage layer and growth medium to avoid soil particles from leaching to the drains and gutters. The top layers will be growing medium and vegetation. Commonly, composition of the growing medium comprises of large portion of inorganic materials such as expanded shale or slate and only small percentage of organic mediums (Mohamad Roseli et al., 2014).

The two major types of green roofs are intensive and extensive. An intensive green roof is also known as a roof garden in which the plants comprise trees and shrubs and need regular maintenance. Therefore, the system requires specific support from the building as it is generally heavy. However, this type of green roof is accessible. The extensive green roof is lighter compared to an intensive green roof in terms of loading. It is less expensive as shown in Figure 2.1 and requires low maintenance, but the selection of plants is rather limited than the intensive green roof. It offers limited accessibility as most of the time, it is only accessible for maintenance purposes.

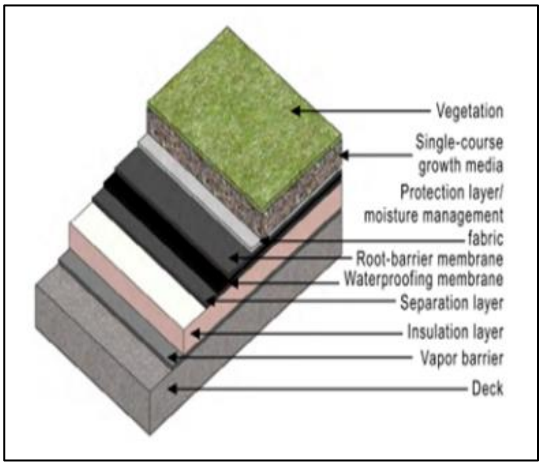


Figure 2.1 Extensive green roof system

Source: Abass (2020)

2.3 Green Roof Components and Layers

There are five main layers in a green roof system which are vegetation layer, substrate layer, filtered layer, drainage layer and lastly the waterproofing layer as shown in Figure 2.2 and Figure 2.3.

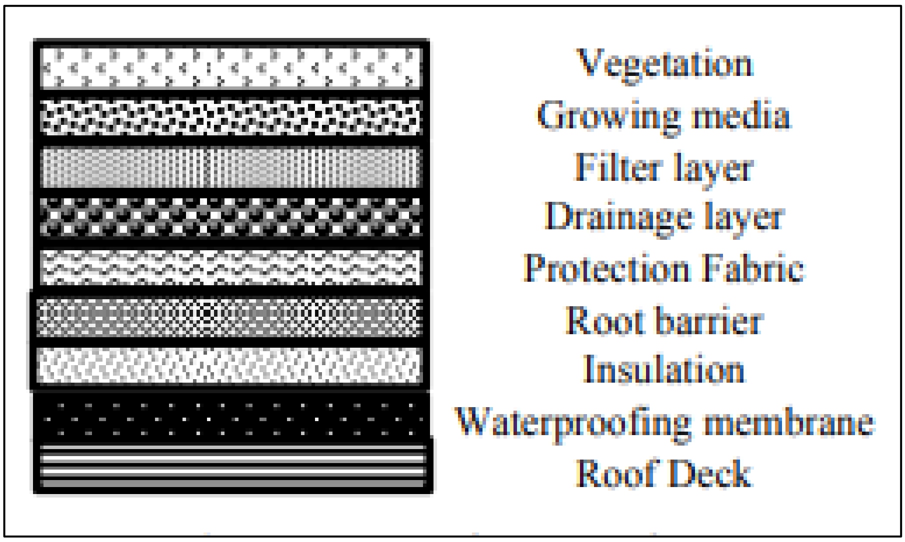


Figure 2.2 The layers of green roof

Source: Chow and Abu Bakar (2016)

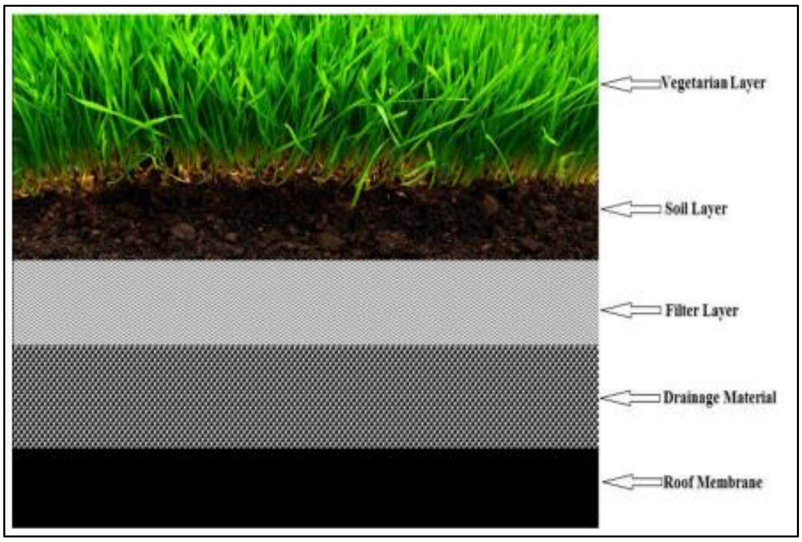


Figure 2.3 Five major components of a typical green roof

Source: Hashemi (2015)

2.3.1 Vegetation Layer

Vegetation layer is the most top layer of the green roof. It is the layer where the plants are placed. The function of this layer is to absorb the stormwater for the plant to growth. The benefits of this layer are the plant can make process of photosynthesis which is the process by which plants use sunlight, water, and carbon dioxide to create oxygen and energy in the form of sugar. Hence, the layer can reduce the carbon dioxide and increase the oxygen for the green roof. It is also absorbing the bad stormwater quality at the same time gives benefits to the plant to grow bigger (Chell et al., 2022).

2.3.2 Soil or Substrate Layer

Substrate layer is the layer which the plant will be planted. The properties necessary for growth media include good drainage and aeration, water holding capacity, and nutrient holding or cation exchange capacity (CEC). It is important to the green roof because it will give nutrient to the plant at the vegetative layer to growing. This layer can provide the nutrient for the plant because it contains pathogens, undesirable insects, and weeds (Petreje et al., 2023).

2.3.3 Filter Layer

Filter layer is the layer where the function is to separate the growing medium from the drainage system layer and to keep the drainage layer from becoming clogged by preventing the other particles including the soil fines and vegetation debris out of the drainage layer of the green roofs system (Shafique, Kim and Rafiq, 2018). Other than that, this filter layer also serves as a root barrier membrane for the vegetation to make sure the roots did not penetrate the drainage system. This is because the permeability of the water through the filter layer must be at least ten times more than the substrate (Cascone, 2019).

2.3.4 Drainage Layer

For the drainage layer, the function is to allow the excess storm water from the growing medium. Other than that, the drainage layer also will protect the roof waterproofing membrane of the first layer of the green roofs system and improve the thermal performance as it stores the excess water from the growing medium (Cascone, 2019). In terms of maintenance, it is important to keep out the vegetation, roots, and unwanted particles such as soil fines and plant debris, from entering the drainage layer to ensure that there are no clogging problems in that layer. The material such as coconut shell can also be used as this layer as it can allow the stormwater to go through it.

2.3.5 Waterproofing Layer

Waterproofing layer or membrane is the most important part in constructing green roof system. It is because the green roofs system cannot simplify to construct directly on the rooftop without any waterproof membrane to avoid leakage as the green roofs system consists of the drainage system. Water is one of nature's most damaging tools over time and if constructed incorrectly, it may damage the rooftop. When it is raining, a huge amount of water will excess the green roof and to prevent the stormwater from leakage, this layer must be created. The materials that are often used in this layer is bitumen sealant, which is waterproof and provide a good waterproofing layer to the green roof (FLL guidelines., 2018).

2.4 The Benefits of Green Roof

In terms of hydrological performance, green roof can be a very effective solution in improving the hydrological performance to overcome and reduce the problems that made by rapid urbanizations. There are several problems of the effect of rapid urbanization that green roof can reduce which is reduce the stormwater runoff, improve the stormwater quality and reduce the temperature in a room.

2.4.1 Reduce the Stormwater Runoff

Different from the roof of a normal house, green roof has many layers that can reduce the flow of stormwater that pass through it, as shown in Figure 2.4. This is because every layer has different permeability which means it can receive stormwater in varying quantities. Moreover, the top layer or vegetation layer can also affect the stormwater flow. This is because the plant reduces stormwater runoff by capturing and storing rainfall in the leaf and releasing water into the atmosphere through evapotranspiration. In addition, the roots and leaf litter create soil conditions that promote the infiltration of rainwater into the soil (Mitsch & Gosselink, n.d.).

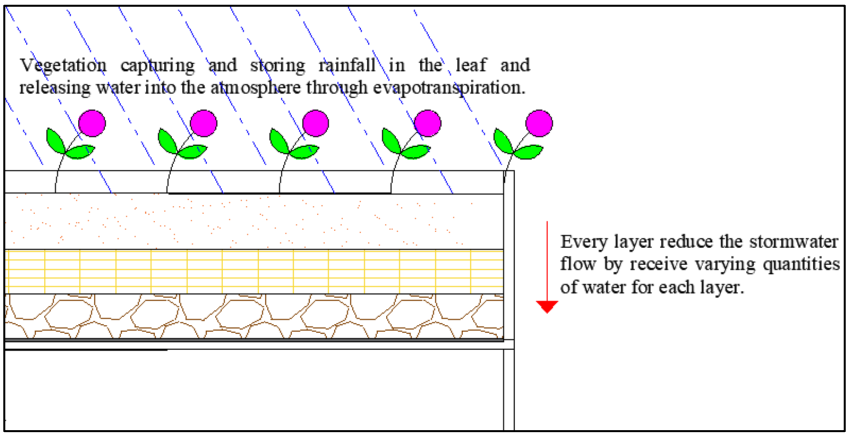


Figure 2.4 A diagram shows the green roof reduce stormwater flow

Source: (Mitsch & Gosselink, n.d.)

