DESIGN AND DEVELOPMENT OF RAINWATER CONSERVATION SYSTEM FOR APPLICATION IN SCHOOL

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A report is submitted
in fulfillment of the requirement for the degree of
Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2020

DECLARATION

I declare that this project report entitled "Design And Development of Rainwater Conservation System For Application In School" is the result of my own work except as cited in the references

Signature	:	
Name	:	HII DING FUNG
Date	:	26 JUNE 2020

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APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature : ....

Name of Supervisor : ....

Date : ....

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DEDICATION

To my beloved mother and father

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ABSTRACT

In this study, a feasible RWH system has been conceptually developed for the selected school premise which is a building in SJK(C) Ayeh Keroh. The design of the RWH system is mainly based on the purpose of the RWH system application within the school premise. The purpose of this RWH system is to supply as backup toilet flushing water for the school building and helps to solve water shortage problems in the school. If the rainwater is abundant, this system can replace the municipal water for flushing toilet purpose. The design components including collection system, piping system, filtering system and storage system. The components of the RWH system are uPVC gutters, filters, uPVC pipes, a 3000 liters polywater tank and a 1/2 HP booster pump. For the water tank component, material selection analysis compared three types of materials which are polywater tank, steel water tank and stainless-steel water tank. Ultimately, polywater tank material was chosen due to its high durability, easy installation, easy to maintenance and variety. The 3000 liters water tank capacity is determined by the demand side approach which the storage tank capacity is determined by analyzing the water demands of that building. For performance analysis, a stress analysis has been conducted by using Solidworks for storage tank component. The result shows that thee storage tank can withstand up to a maximum von Mises stress of 106986.1 N/m^2 and a minimum von Mises stress of 32.0 Nm^2 by defining a pressure of 126477.5 Pa that act onto the inlet of the water tank. The total estimated initial install cost by considering all the material costs and labor costs for this RWH system is about RM 5109.88, without considering the maintenance cost. The cost, application, treatment system, rainfall characteristics, policy, and public perception are the practice and implementation issues that we might face. Lastly, a comprehensive study about the RWH system need to be done before designing the RWH system due to various factors such as cost, application, rainfall characteristics, purposes of RWH system and implementation issues.

ABSTRAK

Dalam kajian ini, sistem RWH yang telah dibangunkan secara konsep untuk premis sekolah terpilih yang iaitu bangunan di SJK (C) Ayeh Keroh. Reka bentuk sistem RWH ini terutamanya berdasarkan tujuan sistem RWH dan keadaan premis sekolah. Tujuan sistem RWH ini adalah untuk membekalkan air pembuangan tandas sandaran untuk bangunan tersebut dan membantu menyelesaikan masalah kekurangan air di sekolah. Sekiranya air hujan melimpah, sistem ini dapat menggantikan air perbandaran untuk tujuan pembilasan tandas. Komponen reka bentuk termasuk sistem pengumpulan, sistem perpaipan, sistem penyaringan dan sistem penyimpanan. Komponen sistem RWH adalah talang uPVC, penapis, paip uPVC, tangki poli air 3000 liter dan pam penggalak 1/2 HP. Untuk komponen tangki air, analisis pemilihan bahan yang membandingkan tiga bahan iaitu tangki poli air, tangki air keluli dan tangki air keluli tahan karat. Pada akhirnya, bahan tangki poli air dipilih kerana ketahanannya yang tinggi, pemasangan yang mudah, penyelenggaraan yang mudah dan pelbagai. Kapasiti tangki air 3000 liter ditentukan oleh pendekatan sisi permintaan yang mana kapasiti tangki simpanan ditentukan dengan menganalisis permintaan air bangunan itu. Untuk analisis prestasi, analisis tegasan telah dilakukan dengan menggunakan Solidworks untuk komponen tangki simpanan dan hasilnya menunjukkan bahawa tangki simpanan anda boleh bertahan sehingga tekanan von Mises maksimum 106986.1 N / m^2 dan tekanan von Mises minimum 32.0 Nm^2 oleh mendefinisikan tekanan 126477.5 Pa yang bertindak ke dalam saluran masuk tangki air. Jumlah anggaran kos pemasangan awal dengan mempertimbangkan semua kos bahan dan kos tenaga kerja untuk sistem RWH ini adalah sekitar RM 5109.88, tanpa mempertimbangkan kos penyelenggaraan. Biaya, aplikasi, sistem perawatan, karakteristik hujan, kebijakan, dan persepsi masyarakat adalah masalah praktik dan pelaksanaan yang mungkin kita hadapi. Akhir sekali, kajian komprehensif mengenai sistem RWH perlu dilakukan sebelum merancang sistem RWH kerana pelbagai faktor seperti kos, aplikasi, ciri hujan, tujuan sistem RWH dan masalah pelaksanaan.

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ACKNOWLEDGEMENT

First and foremost, I would like to express my deepest appreciation to my supervisor Assoc. Prof. Dr. Tee Boon Tuan for giving me this opportunity to do final year project with him. He never hesitated to give me advice and guidance whenever I confronted problems. I am thankful for his patience and advice while leading me in this project.

I would like to thank my course mates for giving me their support, patience, and encouragement. I would also like to thank my family for their support. Lastly, thank you to everyone who had been to the crucial parts of realization of this project.

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LIST OF ABBEREVATIONS

CAD	Computer Aided Design
DID	Department of Irrigation and Drainage
GPM	Gallons Per Minute
HDPE	High-Density PolyEthylene
JKR	Jabatan Kerja Raya
KTAK	Ministry of Energy, Water and Communication
NGT	National Green Tribunal
RWH	Rainwater Harvesting
SMKIS	Sekolah Menengah Kebangsaan Iskandar Syah Melaka
TDH	Total Dynamic Head
uPVC	unPlasticised Polyvinyl Chloride
WHO	World Health Organization

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LIST OF SYMBOL

A	Area, m^2
P	Pressure, Pa
ρ	Density, kg/m^3
g	Acceleration due to gravity, ms^{-2}
h	Height, m
L	Length, m^3
P_L	Pressure loss per meter, Pa/m

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1. CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Rainwater conservation or rainwater harvesting is a practice that is socially acceptable and environmentally responsible all the while and promoting self-sufficiency (Maxwell-Gaines, 2018). It provides us clean water for many purposes such as agriculture uses, household uses, school uses etc. The best way to conserve rainwater is by rainwater harvesting. Rainwater harvesting is a very good sustainable water management practice that can be implemented by anyone at any level. Rainwater harvesting system can be very simple and can be very complicated. Generally, rainwater harvesting is a method to store rainwater that falls to the roof into a tank for later use. Rainwater harvesting can help the community to resolve the water shortage problem and can also be reserved as emergency uses. Some communities were used to import water for their daily needs, by rainwater harvesting, they can reduce the need of imported water. For school, the rooftop rainwater harvesting system can supply the water for toilet flushing, cooking, washing hands and feet of students and staffs, hygiene and ultimately for drinking purpose, if the conserved rainwater is properly treated (Clean India Journal, 2012).

