A SYSTEMATIC REVIEW OF GREEN ROOF TECHNOLOGY USING COCO PEAT AS A SUBSTRATE

FATEN NUR DIYANA BINTI ABDUL MANAN

SCHOOL OF CIVIL ENGINEERING
UNIVERSITI SAINS MALAYSIA
2021

A SYSTEMATIC REVIEW OF GREEN ROOF TECHNOLOGY USING COCO PEAT AS A SUBSTRATE

By

FATEN NUR DIYANA BINTI ABDUL MANAN

This dissertation is submitted to

UNIVERSITI SAINS MALAYSIA

As partial fulfilment of requirement for the degree of

BACHELOR OF ENGINEERING (HONS.)
(CIVIL ENGINEERING)

School of Civil Engineering
Universiti Sains Malaysia

July 2021

DISSERTATION ENDORSEMENT FORM

UNIVERSITI SAINS MALAYSIA

SCHOOL OF CIVIL ENGINEERING
ACADEMIC SESSION 2020/2021

FINAL YEAR PROJECT EAA492/6
DISSERTATION ENDORSEMENT FORM

Title: A systematic review of green roof technology using coco peat as a substrate

Name of Student: Faten Nur Diyana Binti Abdul Manan

I hereby declare that all corrections and comments made by the supervisor(s) and examiner have been taken into consideration and rectified accordingly.

Signature:

Date : 5 August 2021

Endorsed by:

(Signature of Supervisor)

Name of Supervisor: Dr Nuridah binti Sabtu

Date:6 August 2021

Approved by:

(Signature of Examiner)

Name of Examiner: Dr. MOHAMAD FARED MURSHED
School of Civil Engineering
Engineering Campus
Universiti Sains Malaysia

Date: 6.8.2021

(Important Note: This form can only be forwarded to examiners for his/her approval after endorsement has been obtained from supervisor)

ACKNOWLEDGEMENT

The completion of this dissertation could not have been possible without the participation and guidance of many people. I would like to express my gratefulness to the School of Civil Engineering, Universiti Sains Malaysia for providing me educational knowledge and facilities throughout these 4 year to complete my study.

I would like to thank all the lecturers especially Dr Nuridah Sabtu as my Final Year Project Supervisor for her abundant support and encouragement as well as continuous guidance, providing ideas and making her time from the very beginning to complete this Final Year Project dissertation. Next, I would like to thank all the lecturers involve in Final Year Project especially to Dr Noor Hazlinda binti Abdul Rahman for the detailed guidance on Systematic Literature Review and other lecturers for the informative lectures throughout the whole semester.

Last but not least, I would like to convey my gratitude appreciation to my family and friends for their mentally, physically and financially supports and essential guidance to complete this project successfully.

ABSTRAK

Kajian ini dilakukan untuk mengkaji bumbung hijau menggunakan gambut kelapa sebagai substrat. Secara amnya, konsep bumbung hijau dilaksanakan untuk menyokong pertumbuhan tanaman sambil memberikan manfaat estetik, persekitaran, dan ekonomi. Bumbung hijau telah wujud lebih dari satu abad dan telah menjadi salah satu komponen terpenting di kawasan bandar dalam beberapa dekad kebelakangan ini. Bumbung hijau dikategorikan kepada tiga bahagian iaitu intensif, separa intensif dan luas. Sementara itu, gambut kelapa adalah substrat organik dan sumber yang boleh diperbaharui. Ia diproses daripada kulit kelapa. Ia banyak digunakan sebagai substrat kerana kapasiti penahan air yang tinggi sehingga 100%, liang udara sebanyak 13% dan ketumpatan pukal 0.08g/cm^3. Objektif kajian ini adalah untuk menentukan keberkesanan gambut kelapa sebagai substrat di bumbung hijau untuk menahan air hujan dan mengurangkan aliran puncak. Seterusnya, untuk mengkaji keberkesanan gambut kelapa sebagai substrat dalam meningkatkan kualiti air hujan. Oleh itu, kebanyakan artikel yang telah dikaji tertumpu pada topik substrat bumbung hijau. Kajian yang dilakukan membuktikan bahawa gambut kelapa berkesan untuk mengurangkan aliran air hujan dan mengurangkan aliran puncak kerana mempunyai kapasiti pemegangan air yang tinggi untuk menahan air hujan sehingga 100%. Ia juga terbukti bahawa dengan menggunakan gambut kelapa sebagai substrat dapat meningkatkan kualiti air hujan kerana dapat mengeluarkan logam berat dengan kadar penyingkiran logam berat sehingga lebih 99%. Akhir sekali, ia merupakan bahan organik, jadi gambut kelapa adalah substrat lestari yang boleh diperbaharui dan mudah didapati di beberapa negara seperti di Malaysia dan boleh digunakan untuk teknologi bumbung hijau.