2.4.2 Improve the Stormwater Quality

For the stormwater quality, green roof can provide a good quality water by having different layer with varying permeability that can filter stormwater when stormwater infiltrate through each layer, as shown in Figure 2.5. This will affect the stormwater parameters such as Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Total Suspended Solids (TSS). The green roof will give a good quality by decreasing the amount of the parameters in the stormwater. This is because when the turbidity is high, it means that the stormwater is full of sedimentation and it can possibly cause clogs in waterways at the roof, hence to overcome this type of problems, green roof can reduce the amount of TSS in the stormwater and giving a good solution for the clogging waterways (7 Pollution Sources, Loadings, and Wastewater Characterization, n.d.).

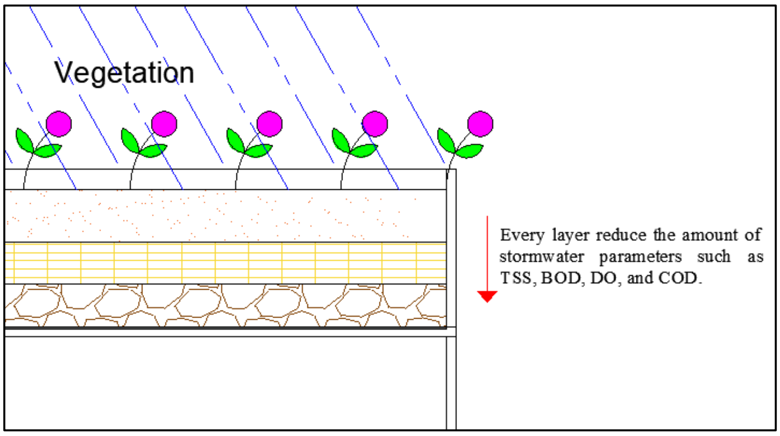


Figure 2.5 A diagram shows the green roof improve stormwater quality

Source: (7 Pollution Sources, Loadings, and Wastewater Characterization, n.d.)

2.4.3 Reduce the Temperature

Lastly, when green roof has been constructed, it will give reduction of temperature in a room, as shown in Figure 2.6. This is because the vegetation at the top layer will consume carbon dioxide and it will release oxygen gas during the photosynthesis process. Furthermore, vegetation lower surface and air temperatures by providing shade and through evapotranspiration. For example, shaded surfaces may be 20–45°F (11–25°C) cooler than the peak temperatures of unshaded materials (Akbari et al., 1997, Huang et al., 1990). In addition, plants also cool the atmosphere because they release water vapor when they get hot, a process similar to sweating.

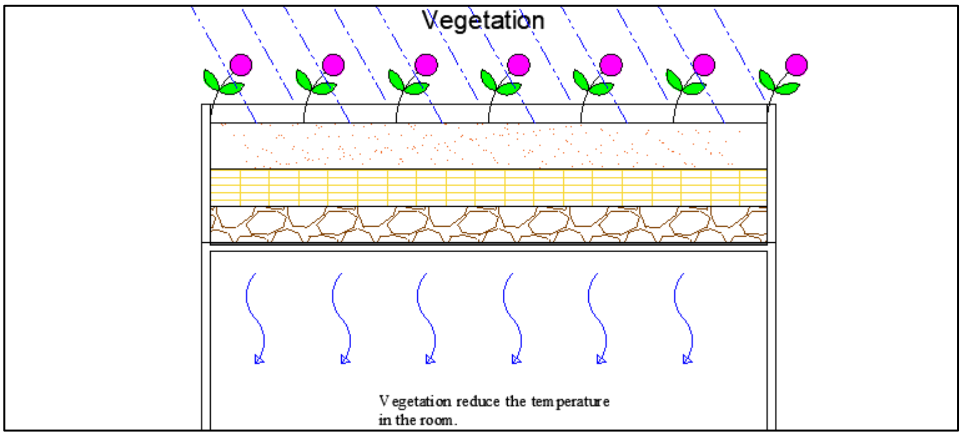


Figure 2.6 A diagram shows the green roof reduce the temperature

Source:(Liu et al., 2021)

2.5 Green Roof Dimension and Layer Thickness

Several articles and journals have explained about the dimension and layer thickness of a green roof, whether it is suitable or not to be applied in a green roof system. This is because, green roof has many types, and also different dimension based on the size that they want to observed. For example, two articles; Larsen (2021) and FLL Green Roof Guidelines (2018) have been found as they both explain the green roof dimension and layer thickness for a lab scale green roof. These two articles are chosen because it is suitable to the scope of study for this project.

Figure 2.6 shows the schematic of common extensive green roof layers and the dimension for each layer.

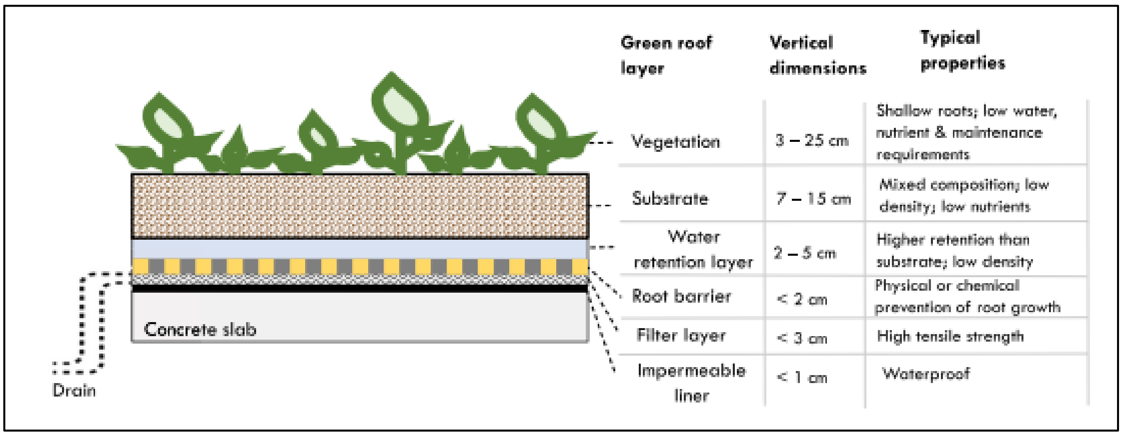


Figure 2.7 Schematic and typical properties of common extensive green roof layers

Source: Lauren and Larsen (2021)

According to FLL (Sachverständige Gartenbau -Landschaftsbau-Sportplatzbau eV & Gartenbau, 2018) guidelines, some data are taken which show the thickness of layer in an extensive green roof model in a lab scale. Table 2.1 shows the material and thickness of common extensive green roof layers (FLL guidelines, 2018)

Table 2.1 Material and thickness of common extensive green roof layers
Source: FLL guidelines (2018)

Information	Description
Extensive green roofs have a much shallower growing media layer that typically ranges from 3 to 6 inches thick. Thickness of substrate layer	From the guidelines, the thickness of substrate layer is in ranges from 3 to 6 inches thick.
The effective depth of the drainage layer is generally 0.25 to 1.5 inches thick for extensive green roof system and increases for intensive designs. Thickness of drainage layer	Based on the guidelines, the thickness of drainage layer is generally 0.25 to 1.5 inches thick.
Plant Cover. The top layer of an extensive green roof typically consists of plants that are non-native, slow-growing, shallow-rooted, perennial, and succulent. Vegetation layer	According to guidelines, the vegetation that are used is typically non-native, slow growing, shallow-rooted, perennial and succulent.

The waterproofing material may be loose laid or bonded (recommended). If loose laid, overlapping and additional construction techniques should be used to avoid water migration. Waterproofing layer	From the guidelines, the waterproofing material that is recommended for waterproofing layer is loose laid or bonded material.

From both articles, Table 2.2 can be construct to compare the data between both articles, hence from the data obtained;

Table 2.2 Comparison between Lauren and FLL

Source: FLL Green Roof Guidelines (2018), Lauren and Larsen (2021)

Article Name	Layer Thickness	
	Lauren M. Cook *, Tove A. Larsen	FLL_greenroofguidelines_2018
Vegetation layer	✓	✓
Substrate/Soil layer	✓	✓
Filter layer	✓	NA
Drainage layer	✓	✓
Waterproofing layer	✓	✓

*NA means Not Available

2.6 Recycled Waste Materials for Green Roof

To achieve the sustainable city, a lot of research has been done in order to obtain the natural material with the use that can help into the sustainability city. For this study, a few materials had been studied in order to achieve the most effectiveness of the green roof. To obtain it, the green roof must have the material of the layer that will help in reducing the problems in urbanization. Hence, the materials must be recycled or reused materials and low-cost products to improve their environmental and economic sustainability (Cascone et al., 2022).

Granules and compounds are mainly obtained from the regeneration of films from the greenhouse and agricultural sector, from industrial waste and from selected material from separate collection. According to Cascone (2022), the recycled plastic granules are mainly constituted by low-density polyethylene. The research for this material has been done and the results of the thermo-physical tests showed that the recycled plastic granules have features that is very similar to perlite. Hence, they may be used as an alternative to natural drainage materials. Other than that, recycled polyethylene had mechanical and environmental performances better than commercial products, hence it reducing the extra load applied on existing building rooftops (Cascone et al.,2022).