Rainwater harvesting can also help to reduce the energy used to pump and treat the municipal water to house or any building. The treatment and pumping of municipal water require a lot to operation energy. Hence, by using rainwater harvesting to replace municipal water with harvested rainwater, it can help to save a lot of energy consumption. By harvesting and using rainwater to replace municipal water, it can help to reduce the water

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bill within the community. Rainwater has a very widely range of uses, it can be for irrigation use, indoor non-portable use, and portable water use. If other water sources unavailable, rainwater can be the water source in the areas. Rainwater harvesting can be the permanent solution to the water crisis problem in different parts of the world (Madaan, 2016). This method is best suit for those areas which has sufficient rain, but the groundwater supply is not sufficient. It can utilize the use of rainwater in that areas. Although our mother earth is made up of three-fourth of water, but only very little of it is suitable for human consumption or agriculture. The rainwater is also unpredictable there is some countries that constantly faced water shortage problem, by using this method, the problem can be easily solved.

The importance of rainwater collection or rainwater harvesting lies in the truth that it can be stored for future use. It is also an excellent source of water for plants and landscape irrigation since it contains no harmful chemicals such as fluoride or chloride. The stored water can used to revitalize the ground level water and improve its quality. This also can help to increase the ground level water which then can be easily accessible. When fed into the ground level wells and tube well are prevented from drying up. This increases soil fertility. Harvesting rainwater reduces soil erosion and checks surface run off water.

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Thus, rainwater harvesting plays an important role in the sustainable water management strategies. The practice of rainwater harvesting is and vital part of developing the sustainable water resource path for all the communities. Rainwater harvesting can be the crucial water supply strategy and paradigm to resolve the demands of population growth and economic development. Rainwater harvesting is an untapped water resource that could be developed quickly within communities and will bring a huge impact.

1.2 PROBLEM STATEMENT

Rainwater harvesting (RWH) in both urban and rural areas has become an important practice worldwide. Generally, there is two types of RWH system that can be designed, which are systems that using surfaces or ground catchments areas and systems using above-ground or rooftop catchment areas (Sung, 2010). RWH system is a good education tools for school children to educate them about the benefits of conservation of water typically rainwater. By implementing this RWH system, they can encourage the next generations to have a responsibility to maintain the sustainability of our natural resources. In term of economy, this RWH system can save money by not wasting the water. RWH system can also solve the low energy pumps and controls problems (Education – School Rainwater Harvesting Systems, n.d.).

Due to the development process in Malaysia, there was a quite number of environmental issues existed and these issues getting serious day by day. The rapid development of Malaysia has caused some natural disasters such as flooding, greenhouse effect, pollution, and global warming. Malaysia has a good water supply system, but the demand of clean water has increased due to the population growth and development. RWH system is an innovative solution for this problem. This system can be used as an alternative water supply in the future and can reduce the cost of water bills for water supply among consumers such as schools. It is very suitable to be implemented in Malaysia due to the high rainfall intensity in Malaysia. In fact, many schools in Malaysia does not have a good rainwater conservation system that can conserved the rainwater for many purposes. Thus, an appropriate RWH system needs to be designed and developed to collect the rainwater and conserved in storage. The collected rainwater can be used as non-potable purposes such as irrigating, washing clothes, watering the gardens, washing cars, flushing toilets, washing hands, hygiene needs etc. RWH system is basically designed to provide enough water for the needs of schools. The practice and implementation of RWH system in school also is an issue that is needs to consider.

Since 2017, the National Green Tribunal (NGT) has ordered all educational institutions in the capital to build RWH systems at their premises at their own expense in India. According to the status report submitted on November 20, 2018, the NGT committee has levied a Rs 5-lakh (RM0.28) fine on schools and colleges where there are no RWH systems (around 40% of schools) or existing ones are not operating. Schools were criticized and punished for not meeting the order in several news reports. But no one questions why these schools, following such strict orders, were unable to enforce the same. In fact, the schools that were able install RWH system were had no clue about how to operate and maintain them. Abundance support in terms of expertise regarding implementing RWH systems and the benefits need to be provided to those schools. The schools need to be made aware of the huge benefits of installing the RWH system in their school buildings. The RWH system in school buildings will help in water augmentation in terms of groundwater recharge or storage and can act as flood control measure. This green initiative can also be used as a demonstrative campaign for the dissemination of information and to provide students with an awareness of sustainability within the education program. To guide the schools to install the RWH system, the creation of zones according to site conditions of the school is necessary. There is a need to provide technical and managerial support to schools for a appropriate RWH implementation. Building capacity is essential to disseminating information in schools related to planning, developing, running, and sustaining the RWH program. Short-term training programs should be implemented for target audiences covering various subject areas on RWH systems. For instance, of teachers and school administrative units, training programs can be conducted; for government officials to manage the school; for organizational maintenance, etc. This model would be useful not only to design and implement appropriately, but also to generate general awareness (Schools need a roadmap for rainwater harvesting, n.d.).

1.3 OBJECTIVE

The objectives of this project are as follows:

1. To overview the practice and implementation issues of RWH system in SJK(C) Ayeh Keroh.
2. To design and develop a feasible RWH system for application in SJK(C) Ayeh Keroh.
3. To provide an overall analysis on the designed rainwater harvesting system.

1.4 SCOPE OF PROJECT

The scopes of this project are:

1. The application of the RWH system is based on the school usage.
2. The design of the RWH system will be focusing on its feasibility and on how it can provide water for non-potable use.

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1.5 SIGNIFICANCE OF THE PROJECT

In this project, a feasible RWH system design can be obtained and can be a reference and guideline for a school to implement and install an RWH system based on the conditions of the school premises. This project will let the user (school) to identify the best RWH system to be installed and implemented based on several criteria such as mechanism, cost, and design.

1.6 GENERAL METHODOLOGY

The actions that need to be carried out to achieve the objectives in this project are listed below:

1. Literature review

   Journals, articles, or any materials regarding the project will be reviewed.

2. Data collection

   Survey on the available design data from the market and previous work.

3. Drafting

   Design the RWH system by using CAD software.

4. Simulation

   Simulate the RWH system.

5. Analysis

   Evaluating the performance of the RWH system and analyse on the results.

6. Report writing

   A report on this study will be written at the end of the project.

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1.7 SURVEY

An interview has been conducted with the principal of SJK(C) Ayeh Keroh. According to the principal, she thinks that the RWH system is applicable to the school premises, but there is some concerns on the system, for example the inconsistent rainfall at Melaka since as a matter of fact, Melaka city has relatively low rainfall based on her observation. She also has concern on the installation cost of the RWH system. However, she thinks that the RWH system was a good idea to solve the water shortage problem and to reduce the school's water bills. It can also act as a backup solution during the dry season.

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2. CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

2.1.1 Water Status and Demand in World

According to Law & Bustami (2013), the earth is covered by 70% of water, but only 2% of the water is directly consumable fresh waters. Moreover, not all the 2% of freshwater can be used, about 30% of Earth's fresh water came from groundwater sources, river, and lakes. This indicate that only 0.6% of Earth's total water can provide freshwater that we can easily obtain and consume. There is no substitute for water. The amount of water that we have now is to be shared with our future generations. There is no additional water supply to meet the increased water demand by the people in the future.