ABSTRACT

This review was conducted to study the design of green roof using coco-peat as substrate. Generally, the green roof concept was implemented to support plant growth while also giving aesthetic, environmental, and economic benefits. It has been around for over a century and have become one of the most important components in urban areas in recent decades. Green roof is categorized into three parts which is intensive, semi-intensive and extensive. Meanwhile, coco peat is an organic and renewable substrate processed from coconut shells. It has good planting performance and reusable. It is mostly used as a substrate because of its high Water Holding Capacity up to 100% , Air-Filled Porosity (13%) and Bulk Density of 0.08g/cm^3. The objectives of this study are to determine the effectiveness of coco-peat as substrate on green roof for the attenuation of stormwater and reducing peak flow. Next, to examine the effectiveness of coco peat as substrate in improving stormwater quality. Therefore, most of the articles reviewed is focused on topic of green roof substrate. The review conducted proved that coco peat is effective to attenuate stormwater and reducing peak flow as it has high Water Holding Capacity to retain stormwater up to 100%. It was also proved that by using coco peat as substrate can improve stormwater quality as it able to remove heavy metals and pollutants by adsorption up to 99% removal rate. Lastly, it is also an organic matter and renewable substrates, so coco peat is a sustainable to be used for green roof technology as it can easily accessible in some countries for example Malaysia.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Background of the study

As the impact of the increasing urbanisation, many buildings are developed within green areas. This resulted in the scarcity of green areas within an urban area as well as increasing the surrounding temperature and decreasing the air humidity (Berndtsson, 2010). These changes are also affected the hydrological processes and negatively impact the downstream water environment in the urban ecosystem (Wen at al., 2021; Zhou, 2014; Hibbs and Sharp, 2012). So, green roof is invented based on the concept of utilization of plant and soil to the rooftop surfaces to develop more sustainable buildings. Green roof is a part of retrofitting Sustainable Urban Drainage System (SuDS) as an integral and integrated part of urban drainage. It is known as vegetative or eco-roof. These terms were used to define two types of green roof types which is extensive (shallow) and intensive (deep) roof with naturalistic or self-established vegetation (Deng and Jim, 2017). Green roof is used in Low Impact Development (LID) practices where it improves the sustainability of urban stormwater management and reduces the impacts on water bodies receiving urban stormwater (Zhan and Chui, 2016).

Green roof concept was designed to promote the growth of vegetation as well as providing aesthetical, environmental and economic benefits. The section of green roof consists of a layer of vegetation planted over a waterproofing system. It is a prolongation system of the existing roofing system which involving waterproofing membrane, root repellent system, drainage system, filter fabric, growth substrate and plants. It supplies the traditional vegetation without disrupting urban infrastructure. In other words, it embraced the green infrastructure while enhancing the man-made roofing structure system. The type of each green roof component is depending on the geographic location (Vijayaraghavan and Joshi, 2015). In 19^{th} century, the main country that leads in green roof technologies in Germany where more than 10% of houses have installed the green roof (Li, 2014; Kohler, 2006).

Additionally, green roof technologies are environmentally beneficial as it can improve the air and runoff quality, effectively reduce the stormwater attenuation, improved insulation of the building as well as reduce the 'heat island' effect and able to withstand heat, cold and high winds. However, there are many types of green roof substrates composed of organic and inorganic compounds. For instance, scoria, pumice, sand, ash, coco-peat, exfoliated vermiculite, expanded perlite, and crushed brick (Vijayaraghavan, 2015). In conclusion, this review is focusing on the systematic review on green roof technologies by using coco peat as the substrate.

1.2 Review Objectives

The content of review papers is mainly determined by review objectives of review proposal or scientific paper. This review is in shambles without review questions. Hence, a systematic literature review is conducted to focus on the following objectives:

- To study the design of green roof using coco-peat as substrate
- To determine the effectiveness of coco-peat as substrate on green roof for the attenuation of stormwater and reducing peak flow
- To examine the effectiveness of coco-peat as substrate in improving stormwater quality

1.3 Review Questions

Recent theoretical development has revealed that green roof study is one of the most sustainable ways to improve quality of life especially in terms of climate changing and improving air and water pollution. However, there is gap in literature to be focused on as there is least study on green roof performance in stormwater management particularly focused on green roof substrates. Therefore, this systematic literature review is focusing on these following review questions:

- How sustainable is the design of green roof incorporating coco-peat as a substrate?
- How effective is the coco-peat as a substrate on green roof in improving stormwater management?
- What are the limitations of using coco-peat as a substrate?

1.4 Scope of Systematic Review

Green roof application is known to have many benefits. It can reduce the peak flows and volume of the stormwater, stormwater attenuation, thermal insulations, reduce urban heat islands effect, and improves air quality. Some scope of study is using green roofs to reduce air and water pollution. However, this review will focus on the effectiveness of green roofs by using coco-peat as substrate in stormwater management only in terms of reducing the peak flows and volume of stormwater and improves the water quality. The coco-peat substrate is used compared to other types of substrate due to its characteristics such as lightweight, low cost, high water holding capacity, and good medium for water retention.

1.5 Advantages of the Systematic Review

Malaysia has the tropical climate and major stormwater problems for instance flash flood, water pollution and water scarcity. By retrofitting green roof technology, it manages to delay the stormwater and reduce the peak flow to mitigate flood. The substrate plays an important part where it will hold the water in its porous texture and the water will flow through the drainage layer before it will be released to the drainage system. It is crucial to use the suitable substrates. Coco peat is chosen due to its characteristic where it has high water holding capacity. It can hold the water for the time being before releasing it through the drainage layer. Thus, it will also improve the water quality. Due to air pollution, the stormwater sometimes can be acidic so green roof substrate act as medium to infiltrate and absorb the acidic rain and escalate the pH value of the runoff during the water retention and release more neutral stormwater runoff to drainage system. Nonetheless, coco-peat has neutral pH value to contain the acidic pH value. Stormwater also contains heavy metals that can affect the quality of the stormwater. However, less study about the coco peat alone was used as substrate in past and current research. Most of the researchers use the mixture of coco peat with other substrate such as pumice, perlite and zeolite. Through this systematic comparison of literature, this review will enhance the knowledge gap that prevail in green roof technology and highlight the capability of the green roof by using coco peat as a substrate to attenuate stormwater through the reduction of peak flow as well as to control the stormwater runoff quality.