Other than that, the material of substrate was also studied by the researcher. A substrate layer with the mixture of calcareous and siliceous aggregate from construction and demolition waste was sourced from local waste management and disposal services. According to Mickovski et al(2013), the substrate mix containing recycled construction waste materials was enough to help plant growth, erosion and slippage and it is also capable of providing good drainage. When vegetated, the green roof system can provide lesser of the drainage water with the magnitude that depends on the type and percentage of the vegetation layer (Mickovski et al.,2013).

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this methodology chapter, the dimension, green roof materials and stormwater quality evaluation methods that have been chosen are described. Figure 3.1 shows the flow chart of the methodology study. The work process starts with the design of the green roof model. The dimension of the green roof has been determined which is 0.6 m × 0.6 m × 0.15 m for the roof model and 0.6 m × 0.6 m × 0.45 m for the building model. Next, the selection of the material for the green roof recycled waste will also be described in this chapter. For the study, the material that had been used for the layer of the green roof is Philippines Grass for the vegetation layer, burnt soil for the substrate layer, coconut fibre for the filter layer, burnt crushed coconut shell for the drainage layer and finally for the waterproofing layer, the chosen material that had been used is the bitumen sealant. Then, this chapter also explained about the process of the burnt crushed coconut shell with detailed. To help the understanding, it included the diagram of the production of the burnt crushed coconut shell with step by step. Other than that, it also described about the preparation for the production of filter layer which is the coconut fibre and the construction of green roof recycled waste (model and layer). After that, the water quality parameters had been explained in this chapter relating to the scope of the study which is the Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Total Suspended Solids (TSS). The quality of the stormwater had been determined based on the amount of concentration in these three parameters. Moreover, the result of the water quality had been discussed with detailed and the suggestion for the improvement of green roof has been explained in the chapter five.

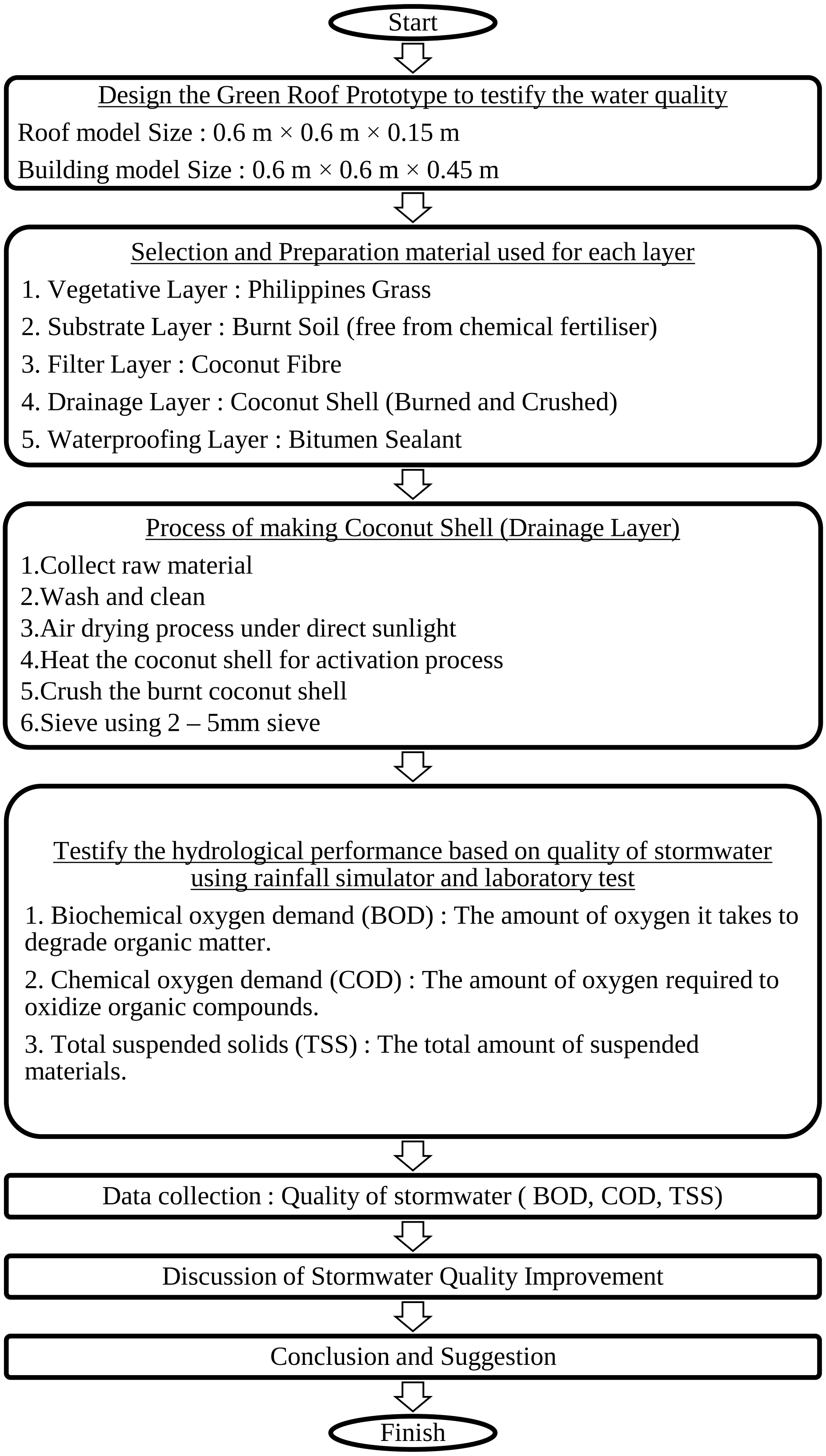


Figure 3.1 Methodology Flow Chart

3.2 Construction of Green Roof Model

For the construction of green roof model, the model is divided into two component which is roof model as the main component and building model as the second component.

3.2.1 Roof Model

Before the construction of the model, the dimension of the first component or main component have been determined which is the roof model. For the roof model, the article that have been referred explain about the dimension of the apparatus for collecting run-off.

Specifically, the study focused on the role of vegetation architecture and species composition on runoff quality and quantity (Booth and Grime, 2001), 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 (Naeth et al. 1991), and with vegetation height. A system of ‘microcosms’ which is small, and self-contained artificial plant communities and lysimeters which is apparatus for collecting run-off was constructed, consisting of trays with dimension 600×600×150 mm deep from black polypropylene plastic (Dunnet et al.,2008). The dimension of the roof model in this study was determined as 600 mm width, with 600 mm length and 150 mm of height as shown in Figure 3.2.

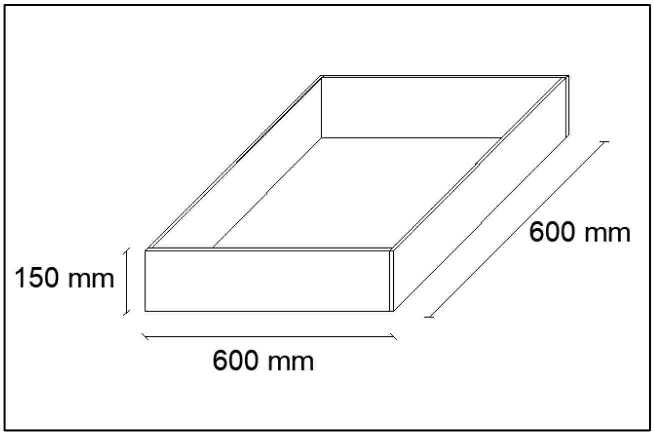


Figure 3.2 Green roof model dimension for roof model

3.2.2 Building Model

For the building model, we have determined the dimension, which is 600 mm×600 mm×450 mm. At the below of roof model, the width and length must be same as the roof model. For the height of the building, we choose 450 mm as the dimension as it can fit the tank to store the stormwater in it. Hence, the building model will be seen as figure 3.3.

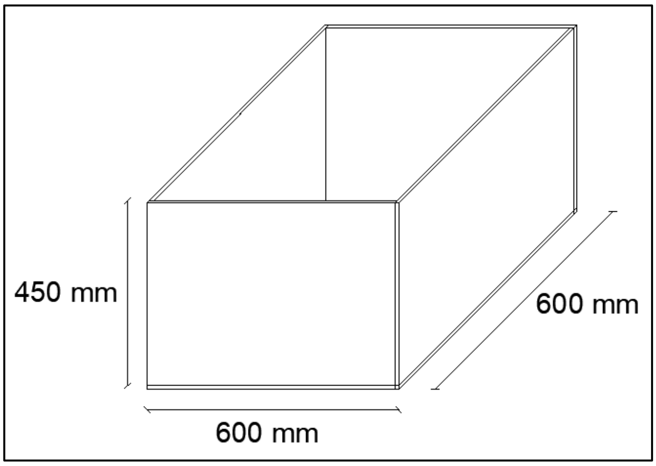


Figure 3.3 Green roof dimension for building model

3.2.3 Tank

For the tank, the tank with volume of 5 Litres had been chosen. This is because refer to the article, they have simulated two types of rain fall which are heavy rain (10 mm/h) and light rain (5 mm/h). For heavy rain, the water tank was filled up to 39 cm and the water allowed to run out until the depth was 37.4 cm (2 L for each tray). For the light rain, the tank was filled up to 22.8 cm and allowed to fall to 22.0 cm (1 L for each tray). Each rainfall event has been simulated for about 15 min. (Dunnet et al., 2008).

From the article, it means that heavy rainfall will be filled up the tank to 39 cm and for the light rain, it is 22.8 cm which means for one event of rain, the average of water tank will be filled up to 20 cm until 30 cm. Hence, the allowable height of tank must be more than 30 cm. Hence, we choose the tank with 35 cm of height and volume of 5 Litres to overcome the limit of the water tank to be filled up.