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2.1.2 Water Consumption and Reserves in Malaysia

According to Anang et al. (2019), there is an increasing demand for water in different sectors such as domestic and industry, irrigation, and others from 1980 to 2020. This growing demand of water is to sustain Malaysia's growing population and industrialization. No slowdown is expected given the plans for Malaysia's continued economic growth. Based on the National Water Resource Study 2000-2050 the water demand for the domestic consumer will be increased from 2000 till 2050, respectively 2,029 million m^3 to 5,904 million m^3. The total volume also rises from 10,833 million m^3 to 17,675 million m^3.

From the research by Christopher Teh (2015), Malaysia consumed more than 300 liters of water per person per day compared to 150 liters per person per day by Singaporeans in 2009. Water consumption per capita per day increase about 7.6 liters per year according to the graph of Malaysian's consumption in 2005 to 209. This increase in water consumption is not matched by an increase in water reserves. At this rate of increase in water usage of Malaysian, Malaysia would be left with nearly no water reserves by 2025.

2.1.3 Physical, Rainfall and Weather Conditions in Malaysia

The climate is equatorial, i.e. hot, humid, and rainy all year round in Malaysia, an Asian state located just north of the equator. Rainfall is abundant and frequent throughout the year, in fact, it is difficult to find an area where it is below 2,000 millimeters (79 inches) per year, or a month when it is below 100 mm (4 inches); however, periods can be found when it is not too high, although they are not the same everywhere. However, the rains are caused by the monsoon regime, since Malaysia is close to the Equator and is surrounded by the sea, there is no real dry season. Furthermore, the rains are quite erratic from year to year, as is generally the case in tropical countries. The monsoons, however, make precipitation more abundant and frequent in areas directly exposed to these winds: between mid-October and January, the north-eastern monsoon prevails, affecting in particular the east coast of Peninsular Malaysia and the north-eastern coast of Borneo, while between June and September, the period of the south-western monsoon usually produces weaker effects in Malaysia. But it should be noted that tropical rains occur predominantly in the form of intense downpours or thunderstorms, usually in the afternoon, so there is no shortage of sunshine, at least in the morning, when the weather is generally good.

According to a review by Lani et al. (2018), the success of RWH system is greatly depends on the quantity and temporal pattern of the rainfall. To maximize its benefit, Malaysia's RWH system development should consider its quantity of rainfall. The higher depth of rainfall would be more reliable for a similar roof area and water consumption rate.

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In addition, the number of rainy days in Malaysia is high, being in the humid tropical region (138 days to 181 days / year). It is therefore necessary to maximize the use of RWH system to have the greatest water savings in the reservoir to be used during the dry period. Given the spatial variation in rainfall in Malaysia, assessing the potential of RWH system for different rainfall regions is crucial.

2.2 REVIEW OF RWH SYSTEM

2.2.1 Policies of RWH System in Malaysia

According to a review by Lani et al. (2018), the drought problem in 1998 in Malaysia has caused the Malaysian's government to embark the RWH system. Following to this water crisis, the Ministry of Housing and Local Government has promoted houses to install the rainwater collector and utilization system in 1999. Following this, various initiative in the form of policies and guidelines have been formulated by various agencies. For example, the Urban Stormwater Management—Part 6: RWHS, MS2526-6:2014 has been initiated by Department of Standards Malaysia in 2014. The main purpose is to facilitate the implementation of RWH system for residential and government buildings. The Department of Irrigation and Drainage (DID) and The Ministry of Energy, Water and Communication (KTAK) are the two government agencies that have implemented the rainwater harvesting system in the early stages of implementation. To support the program, many RWH system projects such as underground and aboveground tanks have been implemented. Most RWH system projects in Malaysia use high-density polyethylene (HDPE) for the aboveground tanks. Total costs to install RWH system range from RM 20,000 to RM 350,000 depending on the size and type of building. The Malaysian government pays attention to RWH system as alternative water source to reduce the dependence on river and other surface waters.

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The RWH system policy should be extended to all buildings with large roof surfaces, such as commercial buildings, which are expected to have a greater economic benefit in the future. Unfortunately, the current policy remains relatively loose. There is no mention in relation to the roof area of the minimum requirement of tank size. Moreover, this policy is still not subject to commercial buildings. Therefore, as a scientific judgment before issuing a legal policy, a comprehensive study considering an optimum tank size according to the different roof sizes and climatic conditions in Malaysia should be conducted for the foreseeable future.

2.2.2 Benefits of RWH System

From the review of Lani et al. (2018), There are two main categories of benefits of RWH system, which is environmental and economic. For environmental benefits, RWH system can be used as alternative water supply to supplement piped water or municipal water. When used at a large scale, RWH system can help to reduce the flash flood in urban area and minimize the soil erosion and to prevent the pollutant from entering the water bodies. In terms of economic benefits, RWH system has potential to reduce the water bills since it is very useful for non-potable water use. For single and multi-family buildings, a financial viability analysis of the RWH system was assessed and found that the payback period of the RWHS investment was between 33 and 43 years, and 61 years for a 20 m^3 tank for single and multi-family buildings, respectively. Because RWH system's benefit is highly dependent on water use, system design, rainfall, and other variables of uncertainty, its long-term performance evaluation is needed to better understand the effects of each variable on its benefits. As a basis for designing the future RWHS, this is very useful.

According to Chiang et al. (2013), the practice of RWH system has receive huge attention in arid and remote areas. RWH systems are applied for both potable and non-potable purposes, including drinking water, agricultural, industrial and groundwater recharge. From a sustainability point of view, rainwater harvesting is a feasible and practical way to conserve water. In addition, RWH systems have advantages of being free of charge, low maintenance, and environmental friendliness.

For instance, according to a research by Halim et al. (2019), soil erosion is a serious issue for the school that are located at hillsides, the heavy rains has caused the overflow of rainwater and erosion at the hillside, and this is a threat for pupils, teachers and the school facilities as a whole. An RWH system has been identified as one of the innovative solutions to sustain the landscape and to minimize the impact to the environment by utilizing the abundance of rainwater.

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2.2.3 RWH System Type

From the review of Lani et al. (2018), in Malaysia, a few types of RWH system have been implemented, namely, backyard system, frontage system and underground system as shown in Figure 2.1. Since backyard and frontage system have no distribution system, it often established as ‘collective systems only’. Among all the three types of RWH system, backyard system is the most popular RWH system because it is cheap and easy to install compared to other systems that require plumbing system. In this system, there are two approaches to locate the storage tank, either elevated or ground. Ground tank is commonly developed for RWH system production in various countries such as Brazil, Australia, and Portugal, and continents such as Africa, whereas the elevated tank typically consists of three tank tiers, i.e. top, middle, and bottom. Usually the top-level tank is used for water supply, while the middle-level and lower-level tanks are used to store the rainwater collected. Metal and polyethylene tanks are commonly used for this system, respectively, in elevated and ground tanks. This adopts the same principle of deployment for backyard system for the frontage system. Normally a switch is made using the reinforced concrete tank to replace the polyethylene tank to allow maintenance work. The concrete tank is more durable than the polyethylene tank, making it more economical in the long run. It is also noted that the use of concrete tanks is relatively cheaper than polyethylene tanks (up to 38 percent). As for the underground system, the cost for small-scale systems such as home consumption, which includes a pump, was about RM 1700.