1.6 Thesis Structure

This thesis consists of five chapters which are Introduction, Literature Review, Methodology, Results and Discussions, as well as Conclusion and Recommendations.

Chapter 1: Chapter 1 is the overview chapter of the study. In this chapter, a brief purpose and objectives of the study is explained. In addition, the problem issues, importance and benefits as well as expected outcome are studied. This chapter is informative and provide better understanding and able to give early overview to the readers in regard to the purpose and context of the whole thesis.

Chapter 2: Chapter 2 consists of literature review according to the relevant variables. This chapter comprises the previous research related to the topic studied for instance the problem statement, purposes and research question of previous research. It will also provide information in depth for the relevant variables of the study based on the previous research.

Chapter 3: Chapter 3 provides detailed description of all aspects of the methodology and procedures from the beginning to the completion of the study. Since this is a systematic literature review paper, this methodology part will consist of comparison of method used in previous research to the related topic as well as equipment, procedures and data collection of the study.

Chapter 4: Chapter 4 will describe the findings obtained based on Chapter 3. The data and results obtained are illustrated in more clear presentation such as graphs, charts and tables. The data and results are then analyzed and discussed to reflect on the study's findings and implications.

Chapter 5: Chapter 5 is the conclusions and recommendations part based on the findings. It will conclude the overall study from previous research articles and recommendations are made to improve the quality of study and to do more effective and precise research in the future.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Green roofs have been around for over a century and have become one of the most important components in urban areas in recent decades (Li and Yeung, 2014). It can be described as vegetated layer on top of roof structure with few other components that has impact towards the buildings and surrounding areas. Additionally, green roofs are not only a solution for increasing building sustainability and energy conservation, but they also provide a number of social, economic, and potential advantages to urban areas (Cascone, 2019).

Green roof are categorized into three parts which is intensive, semi-intensive and extensive. The main differences of these three type of green roof is the substrate layer. The intensive green roof has substrate layer of 20cm – 200cm depth and extensive green roof has substrate layer less than 15cm while the semi-intensive has substrate layer in between 15cm – 30cm (Vijayaraghavan, 2016). It was designed and developed to promote the growth of variety form of vegetation on the rooftop of the buildings for more aesthetic, sustainable and environmentally and economically beneficial. Green roof most part contain a few segments, including vegetation, substrate, filter fabric, seepage material which is the drainage layer, root obstruction and insulation. Each type of green roof segment relies upon the geographic location for its usage and benefits (Vijayaraghavan and Joshi, 2015). However, vegetation and growth substrate is the most crucial role in influencing the quality of stormwater runoff as well as in managing stormwater runoff.

In Malaysia, the Department of Irrigation and Drainage (DID) launched the Urban Stormwater Manual of Malaysia (MSMA) in 2001 and launched the second edition of MSMA in August 2012. This manual presents the new perception of stormwater management. The system was designed to balance three significant components which are water quantity, water quality and amenity. The facilities introduced in Sustainable Urban Drainage System (SUDS) are swales, detention storage, wetland, bioretention and green roof. However, the MSMA design guidelines does not included the green roof as stormwater facilities (Ayub et al., 2015).

Malaysia received high precipitation throughout the year. It is a tropical climate country and has huge area of tropical rainforest and water catchment. Despite the fact that average rainfall per year is 3500mm, Malaysia faces major stormwater issues such as flash flood, water shortage and water pollution. The issues are getting worse as the year pass.

Table 1: Type of Green Roof (Vijayaraghavan, 2016)

Intensive Green Roof	Semi-Intensive Green Roof	Extensive Green Roof
• Substrate Layer: 20 – 200cm • Diversification of plants • High Maintenance and Cost • More Prominent Weight	• Substrate Layer: 15 – 30cm • Moderate type of plant • Frequent maintenance needed and High Cost • Moderate Weight	• Substrate Layer: Less than 15cm • Limited type of vegetation • Low Maintenance and Cost • Low Weight

The expanded soil depth make intensive green roof has more diverse plant preference including shrubs and little trees. Thus, it requires more maintenance for fertilizing, weeding and watering. Attributable to the thin substrate layer, extensive green roofs can put up to only limited types of vegetation including grasses, moss and few succulents. This type of green roof is usually utilized in circumstances where no additional structural support is needed due to its low weight. It is also low maintenance and cost. Next, the semi-intensive green roof has moderate substrate layer so it can accommodate small herbaceous plants, ground covers, grasses and small shrubs. However, it requires frequent maintenance and also high capital expenses. Between those three types of green roof, extensive green roof is the most used word wide due to the structural weight restriction, maintenance and cost (Vijayaraghavan, 2016).