Figure 3.4 The tank for green roof model

3.3 Material for Green Roof Layer

For this project, the material and ingredients has been chosen to construct the Green Roof. For the model, 3 types of different roof have been designed and each roof have different material and criteria. Among the design that we have choose to make a comparison is Green Roof with coconut waste as it layers material, Commercial Roof and Common Residential Roof. Detail of each roof have been explained below;

3.3.1 Green Roof with Coconut Waste

The material that was used in green roof model is Philippines Grass, burnt soil, coconut fibre, coconut shell and bitumen sealant as shown in Figure 3.5.

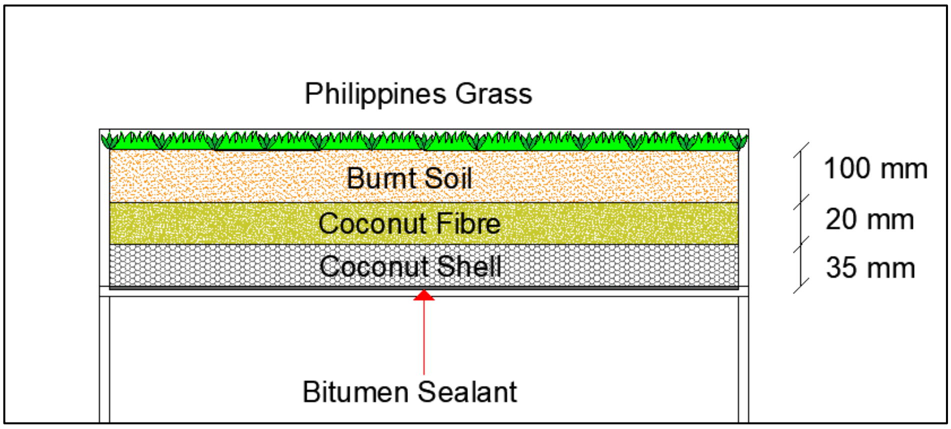


Figure 3.5 Green roof layer with recycled waste material

3.3.1.1 Layer with description

Firstly, the selection material for the vegetation layer of the green roof recycled waste is Philippines Grass as shown in Figure 3.6. This is because Philippines Grass doesn’t need a regular care, hence they don’t need a frequently water because it can live without watering for a long-term period. It is also having a lower maintenance cost compared to other grass such as Japanese Grass, hence it is affordable. The Philippines Grass also doesn’t really depends on the fertilizer. It is because it has the ability to live with only sunlight and water, and without the fertilizer, the grass can still grow. The chosen thickness of the layer is also mentioned in Table 3.1.

For the substrate layer, the best material that have been chosen is burnt soil as shown in Figure 3.6. The reason why it is chosen because burnt soil is free from chemical fertilizer and organic substance that may affect water quality. Other than that, burnt soil is also good at absorbing water without becoming sticky, because the sticky soil like clay will makes it difficult for roots to spread inside it. The other reason is burnt soil are less weight when it absorbing the water, unlike the other soil type such as clayey soil. The chosen thickness of the layer is also mentioned in Table 3.1.

Then, the next material that is used for the filter layer is coconut fibre as shown in Figure 3.6. In a research, a comparative analysis of two different types of substrate between sugarcane bagasse or green coconut fibre showed that the substrates produced from green coconut fibre resulting a relatively lower field capacity compared with the production from sugarcane bagasse. From this result, they conclude that the green roof with the use of coconut fibre as a substrate are more suitable for application in green roofs, since roof overload plays an influential role in this application (Fabbri et al., 2021). The chosen thickness of the layer is also mentioned in Table 3.1.

When it comes to the drainage layer, the material that has been used for this layer is the burnt crush coconut shell as shown in Figure 3.6. Coconut shell-based absorbents have been studied in terms of biosorption for water quality treatment. The researcher has shown a variety of coconut bio sorbents such as for the removal of metals, dyes, pollutants, anions and radio nuclides from water. For the effectiveness, coconut shell has been burnt to reduce the need for regeneration yet achieve effective and sustainable water treatment (Grace et al., 2016). The chosen thickness of the layer is also mentioned in Table 3.1.

Lastly, for the waterproofing layer, the material that has been selected is the bitumen sealant as shown in Figure 3.6. Bitumen is a material that is impermeable which doesn't allow fluid to pass through it, hence it is chosen as the material to overcome the leakage problem in the green roof. It is also chosen because it can control the water flow through the tank and physically attached to the roof while raining. The chosen thickness of the layer is also mentioned in Table 3.1.

Table 3.1 Table of green roof layer

Layer	**Thickness (mm)**	**Description**
Vegetation Layer: Philippines Grass	Not Available	➢ Low maintenance. ➢ Does not need water frequently. ➢ Does not need fertilizers. ➢ Tolerant to direct sunlight.
Substrate Layer: Burnt Soil	100	➢ Free from chemical fertilizer and organic substance that may affect water quality. ➢ Good at absorbing water without becoming sticky.
Filter Layer: Coconut Fibre	20	➢ Easily be found. ➢ Light in weight.

Drainage Layer: Coconut Shell (Burnt-Crushed)	35	➢ Easy to get. ➢ Can reproduce vegetation's natural circumstances for accumulating water.
Waterproofing Layer: Bitumen Sealant	Not Available	➢ Waterproof material. ➢ great water resistance, ballasted, adhered and physically attached to the roof. ➢ available and easy to get at the nearest hardware store.

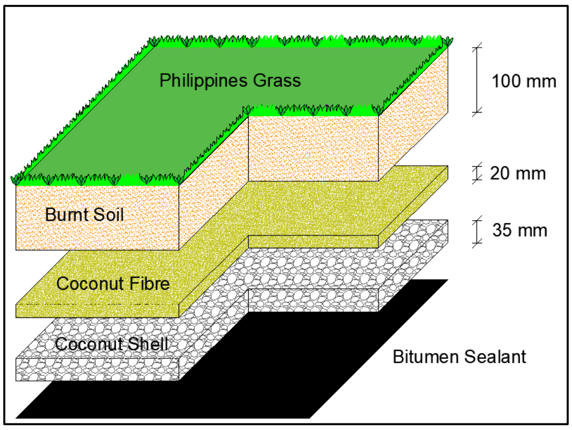


Figure 3.6 Extensive green roof recycled waste

3.3.2 Commercial Roof

The material that was used in green roof model is Philippines Grass, burnt soil, geotextile, drainage plate and bitumen sealant as shown in Figure 3.7.

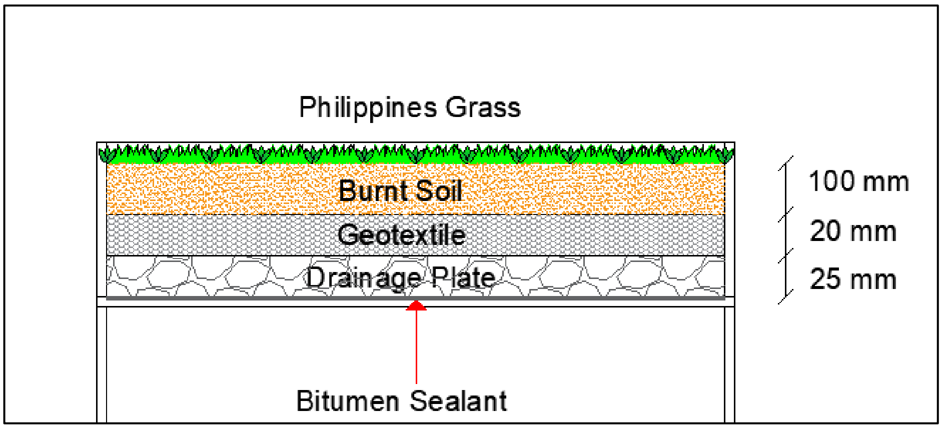


Figure 3.7 Commercial roof

3.3.2.1 Layer with description

Same as the green roof, the selection material for the vegetation layer of the green roof recycled waste is Philippines Grass as shown in Figure 3.8. This is because Philippines Grass doesn't need a regular care, hence they don't need a frequently water because it can live without watering for a long-term period. It is also having a lower maintenance cost compared to other grass such as Japanese Grass, hence it is affordable. The Philippines Grass also doesn't really depends on the fertilizer. It is because it has the ability to live with only sunlight and water, and without the fertilizer, the grass can still grow. The chosen thickness of the layer is also mentioned in Table 3.2.

For the substrate layer, the best material that have been chosen is burnt soil as shown in Figure 3.8. The reason why it is chosen because burnt soil is free from chemical fertilizer and organic substance that may affect water quality. Other than that, burnt soil is also good at absorbing water without becoming sticky, because the sticky soil like clay will makes it difficult for roots to spread inside it. The other reason is burnt soil are less weight when it absorbing the water, unlike the other soil type such as clayey soil. The chosen thickness of the layer is also mentioned in Table 3.2.

Then, the next material that is used for the filter layer is geotextile as shown in Figure 3.8. In a research, a thicker geotextile will reduce the level of turbidity effluent and total coli effluent. Hence, it is shows that the geotextile will affect the stormwater quality parameters and improving the water quality because it can attract the microorganism. The existence of this layer can improve the performance of slow sand filters in removing pollutants such as N and P in raw water (Fitriani et al., 2020). The chosen thickness of the layer is also mentioned in Table 3.2.

For the drainage layer, the drainage plate was chosen because it can provide excellent drainage during heavy rain or when handling runoff coming in from other parts of the roof as shown in Figure 3.8. Their design also ensures that there is always a layer of air above the plates even during the strongest storms, allowing plant roots to remain healthy. The chosen thickness of the layer is also mentioned in Table 3.2.