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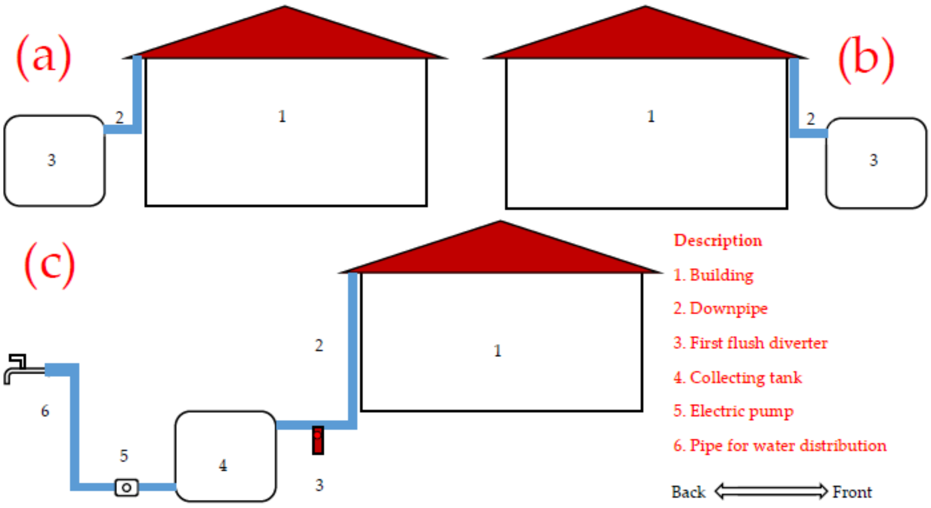

Figure 2.1: Typical design of (a) backyard system, (b) frontage system, and (c) underground system implemented in Malaysia (Lani et al., 2018).

2.3 MAIN COMPONENTS OF RWH SYSTEM

2.3.1 Rainwater Collection System Component

Collection system is where rainwater is initially collected. In the RWH system for the Mnyundo Primary School from the research by Mwamila et al. (2016), the collection system consists of a 168 m^2 corrugated iron roof. The plan and elevation views of schematic of the RWH system at the Mnyundo Primary School are shown in Figure 2.2 and Figure 2.3, respectively. Generally, there is two types of RWH systems can be designed, which is systems using ground catchment areas and systems using rooftop catchment areas (Sung, M.,2010).

Law & Bustami (2013) showed that to determine the storage capacity of storage tank, it is necessary to calculate the roof catchment area of the school building. To calculate roof catchment area, the external length and width of the building beneath the roof are measured. If the building is not rectangular, it must divide into few individual rectangles. For example,

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a L-shaped building can be regarded as two rectangles, after that, the length and width of each rectangle are measured. Then, the length is multiplied by width of every rectangle. The result is the area within each shape. Lastly, the area of each rectangle is added together to get roof catchment area.

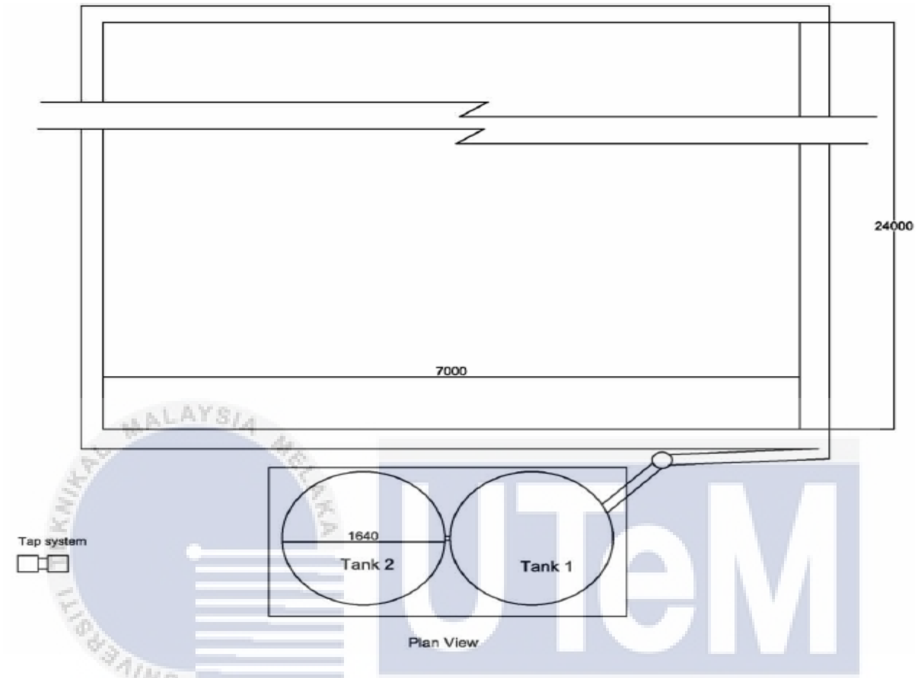

Figure 2.2: Plan view of schematic of RWH system at Mnyundo Primary School (Mwamila et al., 2016).

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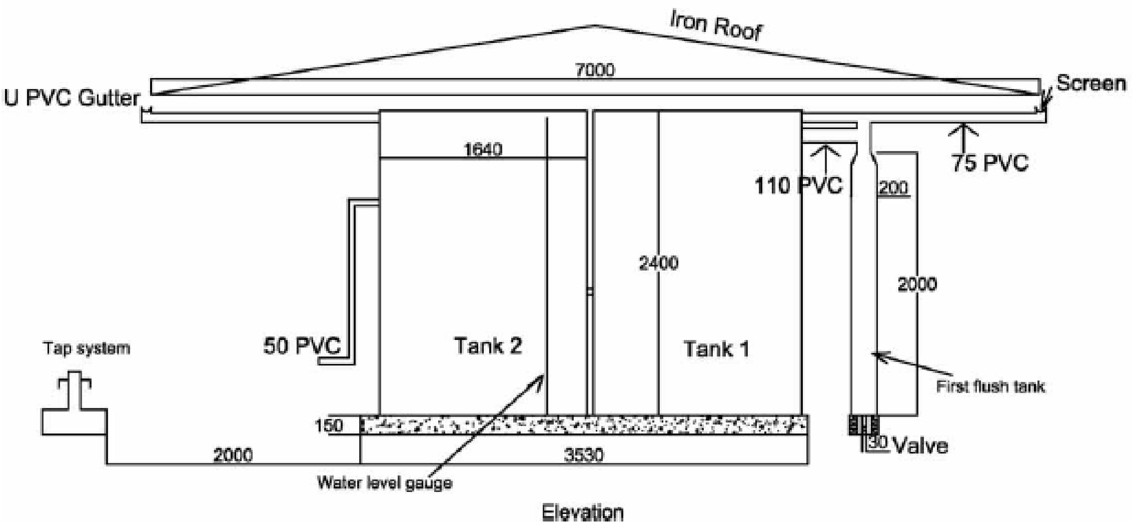

Figure 2.3: Elevation view of schematic of RWH system at Mnyundo Primary School (Mwamila et al., 2016).