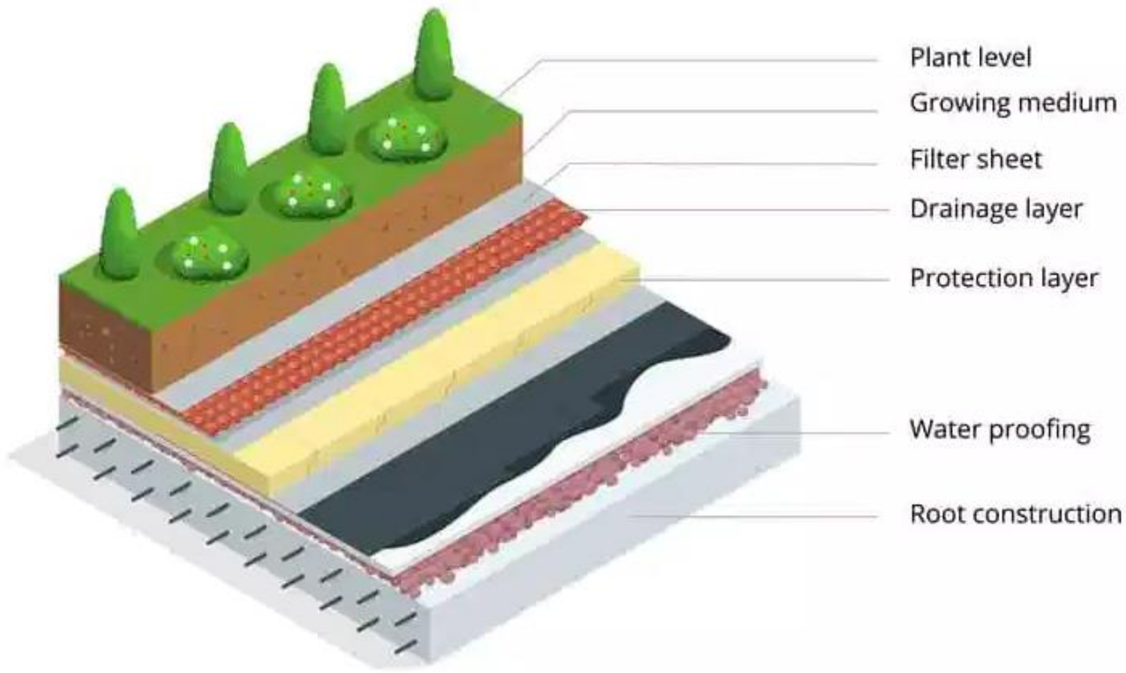

Figure 1: Green roof layer (Harry, 2020)

Figure 2: Type of Green Roof (Roofattic, n.d.)

2.2 Growth Substrate

Growth substrate is a crucial factor for a successful roof garden (Lamera et al., 2014). It is important to evaluate variables such as organic or inorganic, aeration, drainage, water holding capacity (WHC), particle size and bulk density of the substrate (A'saf et al., 2020; Ajlouni et al., 2017; Ondono et al., 2016). The examples of organic substrate that is commonly used in green roof are peat, compost and coco peat meanwhile the inorganic materials including the sand, perlite, vermiculite, gravel, pumice, expanded clay and volcanic tuff (Wilkinson et al., 2015) Taking into account that the growth substrate, vegetation and drainage control the success of green roof, the characteristic for each of these components were enhanced and methodology was suggested to construct practical green roof (Vijayaraghavan, 2016). Some of the benefits of green roof are related to the characteristic of growth substrate including water quality improvement, stormwater attenuation, thermal benefits and sound insulation. Most of the researchers used commercial substrates in their studies, however there were also suggestions to use low cost and lightweight substrate such as pumice (Kotsiris, 2013), zeolite , scoria (Cao, 2014) , vermiculite (Bisceglie, 2014), peat (Ondono, 2014) and crushed brick (Ondono, 2016).

2.2.1 Peat

Peat is a partially decomposed organic matter formed primarily from plant material that has collected in the surface organic layer of a soil due to waterlogging, oxygen shortage, excessive acidity, and nutrient inadequacy. Another type of peat, which is peat moss is a type of dead fibrous substance that occurs in peat bogs when mosses and other live things degrade (International Peatland Society, n.d.)

Figure 3: Peat (International Peatland Society, n.d.)

2.2.2 Perlite

Perlite is one type of mineral that occur naturally. It exists in nature as a type of volcanic glass that is formed when volcanic obsidian glass is saturated with water for an extended period of time. Perlite are commonly made of Aluminium Oxide, Sodium Oxide, Potassium Oxide, Iron Oxide, Magnesium Oxide, Calcium Oxide, 70%-75& of silicon dioxide and 3%-5% of water. It is non-renewable because it occurs naturally. In soil mixtures, including soilless medium, perlite is used as non-organic additive to enhance aeration and change the soil substructure, keeping it loose, draining, and resistant to compaction (Max, 2021)

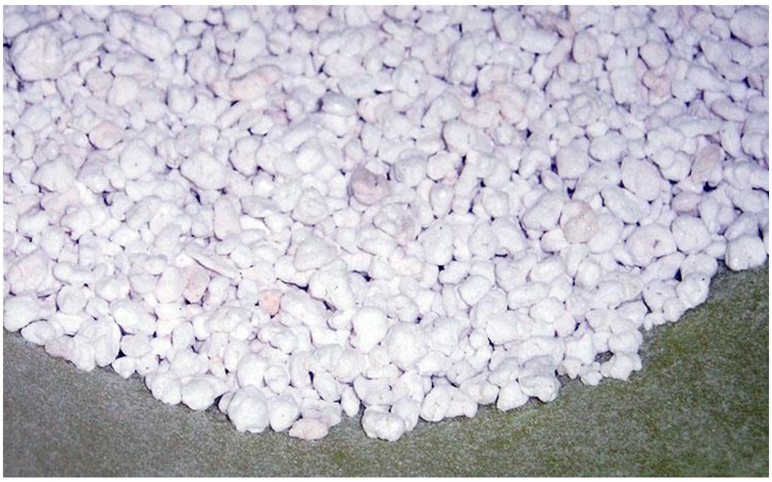

Figure 4: Perlite (Epic Gardening, 2018; Maja, 2009)