Lastly, for the waterproofing layer, the material that has been selected is the bitumen sealant as shown in Figure 3.8. Bitumen is a material that is impermeable which doesn't allow fluid to pass through it, hence it is chosen as the material to overcome the leakage problem in the green roof. It is also chosen because it can control the water flow through the tank and physically attached to the roof while raining. The chosen thickness of the layer is also mentioned in Table 3.2.

Table 3.2 Table of commercial roof layer

Layer	**Thickness (mm)**	**Description**
Vegetation Layer: Philippines Grass	Not Available	➢ Low maintenance. ➢ Does not need water frequently. ➢ Does not need fertilizers. ➢ Tolerant to direct sunlight.
Substrate Layer: Burnt Soil	100	➢ Free from chemical fertilizer and organic substance that may affect water quality.

		➢ Good at absorbing water without becoming sticky.
Filter Layer: Geotextile	20	➢ Not heavy to carry. ➢ Can allow water to pass while maintaining stability of the soil structure.
Drainage Layer: Drainage Plate	25	➢ Allowing plant roots to remain healthy ➢ Provide excellent drainage during heavy rain
Waterproofing Layer: Bitumen Sealant	Not Available	➢ Waterproof material. ➢ great water resistance, ballasted, adhered and physically attached to the roof. ➢ available and easy to get at the nearest hardware store.

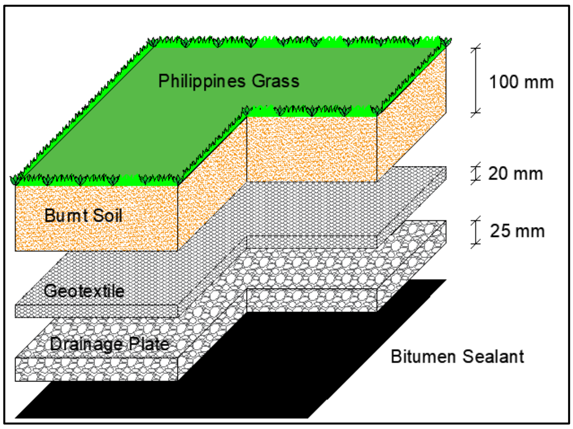


Figure 3.8 Commercial roof

3.3.3 Common Roof or Residential Roof

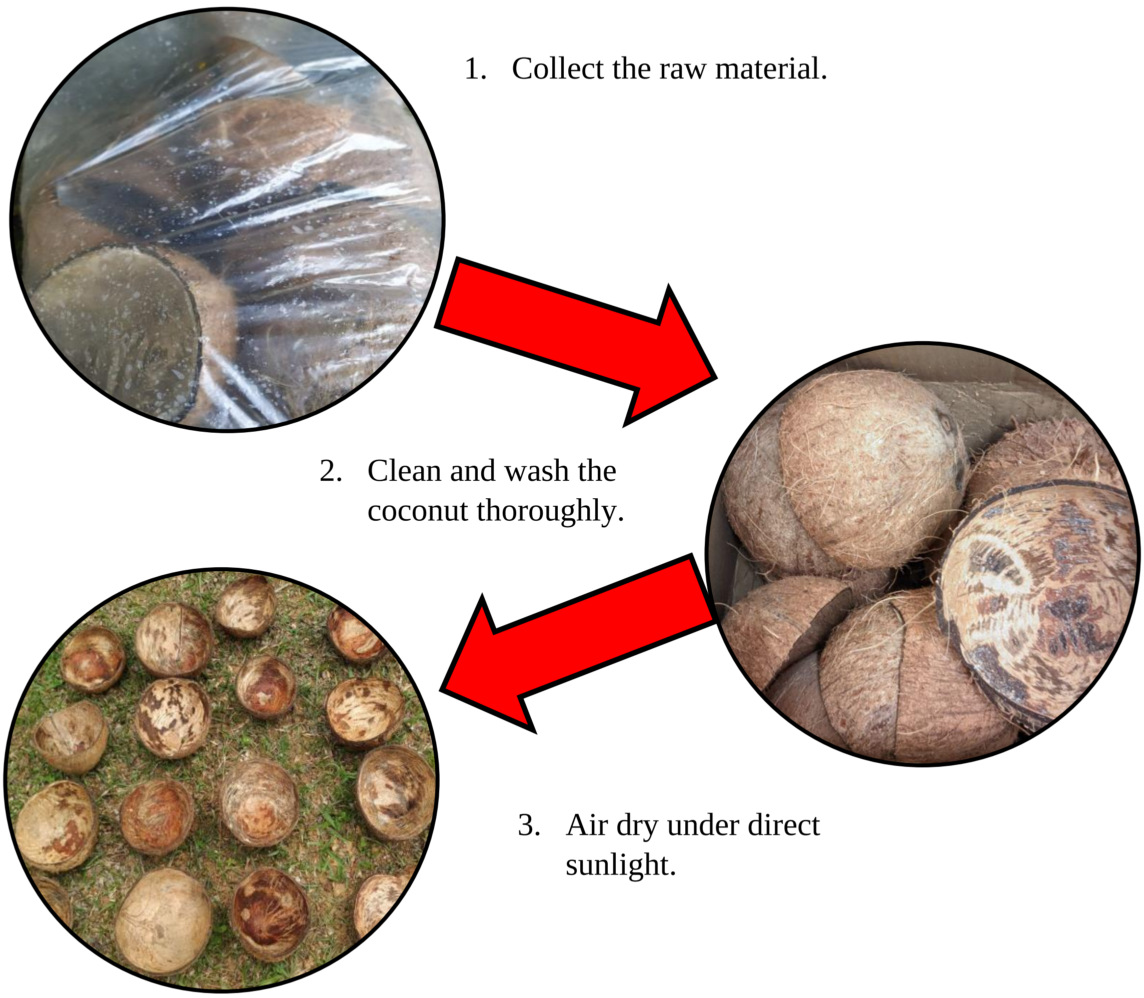
For this type of roof, the model didn't constructed, but the sample of the stormwater have been collected from the stormwater that sliding through the rooftop. The purpose of this data is to analyse the different between common roof with the green roof and commercial roof. The collected stormwater that sliding through the roof will be the sample for the common roof and will be test at Environmental Laboratory at UMP Gambang. For this sample, it also didn't need to wait to collect the sample till the completion of construction of the green roof model because it didn't have to run the model to collect the sample. Figure 3.9 shows a condition when raining where there is a stormwater sliding through the rooftop and fell to the ground.

Figure 3.9 Common roof

3.4 Preparation of Green Roof Material

3.4.1 Burnt Coconut Shell (Drainage Layer)

For the preparation of the drainage layer, the coconut shell was used as the material of this layer. Firstly, to prepare the burnt crush coconut shell, the apparatus that needed in this preparation is sieve 2 mm - 5mm and the material which is raw coconut shell. First of all, clean the coconut by separated the coconut fibre from the shell. Next, dry the coconut shell under the sunlight. After the coconut shell dried, burned it for activation process. When it comes to dark colour, take the burnt coconut shell from the heat and let it cool. Lastly, crush the coconut shell using hammer and sieve between 2 mm until 5 mm with opening size of 2-5 mm. For the safety, when burning the coconut shell, make sure to put the flammable things away from the fire to avoid any incident. The sieve size that is smaller than 2 mm need to be separate from the chosen size to avoid the particle from penetrating the layer below. Figure 3.10 was showed the production of burnt crush coconut shell.



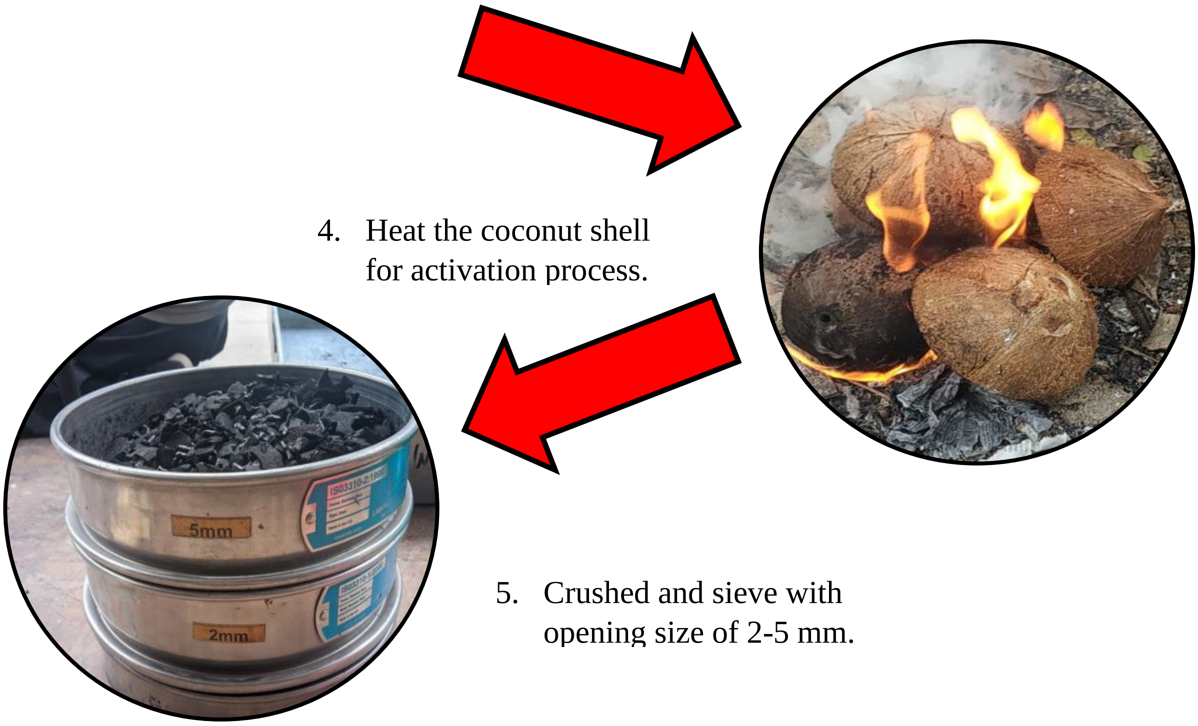


Figure 3.10 The production of burnt crush coconut shell

3.4.2 Coconut Fibres (Filter Layer)

For the preparation of filter layer, the material that were used as the layer is the coconut fibre. To prepare the coconut fibre, gather raw coconut waste from nearby market or used the waste fibre when separating the coconut shell when prepare for the drainage layer. Then, clean the coconut fibre thoroughly to separate the dust from the fibre. Next, dry the coconut fibre under the direct sunlight and lastly, tear the coconut fibre into pieces. For the safety, make sure to clean the coconut fibre at the areas that is not windy. This is because it can prevent dust from the coconut fibre from being blown into the eyes. Figure 3.11 was showed the production of burnt crush coconut shell.