2.3.2 Rainwater Piping System Component

Piping system is the pipes components that connect the other components together, it also enables the flow the harvested water from the rooftop to toilet. In the RWH system from Halim et al. (2019), the RWH system for Sekolah Menengah Kebangsaan Iskandar Syah aims to reduce flow rate in existing normal drainage system, provide water to fertigation pond, generate power for the scrolling and message board. This RWH system act as alternative water supply, promote ecosystem for freshwater habitat, generate energy, reduce rainwater flowrate by diverting and dividing rainwater in existing drainage, and then collected and converted into useful applications. The schematic diagram for the RWH system for SMKIS is shown in Figure 2.4. The piping system of the RWH system for SMKIS responsible for delivering the rainwater from the dam to normal drainage, turbine, and storage tank (Figure 2.4). The dam was built at the rainwater intakes on the top of the hill. Meanwhile in the RWH system from the research by Mwamila et al. (2016), the piping system is consists of PVC gutters and pipes which act as delivery system of rainwater from one place to another place, the location of these pipes and gutters are indicated in Figure 2.3.

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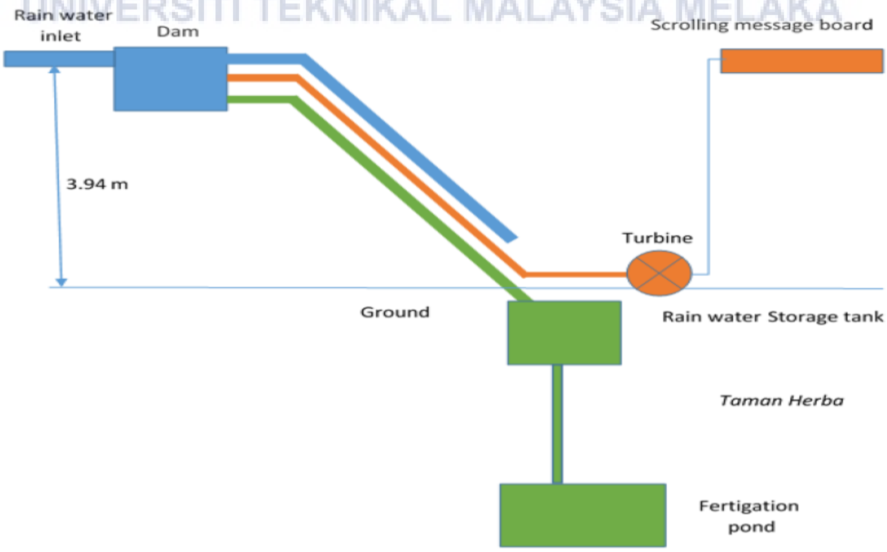

Figure 2.4: Schematic diagram of RWH system for SMKIS (Halim et al., 2019).

2.3.3 Rainwater Treatment System Component

From the research by Lani et al. (2018), most of the RWH system is for non-potable uses such as toilet flushing, watering garden and washing cars, and it is directly used from the collection tank. To design an RWH system for potable use, such as drinking purpose, a treatment system needs to develop although rainwater in Malaysia is relatively clean from major contaminants. Table 2.1 shows the roof rainwater quality in Malaysia. It is obvious that some parameters such as turbidity, lead, fecal coliforms, and total coliforms are presented above the limit that regulated by World Health Organization (WHO). This fact revealed that treatment still need to be done before the rainwater can be widely used for potable use.

Table 2.1: Roof rainwater quality in Malaysia (Lani et al., 2018)

Parameter	Galvanized Iron Roof	Concrete Roof	WHO Standardization
pH	6.6 to 6.4	6.8 to 6.9	6.5 to 8.5
Turbidity (NTU)	10 to 22	25 to 25	5
Total solids (mg/L)	64 to 119	116 to 204	-
Suspended solid (mg/L)	52 to 91	95 to 153	-
Dissolved solid (mg/L)	13 to 28	23 to 47	-
Zinc (mg/L)	2.94 to 4.97	0.05 to 1.93	5
Lead (mg/L)	1.45 to 2.54	1.02 to 2.71	0.05
Fecal coliforms (MPN/100 Ml)	0 to 8	0 to 13	0
Total coliforms (MPN/100 mL)	25 to 63	41 to 75	0

Therefore, to maximize the economic benefit of RWHS, it is worth incorporating a simple treatment system. While many methods are possible such as disinfection, slow sand filtration, membrane filtration, pasteurization, ozonation, and adsorption, it is important to consider their cost and suitability. Before implementation, a specific goal of building RWH system should be considered to maximize the investment benefits. Rainwater management system choice has consequences for the cost of installation and maintenance. For example, harvested rainwater non-potable uses such as toilet flushing, landscape irrigation, and car washing do not require treatment. Conversely, a cost-effective treatment system is required to use collected rainwater for drinking, cooking, showering, and fabric washing.

For instance, the RWH system in the research by Mwamila et al. (2016) has a treatment system consisting of a coarse screen, first flush tank, and sedimentation tank. Since the purpose of this RWH system is to contribute rainwater as the main drinking water source for the school, it is necessary to have a proper treatment system. The treatment components in this RWH system are discussed below. Potential contaminants to the collected rainwater comprise dusty particles, fecal matter from birds, and tree litter falling on rooftops. As the rain falls on the roof, it washes off and mixes up with these contaminants, some of which will be filtered out depending on the size of the mesh openings of the coarse screen on the gutter. The screen can be made of several types of materials including plastic or metal. The purpose of the first flush tank is to divert the initial rainfall, which is expected to wash out most of the contaminants adhered to the roof. When filled up, the ball inside will block the passage and incoming rainwater will proceed without mixing into Tank 1 (Figure 2.3). Generally, it is considered that the contaminant quantity will be halved with each additional millimeter of first flush. For sedimentation tank, the rainwater is diverted from the roof downpipe to Tank 1 after the first flush tank is full (Figure 2.3). Tank 1 has a capacity of $5m^2$. As the rainwater fills up the tank, the remaining particles settle down, as a function of the time spent by the rainwater in the tank. All the treatment components that were mentioned above are to attain acceptable water quality for drinking purposes.