2.2.3 Vermiculite

Vermiculite is a spongy material that ranges in appearance from dark brown to golden brown. It resembles flakes when it dried. It is a form of mineral, to be exact a hydrous phyllosilicate mineral that expands rapidly when heated naturally. When the mineral is sufficiently heated, it will exfoliate. Vermiculite is widely used in industrial and commercial applications, such as packaging, fire protection, refractory and high temperature insulation, loose fill insulation, lightweight concrete screeds, plasters, friction linings, special coatings, swimming pool liners, animal feedstuffs, and horticultural potting mixes, due to its desirable properties. It is widely used especially as non-organic growing substrates as it is a lightweight material that saves energy when used as insulation. It is also non-combustible, very absorbent, pH neutral, inert, non-reactive to all but very strong component (Amy, 2021)

Figure 5: Vermiculite (Amy, 2021)

2.2.4 Gravel

Gravel is made up of very fine, uneven rock and stone fragments. It has a rougher, rocky texture than sand and is smaller than stones. A considerable amount of rocks or gravel will be present in rocky or gravelly soil. Gravel is a coarser-than-sand aggregate of more or less rounded rock particles as it has more than 2 mm in diameter. According to the Food and Agriculture Organization (FAO) classification system, gravel is the particles with diameter in between 2mm-76mm (FAO, 2015). Heavy metallic ore minerals, such as cassiterite (a primary indicator of tin), and native metals, such as gold, can be found in flakes in some gravel beds. In fact, gravels are commonly utilised in construction. Pebbles (4–64 mm in diameter), cobbles (64–256 mm in diameter), and boulders are all types of gravel fragments (larger than 256 mm). Gravel rounding occurs as a result of abrasion during conveyance by streams or grinding by the sea (Britannica, 2019).

Furthermore, gravel is commonly builds up in areas of stream channels and on beaches where the water moves too quickly for sand to settle. Gravel formations are often more limited and varied in coarseness, thickness, and configuration than sand or clay deposits due to changing circumstances. An inner zone of breaking waves may have a persistent deposit of gravel or pebble beds (Britannica, 2019).

On a sandy beach, a persistent accumulation of gravel or pebble beds may occur around the inner zone of breaking waves. As a results, the tips of stony cliffs are generally the source of cobble and pebble beaches (Britannica, 2019).

On the other hand, Chinkulkijniwat et al., (2010) studied that the highest attainable dry bulk density rises as gravel content rises, but the optimal water content for compaction decreases (Jan et al., 2013). Yue et al., (2015) also concluded gravel sizes is the most significant factors in determining characteristic of soil and vegetation.

Figure 6: Gravel (Stan, 2019)

2.2.5 Zeolite

Zeolite is composed up of silicon, aluminium, and oxygen. It is a type of crystalline mineral. Inside the mineral, these components produce holes and channels that attract water and other tiny molecules. It is also known as a molecular sieve, and a commonly used as absorbent and catalyst. Zeolite is an alkaline-hydrated aluminosilicates that come in more than 50 distinct forms and have a wide range of applications, including soil-binding agents and nutritional supplements for animal and aquatic life.

With its various applications in agriculture, the importance of zeolites has been realised to a larger extent. Natural zeolites are good soil remedying substances because they have a high water and nutrient holding capacity (WHC); they improve infiltration rate, saturation hydraulic conductivity, cation exchange capacity, and limit water loss through deep percolation.

In addition, by combining cation exchange capability with a preference for ammonia and potassium, zeolite improves soil structure. Because of these qualities, zeolite can buffer soil and reduce ammonia toxicity. Zeolite, unlike other soil additives like lime, does not degrade over time.

Furthermore, zeolite can efficiently absorb heavy metals such as cadmium (Cd), lead (Pb), nickel (Ni), anions such as chromate (CrO_4^{2-}) and arsenate (AsO_4^{3-}), and organic pollutants such as benzene, toluene, ethylbenzene, and xylene (BTEX) from soil or water bodies (Mousumi et al., 2021)

Figure 7: Zeolite (Austin Air, 2017)

2.3 Stormwater Attenuation

Green roofs are generally known to retain stormwater and delay peak flow so that it can reduce the risk of flooding (Chen et al., 2016). It works to retain the stormwater when the growing substrates absorb the stormwater and retain it in the pore spaces. Furthermore, green roofs also have vegetation to store the water in the plant tissues or the plant will conduct transpiration process to transpired back the water into the atmosphere or it will be evaporated (Nagase and Dunnet, 2012). Then, the water will go through filter fabrics and flow through the drainage layer and drain out from the layer. Apart from that, the growth substrates usually play important roles to attenuate stormwater due to the components are lightweight, so it has higher Water Holding Capacity (WHC). An examination was conducted by Vijayaraghavan and Joshi (2014) to identify the characteristics of the substrates. The study identified that the attenuation of the stormwater is predominantly due to the high water holding capacity of the growth substrate. Higher WHC is proven to delay the runoff during the simulated green roof experiment (Graceson et al, 2013). Table 2 shows few researches that have been conducted.

Table 2: Findings on green roof performance as stormwater attenuation

Authors	Year	Findings
Monteiro et al.	2017	Several benefits of green roofs are directly associated with the properties of growth substrate, including water quality improvement, peak flow reduction, thermal benefits and sound insulation.
Vijayaraghavan and Franklin	2015	Substrate supplemented with coir *Sargassum wightii is an* example of a bio sorbent. It also increased retention of the same elements in the planted substrate and reduce losses in runoff.