Figure 3.11 The production of coconut fibre

3.5 The Construction of Green Roof Recycled Waste

3.5.1 The Construction of Green Roof Recycled Waste (Model)

For the roof model of the green roof construction, the apparatus that is needed is Gypsum Board, sealant, stationery, tape, cutter, and the driller. First of all, mark all dimension on the gypsum according from the plan. Next, when all of the dimension has been marked, cut off the gypsum board using cutter, it is more efficient to cut with cutter instead of the saw because of the gypsum board's texture that is brittle. Then, the gypsum board part was combined by using sealant and wait for about 3-4 hours to dried the sealant. After the sealant dried, drill a hole at the middle of the roof model and lastly, seal the hole with suction pipe to allow the water to go through it. For the safety, make sure to wear the thick glove when cutting and sealing the gypsum board because it is dangerous and might cause injury if not careful. Figure 3.12 was showed the construction of green roof recycled waste (model).

1. Mark the dimension of the green roof model on the gypsum board.

2. Cut the gypsum board using cutter.

3. Seal all the part with sealant.

4. After the seal dries, punch a hole at the roof model and seal with the suction pipe.

Figure 3.12 The Construction of Green Roof Recycled Waste (Model)

3.5.2 The Construction of Green Roof Recycled Waste (Layer)

Meanwhile for the layer preparation of the green roof, it is simpler compared to the activity before. Firstly, apply the bitumen sealant at the bottom layer. After the bitumen dried, put the burnt crush coconut with 35 mm thickness as the drainage layer. Use ruler to make the measurement of the thickness to be more precise. Next, for the filter layer, put the coconut fibre with 20 mm thickness and put 100 mm thickness of burnt soil for the substrate layer. Finally, plant the vegetation layer which is Philippines Grass at the top of the layer. For the safety, make sure to use hand glove while applying the bitumen sealant at the gypsum board to keep the bitumen away from the hands. Figure 3.13 was showed the construction of green roof recycled waste (layer).

1. Apply the bitumen sealant at the bottom layer.

Figure 3.13 Construction of Green Roof Recycled Waste (Layer)

3.6 Water Quality Parameters

For this part, we will explain about the experiment that are involved in the scope which is the improvement in stormwater quality. There are 3 Experimental that is influential in improving the water quality, which is Biochemical Oxygen Demand (BOD) Test, Chemical Oxygen Demand (COD) Test and lastly Total Suspended Solid (TSS) Test.

3.6.1 Biochemical Oxygen Demand (BOD)

3.6.1.1 Introduction

Aerobic bacteria utilize the organic materials contained in wastewater as "food" in the presence of free oxygen. The BOD test estimates the amount of "food" available in the sample. The more "food" in the waste, the more Dissolved Oxygen (DO) will be required. The BOD test assesses the strength of the wastewater by measuring the quantity of oxygen required by bacteria as they stabilize organic materials under regulated time and temperature settings (Ryu et al., 2022).

The BOD test is used to determine plant efficiency (in terms of BOD removal) and control plant processes by measuring waste loads to treatment plants. It is also used to assess the consequences of discharges on receiving bodies of water. The length of time (5 days) required to receive the findings is a significant downside of the BOD test (Ryu et al., 2022).

When all oxygen-consuming components in a sample are measured, the result is known as "Total Biochemical Oxygen Demand" (TBOD), or simply "Biochemical Oxygen Demand" (BOD). Because the test is conducted over five days, it is commonly referred to as a "Five Day BOD," or a BOD5. But due to limit time, we only conduct BOD3 where it only takes 3 days. Many nitrifying organisms are produced throughout the treatment process in the effluent of many biological treatment plants. These organisms can generate an oxygen requirement by converting nitrogenous molecules (ammonia and organic nitrogen) to more stable forms (nitrites and nitrates). A portion of this oxygen demand is generally measured in a three-day BOD (Ryu et al., 2022).

It is sometimes preferable to quantify only the oxygen demand exerted by organic (carbonaceous) chemicals, rather than the oxygen demand exerted by nitrogenous molecules. To do this, a nitrification inhibitor can be added to the samples to prevent the nitrifying organisms from consuming oxygen. CBOD stands for "Carbonaceous Biochemical Oxygen Demand (Ryu et al., 2022)."

3.6.1.2 Evaluation Formula

To evaluate the performance of BOD testing, an equation has been provided in term of determined the BOD in the stormwater. Hence, the equation that is provided as shown in equation (3.1);

$$BOD_t = \frac{DO_i - DO_t}{P}$$

Equation (3.1)

Which;

$BOD_t = Biochemical\ Oxygen\ Demand\ \left(\frac{mg}{L}\right)$
$DO_i = Initial\ DO\ of\ the\ diluted\ stormwater\ sample\ after\ preparation \left(\frac{mg}{L}\right)$
$DO_t = Final\ DO\ of\ the\ diluted\ stormwater\ sample\ after\ incubation\ \left(\frac{mg}{L}\right)$
$P = Dilution\ factor$

with the value of P;

$$P = \frac{Volume\ of\ Sample}{Volume\ of\ Sample + Volume\ of\ Dilution\ Water}$$

3.6.2 Chemical Oxygen Demand (COD)

3.6.2.1 Introduction

The amount of oxygen required to completely chemically oxidize the organic water constituents to inorganic end products is known as the chemical oxygen demand (COD). COD is an important, rapidly measured metric for estimating the organic matter content of water samples. Some water samples may contain difficult-to-oxidize chemicals. COD levels may be a poor indication of theoretical oxygen demand in some circumstances due to partial oxidation under the current test methods. It should also be mentioned that the importance of the COD value is dependent on the makeup of the water under study (Raposo et al., 2010).

COD is a pollutant measurement used in natural and waste waters to quantify the strength of discharged waste such as sewage and industrial effluent waters. It is commonly measured in both municipal and industrial wastewater treatment plants and provides an indication of the treatment process's efficiency. The dichromate reflux method is favoured over other oxidant-based procedures due to its superior oxidizing ability, adaptability to a wide range of samples, and ease of manipulation. Most organic compounds are oxidized at 95-100% of their theoretical value (Raposo et al., 2010).

3.6.3 Total Suspended Solid (TSS)

3.6.3.1 Introduction

Water contains impurities such as suspended, colloidal, and dissolved materials. Water can be defined broadly as a mixture of various types of solids in a liquid base based on its contaminants. Solids are classified into five types: settleable, suspended, dissolved, volatile, and fixed. Total solids are a synthesis of all of these. The term "total solids" encompasses both "total suspended solids" (the fraction of particles retained by a filter) and "total dissolved solids" (the fraction that passes through the filter) (Gong et al., 2021).

Water clarity is a physical property that describes how clear or transparent water is. The depth to which sunlight penetrates water determines its clarity. The greater the amount of sunlight that can reach the water, the clearer it is. Water clarity is critical in aquatic ecosystems. Plants, as we all know, will die if they do not receive enough sunlight. Furthermore, as there are fewer plants, there are fewer food sources for many species. Underwater plant beds provide food and shelter for aquatic animals such as fish. Furthermore, because plants produce oxygen, fewer plants equate to less oxygen in the water (Gong et al., 2021).

The number of particles in the water or the amount of light that can pass through it is measured as water clarity. Total solids have an impact on water clarity as well. Higher solids slow the passage of light through water, which causes aquatic plants to perform slower photosynthesis. Water will heat up quickly and retain more heat, potentially causing harm to aquatic animals adapted to a lower temperature regime. Total solids are influenced by industrial discharges, sewage, fertilizers, road runoff, and soil erosion (Gong et al., 2021).

In this experiment, a well-mixed sample is evaporated in a weighted plate and dried to a consistent weight in an oven heated to 103 °C to 105 °C. The material residue left after a sample has been evaporated and dried in an oven is referred to as TS (Gong et al., 2021).

3.6.3.2 Related Evaluation Formula

To evaluate the performance of TSS testing, an equation has been provided in term of determined the TSS in the stormwater. Hence, the equation that is provided as shown in equation (3.2);

$$TSS = \frac{[(Weight\ of\ filter\ and\ dish\ +\ residue) - (Weight\ of\ filter\ and\ dish)] \times 1000}{Volume\ of\ sample\ filtered}$$

Equation (3.2)

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter shows the result based on the data collection and experiment that we get. This chapter is also the chapter which justify the result in a graph to get the observation explanation on how the green roof model can improve the water quality.