2.3.4 Rainwater Storage System Component

Storage system is where the harvested rainwater is temporarily stored. According to Law & Bustami (2013), two types of approach can be used to estimate the sizing of storage tank of RWH system in SJK Chung Hua No.2, Kuching, which are demand side approach and supply side approach. The demand side approach is the simplest method to calculate the storage requirement based on the required water volume or known as the consumption rates and occupancy of the building. However, this approach is only suitable in areas with a distinct dry season. The tank is designed to meet the necessary water demand throughout the dry season. The required storage capacity can be determined by Equation 2.1:

Required storage capacity (m^3) = demand (m^3) x dry period (Equation 2.1)

Supply side approach on the other hand, is the method to estimate the most appropriate storage tank capacity for maximizing supply by represent roof run-off and daily consumption graphically. This method will give a reasonable estimation of the storage requirements. Daily or weekly rainfall data are required for a more accurate assessment. In low rainfall areas where rainfall has an uneven distribution there may be an excess of water during some months of the year, while at other times there will be a deficit. The volume of rainwater harvested can be determine by formula below:

Volume of Rainwater Harvested (m^3) = total roof catchment area (m^2) x average annual rainfall (m) x runoff coefficient (Equation 2.2)

From the result obtained in the research by Law & Bustami (2013), the most reliable one will be the demand side approach and the value to be used for storage tank capacity determination is 4.32 m^3, which is the daily usage or demand of selected school building. There are two storage tanks proposed for the toilet flushing of both male and female toilets which are located on left hand side and right-hand side of the school building. The size of each tank is 2.0 m diameter and 0.7 m height, the volume would be 2.2 m^3 and hence the total volume of two tanks is 4.4 m^3 which fulfilling the daily demand of school building (4.32 m^3).

For the RWH system in the research by Mwamila et al. (2016), storage system of two 5 m^3 plastic tanks, the first tank being used as sedimentation tank as well as storage (Figure 2.3).

2.4 COMPARISON OF EXISTING RWH SYSTEM

Three distinct RWH system with different functions and purposes has been chosen to be discussed and compared to identify the best design of RWH system for school application. The three approaches of RWH system were RWH system for SJK Chung Hua No.2, Kuching by Law & Bustami (2013); RWH system for Sekolah Menengah Kebangsaan Iskandar Syah (SMKIS) by Halim et al. (2019) and RWH system for Mnyundo Primary School in Mtwara, a southern region of Tanzania by Mwamila et al. (2016). Each RWH system listed above have its own objectives in different aspects. Table 2.2 below shows the comparison of RWH systems in different aspects.

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Table 2.2: Comparison table of the three RWH systems

Aspect RWH system	SJK Chung Hua No.2, Kuching	SMKIS	Mnyundo Primary School
Objective	Estimate the potential amount of water supply can be replaced by rainwater that could be stored for supplementary use, mainly for flushing toilets.	Reduce flow rate in existing drainage system, provide water to fertigation pond, generate power for the scrolling and message board.	Solve problem of schoolchildren who miss classes while fetching water for daily use, reduce water scarcity.
Function	Flushing the toilets, reduce the amount of treated water for non-potable use, care for the environment.	Alternative water supply, promote ecosystem for freshwater habitat, generate energy, reduce rainwater flowrate by diverting and dividing rainwater in existing drainage, and then collected and converted into useful	Contribute rainwater as the main drinking water source for the school, also for knowledge transfer, capacity building, and installing a sense of ownership to local people.

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		applications.	
Type	Simple RWH system with rooftop catchment areas.	RWH system which connect to normal drainage system, turbine, and fertigation pond.	Rooftop RWH system with collection system, treatment system and storage system.
Components	Two storage tank, down pipes, and conveyance pipes.	Dam, filter, storage tank, turbine, fertigation pond, piping system.	Corrugated iron roof, PVC gutters and pipes, coarse screen, first flush tank, sedimentation tank, two storage tanks, the taps and the water level gauge.
Treatment System	Not available.	Not available.	Treatment system consisting of a coarse screen, first flush tank, and sedimentation tank.
Cost	RM 16,699.60 for material of whole system and 5% of maintenance fees for 20 years. Payback period is 7.12 years.	Not stated.	RM 15,049.81 for whole project, labor and material costs accounted for 14% and 86% respectively.

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Based on the comparison Table 2.2, it can be concluded that the design of the RWH systems is mainly depends on the function of the RWH system. For example, since the RWH system for Mnyundo Primary School is used for drinking purpose, a treatment system is needed to monitor the quality of harvested rainwater so that it can be drinkable by the school's staffs and children. Another example is the RWH system for SMKIS, the harvested rainwater has to be divided into three different pathways with each of it connected by its own pipes in order to meet the functions of the RWH system to reduce rainwater flow rate in normal drainage system, provide water for fertigation pond and generate electricity by turbine.

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3. CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter describes the methodology used in this project to design and develop a feasible rainwater harvesting system for the application in school. The flow chart of the project is shown in Figure 3.1. This project begins by studying the existing rainwater harvesting system for application in school. Several approaches have been chosen to make comparison among these systems and a new design of rainwater harvesting system for application in school is proposed. After that, mechanism analysis and cost analysis for the design is done in this chapter. Then, the design is drafted in CAD software. In this project, Solidworks is the CAD software that is used to draft the design of RWH system. After the design has been drafted, a simulation has been done to identify and analyze the system feasibility.

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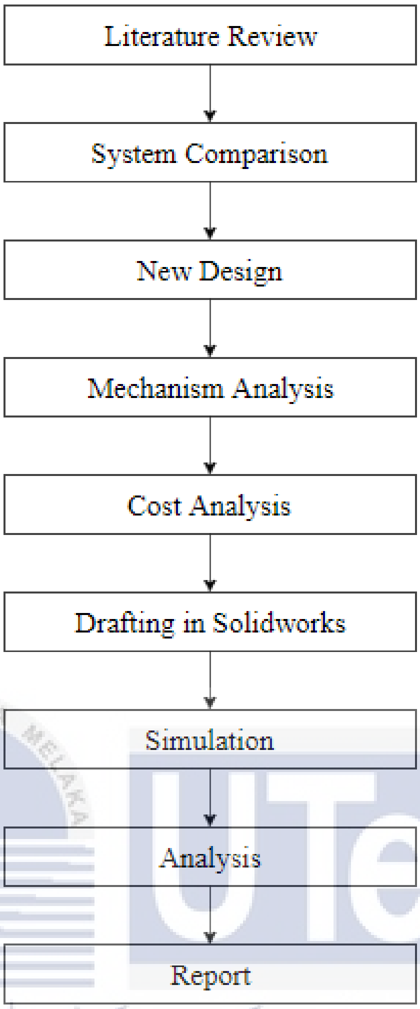

Figure 3.1: Flow chart of the project.

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3.2 DESIGN COMPONENTS

In this project, a new rainwater harvesting system design is proposed. This design comprising the collection system, filtration system, piping system and storage system. The collection system is where the rainwater initially collected. It may be contaminated with other substances and hence, the rainwater is channeled to a treatment system through a piping system. The treatment system is responsible to treat the harvested rainwater to increase the rainwater quality so that it can also be a water supply for potable uses. Then, the treated water is then transfer to storage system in order to store the water for both potable and non-potable use. Figure 3.2 below shows the conceptual design of the RWH system in this project.