		The overall stormwater retention efficiencies were 26%, 27%, 29%, 33%, 40% and 54% according to soil depths of 5, 10, 20, 40, 80, and 160 cm respectively. As expected, efficiencies increased with soil depth.
Vijayaraghavan and Joshi	2015	A substrate using 30% perlite, 20% vermiculite, 10% sand, 20% crushed brick, 10% coco-peat and 10% T. conoids was found to have high water retention capacity (49.5%).
Graceson et al.	2013	They concluded that particle size distribution can be a more significant factor for Water Holding Capacity (WHC) and stormwater retention.
Farrell et al.	2013	Higher WHC is an important advantage as it enables the substrate to store water thereby decrease runoff volume, besides, the stored water can be available to plants during drought conditions.
Speak et. Al	2012	Average retention of 65.7% can be achieved on an intensive green roof on University of Manchester campus compared to 33.6% on an adjacent paved roof.
Nagase and Dunnett	2012	There are several vegetation species used in extensive green roofs. Different plant type results in significant difference in the amount of stormwater runoff.
Nagase and Dunnett	2011	The organic material, coco-peat, exhibited the lowest bulk density and reasonably high WHC and hydraulic conductivity. The main benefits of using organic matter are that it maintains good soil structure, increases cation exchange capacity, improves water retention, and supply of limited nutrients to plants.

2.4 Stormwater Quality

Several studies considered the total performance of green roof substrate throughout the entire life cycle (Peti et al., 2012) and seasonal and temporal variability in runoff quality (Buffam et al., 2016). Green roofs can also be the adsorbents and filters to reduce runoff pollution. Xue et al., (2020) found that green roof has purification effects on runoff pollution. Here water quality concentrations from green roofs are lower than typical roofs. This was proven by Zhou et al., (2010) where they concluded that the removal rate of total nitrogen from the runoff from green roof is between 50% to 70% (Liu et al., 2021). Additionally, the substrate chosen must in low organic matter and the vegetation is crucial for a preferable water quality outcome (Beecham and Razzaghmanesh, 2015). Furthermore, current research focusing on runoff quality for the mixture of substrates. The individual components of the substrates such as coco peat alone as a substrate are very little (Berndtsson, 2010; Vijaraghavan, 2016)

2.5 Coco-peat

Coco peat is an organic and renewable substrate processed from coconut shells. It has good planting performance and reusable. Aside from the affordable price, it can be used as a substrate in the soilless cultivation such as cucumber, lettuce and tomato. Some of the researchers mixed up the substrate component. For example, the green roof substrate used is composed of 20% compost and 80% coco coir. They mixed the coir and compost manually until a homogeneous mixture is obtained. (Maheshsingh et al., 2020). Coco coir or coco peat is mostly used because of its high water holding capacity and air-filled porosity when mixing with different particle sizes and ratios (Dvorak and Volder, 2013). Additionally, green roof substrate that contains of 20% coco-peat can filter approximately 6000mm rainfall without exceeding United States Environmental Protection Agency (USEPA) freshwater regulations for heavy metals (Vijayavaraghavan and Joshi, 2014). In another experiment conducted by Vijayaraghavan and

Franklin, (2014), the study found that organic constituent such as coco-peat enhances 5.2 times their original weight under maximum moisture conditions. Heat storage capacity is low for substrate that is mostly composed of coco peat which has higher values of organic content (Julia et al., 2017). Also, significant quantities of light metal ions were leached from substrate components, in particular peat followed by vermiculite. These are macronutrients that are essential elements for plant growth. Coco-peat found to have very high K content whereas significantly less Ca and Mg contents (Cascone et al., 2018).

b) c)

Figure 8: a) Coco peat b) Coco Husk c) Coco fibre/coir

2.6 Water Holding Capacity (WHC)

Water Holding Capacity is defined as how much water for certain soil can hold. It is also known as Water Retention Capacity. Soil has pores which is the existing spaces between soil particles that allow gases and moisture to flow through or retain within the soil profile. The ability of soil to retain water is highly correlated with particle size where it means the water molecules tend to adhere to fine particles than coarse particles. For example, water molecules tend to bind to clayey soil than sandy soil because clay has larger surface area than sandy soil to hold, hence clayey soil can retain more water than sandy soil as well as having higher water holding capacity. However, in loamy soil, nutrients are more easily leached which results in low water holding capacity (Yu et al., 2013; Rehman et al., 2020). Table 3 shows findings on water holding capacity findings specifically for coco peat.

Table 3: Water holding capacity for coco peat

Authors	Year	Findings
Beuchel	2021	• Coco husk has water holding capacity of 40%
Kalaivani and Jawaharlal	2019	• Determine water holding capacity using Kneer-Box Rackzowski box method as suggested by Viji et al (2012). • Highest water holding capacity was found in Cocopeat alone with 66.37% of holding capacity compared to coco peat mixture with other media such as vermi compost, bio compost, and press mud.
Ilahi and Ahmad	2017	• Determine water holding capacity of coco peat with perlite mixture with ratio of 3:1 by using filter funnel with stopper at lower part.

		• They used sample with ratio 1:2 of media:water and left for oven-dried for 24hr at 105˚C. • Use water holding capacity formula: WHC = $\frac{Mass\ of\ water\ retained\ from\ sample}{Mass\ of\ oven\ dried\ sample}\ x\ 100\%$ • Water holding capacity for coco peat with perlite mixture is 912.54% of dry weight.

Figure 9 shows different type of soil texture by Cassie (n.d.) which is texture for clayey soil, sandy soil, silty soil and loamy soil that contributes in the potential of each soil water holding capacity. Next, Figure 10 shows particle size for different type of soil by Rain Machine website. Sans has larger particle size with 0.05mm – 2mm and it is porous so it has lower water holding capacity meanwhile silty soil has 0.002mm – 0.05mm soil particles which is smaller than sand hence silt can hold more water than sand. However, clay has the smallest soil particles that can retain more water and has the highest water holding capacity.