4.2 Experiment Results

For the result, the testing has been conducted in Environmental Laboratory, UMP Gambang. The experiment has been conducted four times to get the average of the result. From this data, the graph comparation between green roof recycled waste, commercial roof and the common roof can be plotted and the discussion can be made based on the graph.

4.2.1 Result Testing

Based on the result testing, the graph of concentration (mg/L) for the three sample has been plotted. From the graph, it showed that the concentration for the green roof recycled waste is the highest value in TSS and COD which is 40.3 mg/L and 410 mg/L, but it has a low concentration in BOD which is 23.7 mg/L. The sample which has the second highest of concentrations is the commercial roof which have 75.3 mg/L of concentrations in BOD, 21.9 mg/L in TSS and 87.3 mg/L in COD, and lastly the lowest concentrations goes to common roof sample with the amount of 3 mg/L in TSS, 6.9 mg/L in BOD and 18.5 mg/L in COD. From the graph, it seems that the green roof recycled waste has 37.3 mg/L concentrations more than the common roof and 18.4 mg/L more than the commercial roof in TSS test. Meanwhile for the BOD test, green roof recycled waste has lowest concentration compared to commercial roof which is 51.6 mg/L less than commercial roof and 16.8 mg/L more than the common roof. Lastly, in COD test, green roof has the highest amount of concentration compared to others with 391.5 mg/L more than the common roof, and 322.7 mg/L more than the commercial roof.

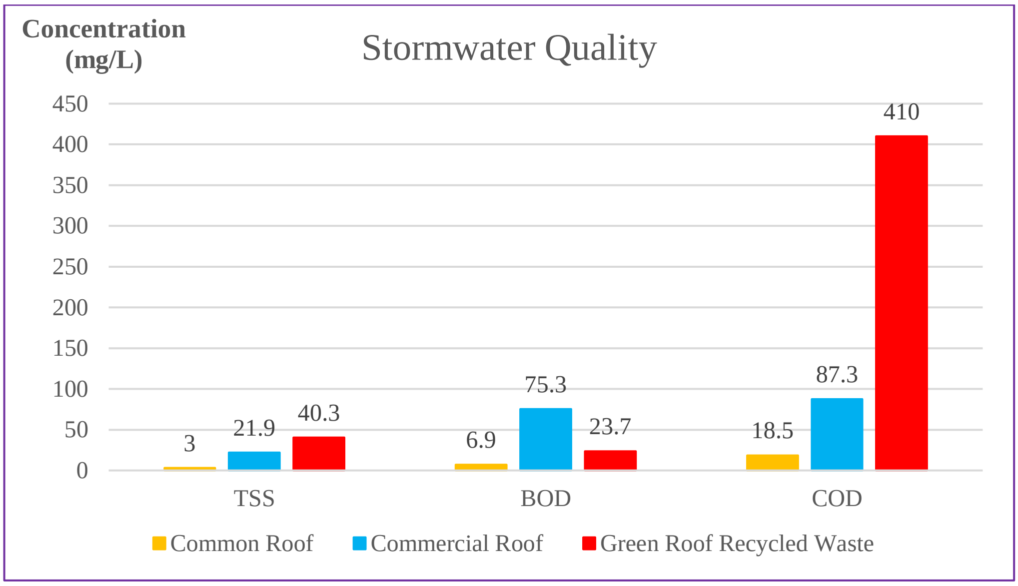


Figure 4.1 Water Quality Results

4.2.2 Discussion

The main reason that might be occurs for resulting this is because of the preparation material for layer of the green roof recycled waste was not done properly. For example, when preparing the drainage material, make sure to sieve the size of the burnt coconut shell between 2-5 mm only, and separate the smaller size, otherwise it can go through the void of the layer and effecting the water quality. This statement can be further strengthened by the result of green roof recycled waste sample which have the highest concentrations in Total Suspended Solid Test (TSS). The smaller particle than the sieve size has been trapped in the filter disc, resulting the bad result for green roof recycled waste in the TSS as shown in Figure 4.2.

Other than that, the problems that might be the factor of the high concentration is because the colour of the sample itself. The non-colour or clear water of the stormwater give lower concentrations in Chemical Oxygen Demand Test (COD). This statement can be further strengthened by the result of common roof sample which have the lowest concentrations compared to the others in COD test. Meanwhile, the commercial sample's colour is orange, hence it gives a high amount of concentrations in the reading and lastly, for the green roof recycled waste, it gives the highest value of concentrations in COD because the colour of the sample is dark. It is because when conducting the rainfall simulator, the coal from the burnt coconut shell which have a smaller size, go through along with the flow of stormwater, resulting the dark colour of the sample as shown as Figure 4.3.

Lastly, for the Biochemical Oxygen Demand Test (BOD), the green roof recycled waste contains a small particle of coal from the burnt coconut shell, which is means that it might contains a lot of bacteria and resulting the bad quality of the stormwater as shown in Figure 4.4. It is also giving the bad result on the dissolved oxygen which means it can't be drink and the fish and other aquatic organisms cannot survive. For the commercial roof, it has higher concentration compared to green roof recycled waste as shown in Figure 4.1. This is because, although the material is not dusty, but it cannot filter a lot of sedimentation that has bad smells. It is also not good for water quality environment because it gives a bad smell compared to the other sample, hence the commercial sample can't be a good water quality for the environment.

Figure 4.2 TSS result for the three sample

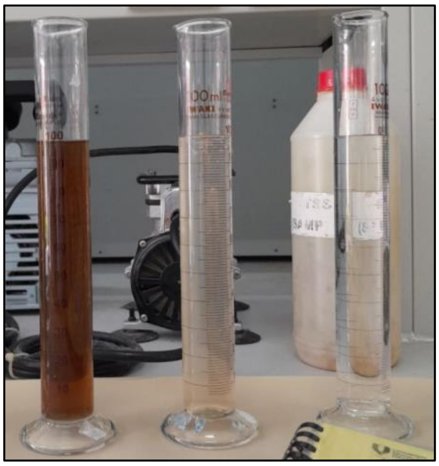


Figure 4.3 COD sample

Figure 4.4 BOD results after conducting BOD test

CHAPTER 5

CONCLUSION

5.1 Introduction

In this chapter, it will answer the objectives of this study for this scope. To strengthen the reason, we will give the supporting result from the data that we get from the experiment in Chapter 4. We also give suggestion on how to improve the Green Roof to be more effective in stormwater quality.

5.2 Conclusion and suggestion

This study had achieved all of the objectives in the study. Firstly, the green roof model that can improve the surface runoff quality using coconut waste as the green roof materials has been constructed. The dimension of the green roof is 600×600×600 mm with the combination of the roof and the building. For this study, the use of material for the green roof is Philippines Grass, burnt soil, coconut fibre, burnt crush coconut shell and bitumen sealant. This is because Philippines Grass doesn’t need a regular care and also doesn’t really depends on the fertilizer. For the substrate layer, the reason why burnt soil is chosen because burnt soil is free from chemical fertilizer and organic substance that may affect water quality. Other than that, the material that is used for the filter layer is coconut fibre because the green roof with the use of coconut fibre as a substrate are more suitable for application in green roofs, since roof overload plays an influential role in this application. When it comes to the drainage layer, the material that has been used for this layer is the burnt crush coconut shell because it has the ability to remove the metals, dyes, pollutants, anions and radio nuclides from water. Lastly, for the waterproofing layer, the material that has been selected is the bitumen sealant because it is impermeable which doesn’t allow fluid to pass through it and physically attached to the roof while raining.

After that, the green roof is not capable to improve the quality of the concentration of pollutants in stormwater. For the result of the green roof system, it is not as expected, because the water quality parameter for green roof recycled waste is higher than the others in TSS and COD but it is low in BOD. From the graph, the concentrations of green roof recycled waste increase 93% of itself more than the common roof in TSS test. It is also increase 46% of itself more than the commercial roof in the TSS. For the BOD, green roof is also increase 70% of itself more than the common roof and less 69% of the commercial roof. Lastly, for the COD, green roof has the highest amount of concentration compared to the others which is 410 mg/L and it is 79% higher than the commercial roof and 95% higher than common roof.

The explanation on why the green roof show less effectiveness is also have been explained in this study. It is because of the preparation material for layer of the green roof recycled waste was not done properly. For example, when preparing the drainage material, make sure to sieve the size of the burnt coconut shell between 2-5 mm only, and separate the smaller size, otherwise it can go through the void of the layer and effecting the water quality. Other than that, the problems that might be the factor of the high concentration is because the colour of the sample itself and lastly, the green roof recycled waste contains a small particle of coal from the burnt coconut shell, which is means that it might contains a lot of bacteria and resulting the bad quality of the stormwater. Hence, the problems that resulting the high amount of concentration of the green roof sample might come from the preparation of the material that been used.

To sum up everything, this study was carried out to evaluate the performance of recycled waste green roof system in reducing the runoff pollutant as well as improving the runoff quality. Green roof is the system that is efficient in improving water quality but only when the selection material is correct. Sometimes it didn’t work as it was, it maybe because of the preparation material that were not conduct properly. Green Roof is designed to overcome the problems that came from the rapid urbanization such as the increase of impervious area such as rooftops. The used of green roof system is to filter all of the sedimentation that occurs from the stormwater runoff that picks up dirt on the rooftop. The green roof is also known as the most friendly-environment system in terms of cost, material and the maintenance.

At the end of this study, the green roof system can be applied to all buildings as it is very lightweight due to the material that been used. There are five basic layers of the green roof that consists of vegetation layers, substrate layer, filter layer, drainage layer, and waterproofing layer. Besides that, the green roof is also seeming aesthetically in various looks, depends on the selection of the material for the vegetation. For example, we can use the vegetations like morning glory, as it is colourful and give a nice view on the roof. Other than aesthetic, green roof is also having multiple function in terms of hydrological and environmental performances. It can improve the performance of hydrological in term of reducing peak flow runoff, it is also can improve the water quality depends on the selection material that been used and also it can reduce the heat temperature in a room.