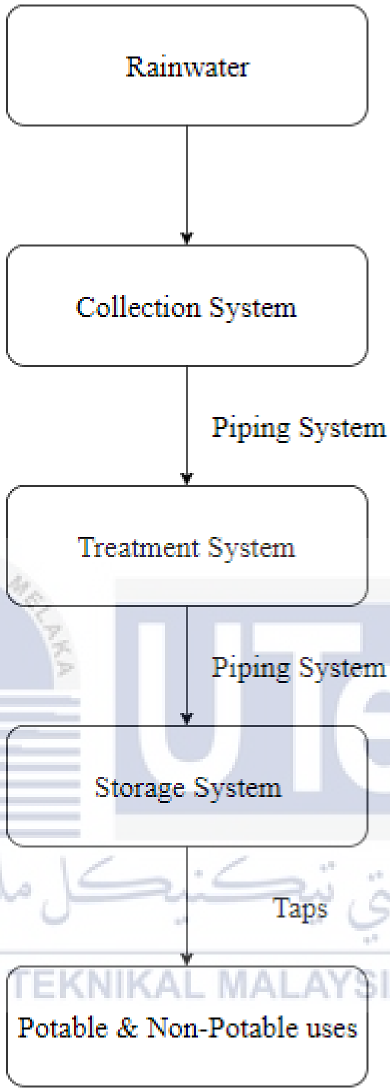

Figure 3.2: Conceptual design of RWH system.

3.3 MECHANISM ANALYSIS

3.3.1 Data Collection

Law & Bustami (2013) claims that monthly and annual rainfall data for area of where RWH system is installed are needed in order to determine the potential amount of rainwater that can be stored by the respective catchment area of selected school building. For the scenario of the RWH system in the research of Law & Bustami (2013), the rainfall data can get form DID (Department of Irrigation and Drainage) of Samarahan Branch. The location for monthly and annual rainfall data is at Kuching Airport Station, which is the nearest station to SJK Chung Hua No. 2, Kuching. Apart from rainfall data for target area, the data such as the number of teachers, students and staffs also need to be collected to determine the average daily use of water in liters or m^3. The water demand is based on the purposes of installing the system will be calculated and several assumptions for this is made. For the case of RWH system for SJK Chung Hua, No. 2, the RWH system is used to supply water for the toilet flushing purpose and hence the water demand is based on the toilet flushing usage. It is assumed that every student is using the toilet only during weekdays, the number of students is constant, and the staff are not using the toilet. Thus, it is found that the daily, weekly, monthly, and yearly water demand is 4.32 m^2, 21.6 m^2, 86.4 m^2 and 1036.8 m^2, respectively. Besides that, to calculate the roof catchment area, the dimensions of the building beneath the roof that is external length and width are needed to be measured.

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3.3.2 Roof Catchment Area

The calculation of roof catchment area is simply the total area of the building beneath the roof. One approach that used in the research by Law & Bustami (2013) is by multiplying the external length and width of the rectangular building, if the school building consists of or can divided into more than one rectangle, then the roof catchment area will be simply the summation of the area of the separate rectangles. For example, an L-shaped building can be regarded as two rectangles, the roof catchment area would be the total area of these two rectangles. The calculation of roof catchment area can be represented by Equation 3.1 below:

$$Roof\ area = A_1 + A_2 + A_3 + \ldots + A_n \qquad \text{(Equation 3.1)}$$

Where A is the area of building beneath the roof which is equals to the external length multiples by width.

3.3.3 Potential Volume of Rainwater Harvested

According to Law & Bustami (2013), the potential volume of rainwater harvested can be calculated by multiplying the roof catchment area to the rainfall intensity. The rainfall intensity is the average annual rainfall and the monthly precipitation of the target area. The average annual rainfall is the average rainfall intensity in a period of years, for example, in the research of Law & Bustami (2013), the average annual rainfall is taken form the period of 2002 to 2011. The monthly precipitation is the average precipitation in a month. The calculation of the volume of rainwater harvested can be represented by Equation 3.2 and Equation 3.3 below:

$$Volume\ (m^3) = catchment\ area\ (m^2)\ x\ average\ annual\ rainfall\ (m)\ x\ runoff\ coefficient$$

(Equation 3.2)

And

$$Volume\ (m^3) = catchment\ area\ (m^2)\ x\ monthly\ precipitation\ (m)\ x\ runoff\ coefficient$$

(Equation 3.3)

According to Farreny (2011), the runoff coefficient is a non-dimensional value that estimates the portion of rainfall that becomes runoff, considering losses due to spillage, leakage, catchment surface and evaporation. Runoff coefficient is useful for predicting the potential water running off a surface, which can be conveyed into a rainwater storage system. Typically, the roof's runoff coefficient is estimates as 0.8. The result volume of rainwater harvested is the predicted value which may subjected to change due to climatic and weather change. It can also use to determine whether the potential rainwater harvesting is meets the water demand of the school. From the result of volume of rainwater harvested calculated in the research of Law & Bustami (2013), the volume of rainwater harvested based on annual rainfall from 2002 to 2011 and monthly precipitation for 2011 are 2172.7 m^3 and 2325.8144 m^3 respectively, which is enough for the annual water demand of 1036.8 m^3. Hence, the RWH system is able to supply the water for the non-potable use of flushing the toilets in the school buildings. Generally, the potential amount of rainwater harvested is mainly depends on the rainfall data of the target area and the roof catchment area of the selected school buildings.

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3.3.4 Storage Tank Capacity

According to the research of Law & Bustami (2013), there is two approach which can be used to determine the sizing of the storage tank for the RWH system, which is the demand side approach and supply side approach. According to Malaysian Water Association (2000), the design on storage tank should be for one day usage, hence, the value used to design the storage tank is based on the daily water demand, which is 4.32 m^3, for the SMK Chung Hua, No2 Kuching. This method is known as the demand side approach. Based on the founding, the supply side approach is not applicable to be used for the study because the calculated size of storage tank is 1289.01m^3, which is too big. This method is normally adopted and used in place where the rainfall is less. The design of the storage tank must fulfil the daily demand of school building, which is 4.32 m^2, according to Law & Bustami (2013). Generally, the sizing of the storage tank should be based on the water demand of the school buildings.

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3.3.5 Water Quality

From the research by Mwamila et al. (2016), to attain an acceptable water quality, monitoring is necessary especially when the water harvested will be used for drinking purposes. The water samples from the RWH system need to be taken and analyzed for physical, chemical, and microbiological quality. This is to monitor the water quality of the treated rainwater by the designed RWH system so that the harvested water can be safe to consume. The monitoring process involves the assurance of the parameters such as pH, total dissolved solids, and total coliform need to be presented below the WHO standardization of water quality. By consuming the contaminated water, once will have high probability to get infected by diarrhea and other diseases. The designed treatment system for the RWH system should have the capability to assure that the values of the parameters for the harvested water present below the recommended standard values of WHO.

3.3.6 Water Quantity Control

Based on the research of Mwamila et al. (2016), since most of the storage tank are not transparent, it is difficult for people to monitor the water level while the consumption is ongoing. In most cases, the users only realize that the water level has decreased only when the water stops flowing out of the tap, which is too late already. An individual also needs to climb up the tank and check the water level by opening the tank cover, this is very risky and dangerous. To monitor the water level, a simple water level gauge can be taped onto the outer tank wall (Figure 3.3 (a)). The gauge was made by tying a fishing plumb to the bottom and a ball to the top of a wire, which had a length equal to the height of the tank. In a clear hosepipe, the wire set up was mounted (Figure 3.3 (b)). The gauge works based on a principle of buoyancy, whereby high upward pressure occurs when the tank is loaded, forcing up the ball and down the plumb to the bottom of the hosepipe. The upward pressure reduces as the tank empties and the ball starts to sink, pulling up the plumb. It allows users to track the level of water safely. Using this simple technology, users will be able to change their demand to save more water for potential use once the rainy season is over or to prevent loss of overflow during the rainy season.