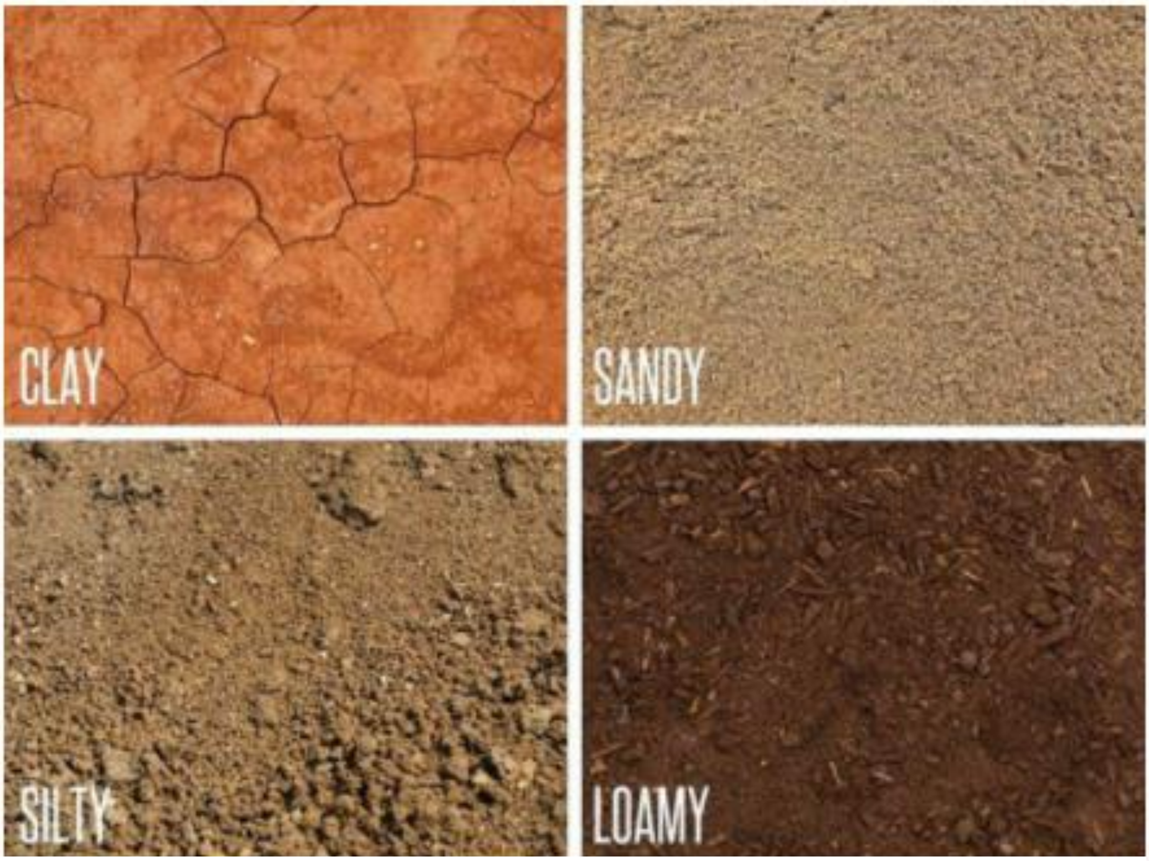

Figure 9: Different type of soil (Cassie, n.d.)

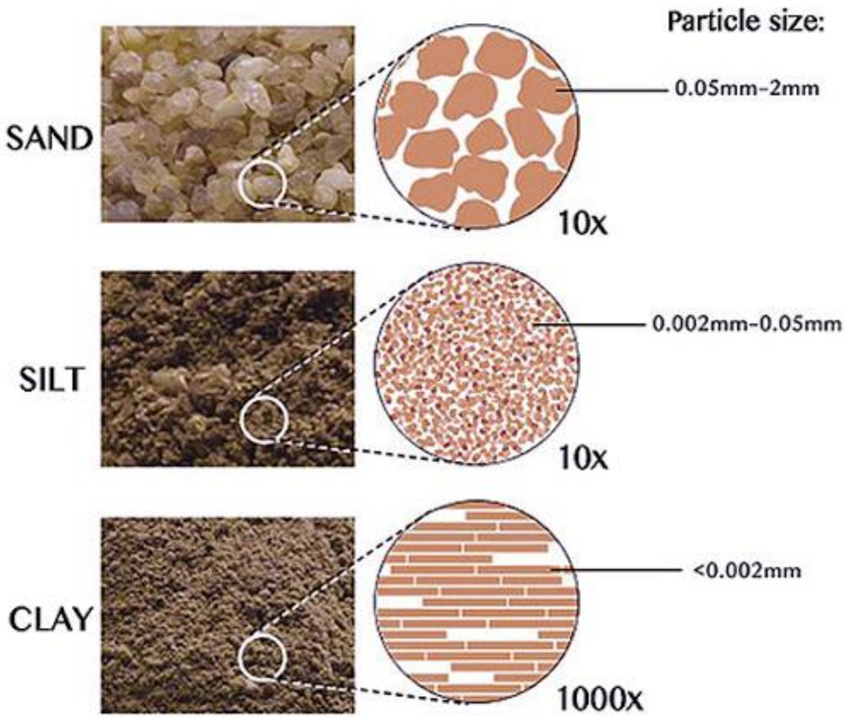

Figure 11: particle size for different type of soil (Rain Machine, n.d.)

Based on Figure 11, sand has the largest particle size which is highly permeable towards water meanwhile clay has the smallest particle size which is low permeable towards water. High permeability towards water results in low water holding capacity as well as low permeability towards water results in high water holding capacity for the soil.