Although it is not the best idea to be the solution of the rapid urbanization, extensive green roofs are the most commonly practiced around the world. It is the solution for the problems of waste material because the material can be used as the layer in the green roof system. It is also can be the key factor in sustainable cities, and they can contribute to achieving regional and national Sustainable Development Goals (SDGs). In the other terms, green roof is the efficient and productive building which can bring into the sustainability of the city. It is because green roof contains the waste material which may be the cause of poor environmental pollution. Hence, the extensive green roof is one of a solution that can brought the environment into the good future.

As the suggestion of the improvement of the green roof system, the material of the layer can be change into another material that is cleaner and more possible to create a good stormwater quality. For example, other than burnt the coconut shell, we can use it raw because one of the problems that resulting the high concentration in the sample is the dust that came from the coal of the burnt crush coconut shell. Hence, the coconut didn’t need to be burned and can be used raw. Other than that, we can also use the material in the substrate layer as the fertilizer such as banana peels and eggshells which are used as organic fertilizer to give nutrients for vegetation growth. This is a new alternative that needs to implement as it can green the world.

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APPENDICES

Appendix A: Experiment at Environmental Laboratory, UMP Gambang

A. Biochemical Oxygen Demand (BOD) Test

a. Objective of the Experiment

- To calculate the pollution strength of home and industrial wastes in terms of the oxygen required in the oxidation process.

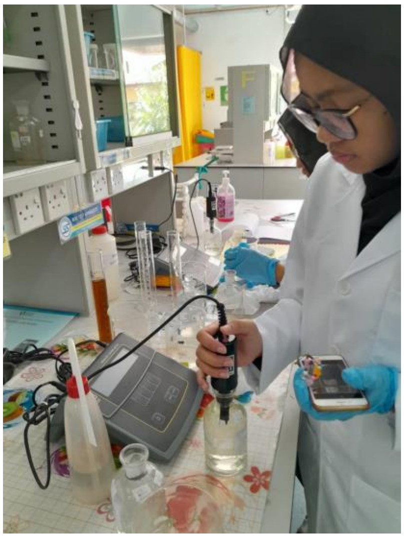
b. Apparatus

- BOD Incubator
- BOD Bottle
- Dilution Water
- Measuring Cylinder
- Dissolved Oxygen Meter
- Beakers

c. Procedures

1. Prepare 3 litres dilution water with one phosphate by bubbling compressed for 30 minutes.
2. Prepare 300 ml sample of BOD and 700 ml of dilution water and pour into a beaker.
3. Mix it together and pour into three bottles of BOD's bottles.
4. Wait a few minutes, and then put the DO meter to take the BOD reading.
5. After taking reading, top up the BOD bottles until full again.
6. Take the reading of BOD sample for the continuous 3 days.

The FYP student was conducting the BOD test



The FYP student was taking the reading of BOD in BOD test

B. Chemical Oxygen Demand (COD) Test

a. Objective of the Experiment

- To determine the Chemical Oxygen Demand (COD) in all types of water and wastewater.

b. Apparatus

- Vials
- Vials Rack
- COD Reactor
- Spectrophotometer
- Micropipette
- Beakers
- Low Range and High Range COD

c. Procedures

1. Collect your sample in the appropriate size container and preserve with the appropriate volume of sulfuric acid.
2. Properly label enough prepared COD vials (without mercury for non- regulatory samples) for all samples and standards to be digested.
3. Turn on your COD reactor and ensure it is set to 150°C.
4. Homogenize your sample by mixing or shaking aliquot 2 ml of sample or standard into each vial and replace the cap.
5. Caution: The tubes and solutions inside will become very hot upon addition of samples/standards handle them carefully.

6. Once the reactor is at the proper temperature, place the vials containing samples/standards in the reactor and set the timer for two hours.

7. After two hours, remove the vials from the reactor and allow them to cool to room temperature.

8. Caution: Do not accelerate the cooling of the vials via any means. Rapid thermal changes can cause the vials to crack and hazardous spills to occur. Once digested, do not open the vials without proper ventilation and protection. High pressure build-up of potentially toxic gases may be present. If participating in the COD disposal program, do not open the vials after digestion for any reason.

9. Set your spectrophotometer to the appropriate wavelength and read the absorbance.

The FYP student was taking the reading of COD in COD test

d. Evaluation Formula

To evaluate the performance of COD testing, an equation has been provided in term of determined the COD in the stormwater. Hence, the equation that is provided is;

$$Average\ COD = \frac{reading\ 1 + reading\ 2 + reading\ 3}{3}$$

C. Total Suspended Solids (TSS) Test

a. Objective of the Experiment

- To measure the amount of Total Suspended Solids (TSS) present in a water sample.

b. Apparatus

- Glass microfiber filter disc, 5.5m, Whatman 934-AH (47 mm)
- Suction flask, 1000 ml
- 47 mm glass microanalysis filter holder (funnel, clamp and base)
- Drying oven for operation at 103 °C to 105 °C
- Desiccator
- Analytical balance, capable of weighing to 0.1 mg
- Distilled water

c. Procedures

1. Insert the filter disc onto base and clamp.

2. Wash the dish with 3 successive ml distilled water when vacuum applied in the measuring cylinder.

3. Remove all traces of water by shake slowly the suction flask.

4. Switch off the vacuum, then remove funnel from base and place fitter disc on the watch glass.

5. Dry in oven at 103 °C to 105 °C for 1 hour.

6. After 1 hour, take out the filter disc from the oven.

7. Put the filter disc into the desiccator in about 20 to 30 minutes.

8. Weight it with the analytical balance and record it.

9. Place the filter on the base and clamp on funnel.

10. Shake the sample vigorously.

11. Pour 100ml sample into measuring cylinder.

12. Turn on the vacuum and pour the sample into the funnel, and shake funnel slowly.

13. Wash the measuring cylinder with distilled water and pour into the funnel by two times.

14. Wash the funnel with distilled water.

15. Remove the filter disc.

16. Dry in oven at 103 °C to 105 °C for 1 hour.

17. After 1 hour, take out the filter disc from the oven.

18. Put the filter disc into the desiccator in about 20 to 30 minutes.

19. Weight it with the analytical balance and record it.

The FYP student was washing the funnel with distilled water in TSS test

The FYP student was conducting the TSS test

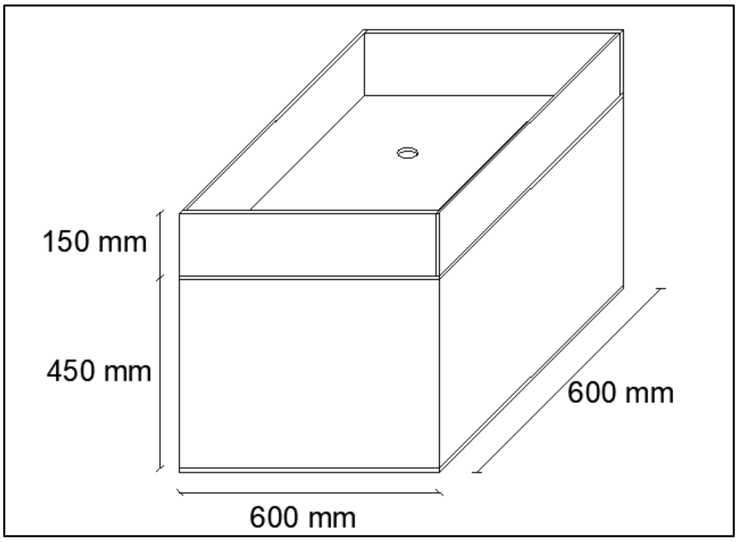
d. Evaluation Formula

To evaluate the performance of TSS testing, an equation has been provided in term of determined the TSS in the stormwater. Hence, the equation that is provided is;

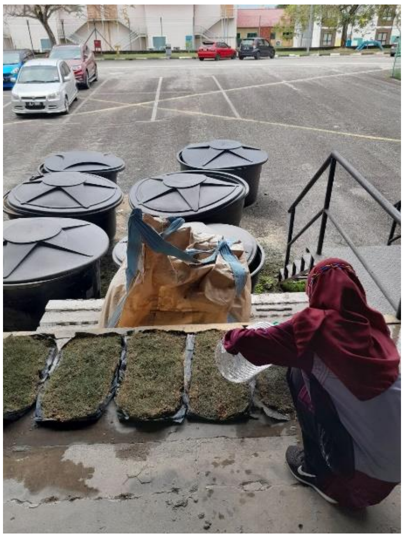
$$TSS = \frac{[(Weight\ of\ filter\ and\ dish\ +\ residue) - (Weight\ of\ filter\ and\ dish)] \times 1000}{Volume\ of\ sample\ filtered}$$

D. Raw Data of The Experiment BOD, COD and TSS

Parameters (mg/L)	Common Roof	Commercial Roof	Green Roof Recycled Waste
Biochemical Oxygen Demand (BOD)	6.9	75.3	23.7
Chemical Oxygen Demand (COD)	18.5	87.3	410.0
Total Suspended Solids (TSS)	3.0	21.9	40.3


150 mm
450 mm
600 mm
600 mm

Appendix B: The construction of green roof at Hydraulics and Hydrology Lab, UMP Gambang



The FYP student was watering the Philippines Grass

The FYP student was sealing the suction pipe into the roof model

The FYP student was drilling the hole at the roof model

The FYP student was combining the part of green roof model