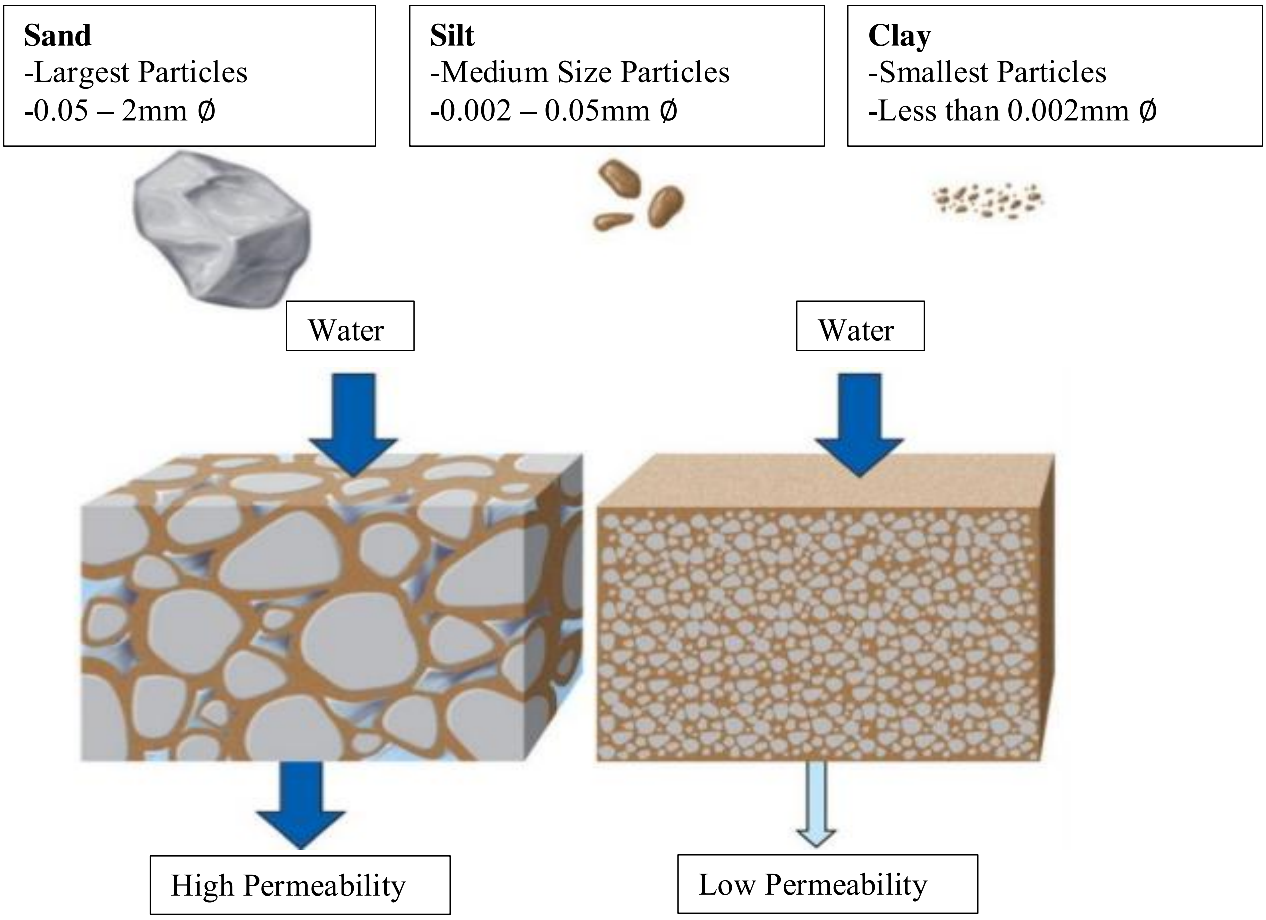

Figure 12: Soil particle size and its permeability (Candice, 2017)

Consequently, water holding capacity of soil can be influenced by soil organic matter and texture which has lots of impact towards plant growth, soil drainage and soil functional characteristics. With increasing in altitude water holding capacity will be decreased (Bordoloi et al., 2019). Additionally, Querejeta (2017) also agree that the texture of the soil such as sand, clay, silt or clay, the structure of the soil such as bulk density and porosity, and the organic matter are the primary determinants of soil water retention capacity, hydraulic conductivity and permeability. Recent research has demonstrated that soil structural properties can be used and are the essential indication of soil water retention capacity (Hayashi et al., 2006; Sakaki and Smits, 2015; Rabot et al., 2018). Gan et al., (2019) and Yang and Wang, (2019) found water retention curve depicting soil water retention capacity is an important feature of soil hydraulic properties that influences snowmelt water and solute dynamics in part.

Furthermore, most of soil activities rely on soil water retention and transport which explains their significance for environmental processes throughout Earth's Critical Zones. Soil hydraulic parameters are critical in irrigation and drainage studies to anticipating nutrient leaching, providing water to plants and additional agronomical and environmental purposes. The structure of the soil porous system, which is made up of pores of various geometries and sizes is reflected in soil hydraulic characteristics (Rousseva et al., 2017)

According to German roofing greening recommendations, the depth of the growing media is the main source of variance in the water retention capacity of green roof (FLL, 2008). However, according to findings by Graceson et al., (2013), water retention was not significantly improved by increasing the depth of the growth media alone. The composition of the growing media also had an impact on water holding capacity, which in turn affected water retention on the decks. Both intra-particle pore spaces and inter-particle pore spaces distribution, which was influenced by particle size distribution, were major deciding variables of water holding capacity and rainwater retention. Table 4 shows recent studies on water holding capacity of the soil.