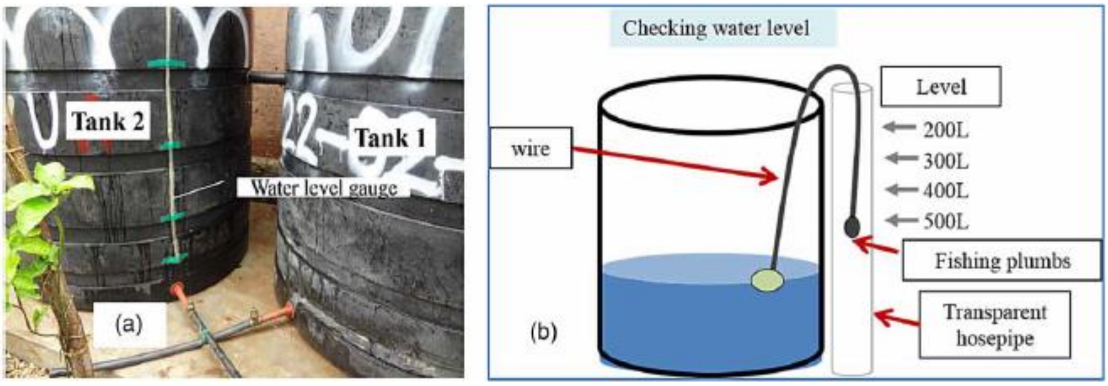

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Figure 3.3: (a) Water level gauge taped onto the supply Tank 2. (b) Illustrations of water level monitoring with the gauge (Mwamila, Han & Kum, 2016).

3.3.7 School Water Demand

The school water demand is differencing for each school, it is depending on the water usage by the staffs and students in the school. For example, according to the research of Law & Bustami (2013), the water demand is focused on the amount of water used to flush the toilets in SJK Chung Hua No.2, Kuching. From the analysis, they found that the daily water demand for the school is $4.32m^3$. This value of water demand is crucial for RWH system because it can help to determine the suitable tank capacity of the RWH system.

3.4 COST ANALYSIS

Based on the research by Mwamila et al. (2016), the system cost is contributed by the labor and material of the RWH system, by which the labor and material costs accounted for 14% and 86% of total cost of RM 15,049.81. The labor cost incorporates the laborers and masons involved during the mobilization and throughout the construction phase. Meanwhile in the research by Law & Bustami (2013), the system cost comprises the total material cost and the maintenance 5% of the total material cost for 20 years. The total cost for this RWH system is RM 16,699.60 and has a payback period of 7.12 years. The payback period is simply the ratio of the installation cost of the RWH system with the annual benefit of the RWH system. Thus, to calculate the system cost, once must consider of the material used and its prices in the market, labor forces used to construct the RWH system and also the future's maintenance fees.

3.5 DRAFTING AND SIMULATION

The design of the RWH system is drafted in CAD software, which include CATIA and Solidworks. In this project, Solidworks will be used to draft the whole RWH system for school application. The dimensions of the designed RWH system will refer to the existing RWH system in school. Afterward, a simulation of the RWH system needs to be done by using Solidworks simulation. A simulation report will be generated by Solidworks simulation and will be analyzed. Figure 3.4 below shows the interface of the Solidworks software.

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Figure 3.4: Solidworks interface.

3.6 SYSTEM ANALYSIS

Based on the result, an analysis of the designed RWH system for application in school is being conducted. The feasibility of this RWH system is also discussed in this project. Modification and justification are made to improve the RWH system. The performance of the RWH system for the application in school also is discussed in this project. The practice and implementation issue of RWH system in school is also being discussed in this project.

4. CHAPTER 4

RESULT AND ANALYSIS

4.1 INTRODUCTION

This chapter describes the data and result that obtained and produced in this project. The focus of this chapter is to highlight the RWH system that specially designed for SJK(C) Ayeh Keroh and the purposes to install this RWH system. The RWH system is designed by taking one of the school premises at SJK(C) Ayeh Keroh as reference. SJK(C) Ayeh keroh is a primary school that located at Ayeh Keroh city, Melaka. It has suitable premises to install the RWH system. The design of RWH system for SJK(C) Ayeh Keroh has been drafted in Solidworks and simulation has been done on the storage system, which is the tank component. All the design components of this RWH system will be discussed in this chapter. The discussions will mainly discuss on the components' functions and the material selection analysis. The material selection analysis is analyses by using the material universe. Relevant calculations will also be included in this chapter to support the discussions. Finally, an estimation of overall installation for the whole RWH system also being included in this chapter.

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4.2 RWH SYSTEM FOR SJK(C) AYEH KEROH

In this project, RWH system is based on one of the school premises in SJK(C) Ayeh Keroh. The reason to choose the building is because there is a constant water demand for the building which is the flushing water for the toilet. The building's shape is also relatively relevant to install the RWH system. The selected building is also a separated building which is not connect to another building block. This will ease the design process of the RWH system. The proposed RWH system for the building is a rooftop RWH system which collect rainwater at the rooftop and channeled the harvested rainwater into a storage tank that located on the ground through piping system.

The purpose of installing the RWH system is to supply flushing water for the toilet inside the selected building. The harvested rainwater will be channeled to toilet through a backup pipeline that connect the storage tank and the toilet. It is act as a backup flushing water supplier whenever the municipal water is no longer available for the toilet especially when facing water shortage problem. However, it can also replace the municipal water that supply to toilet when the rainwater is abundant and thus, this can help to reduce the water bills of the school. By installing this RWH system, the teachers can help to educate the students at SJK(C) Ayeh Keroh about the benefits of conservation of water typically rainwater. By implementing this RWH system, they can encourage the next generations to have responsibility to maintain the sustainability of our natural resources. By this RWH system, money can also be saved by not wasting the water. The RWH system can enable the staffs and students to utilize the rainwater for many other purposes, for the RWH system in this project, the rainwater collected is use as flushing water for toilet which is one of the non-potable purposes. This can help to greatly reduce the amount municipal water used. Figure 4.1-4.4 shows the school that is selected for this project, which is SJK(C) Ayeh Keroh. All the photo shown below are taken under the permission from the school authorities.

Figure 4.1: SJK(C) Ayeh keroh.


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Figure 4.2: The selected building for the RWH system.

Figure 4.3: Target building for the RWH system.

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Figure 4.4: The toilet inside the selected building for RWH system.

4.3 RWH SYSTEM DESIGN

4.3.1 Overview of the RWH System

The main purpose of the RWH system is to supply the flushing water for the toilet inside the selected building that located at SJK(C) Ayeh keroh. The RWH system comprising several systems, which are the collection system, filtering system, piping system and storage system. The collection system is the gutter part of the RWH system and the rooftop of the selected building. The piping system connected the components of the RWH system together. The filtering system is the filters that located at the gutters. The storage system is the water tank that used to store the harvested rainwater and the water pump that used to pressurize the harvested water.

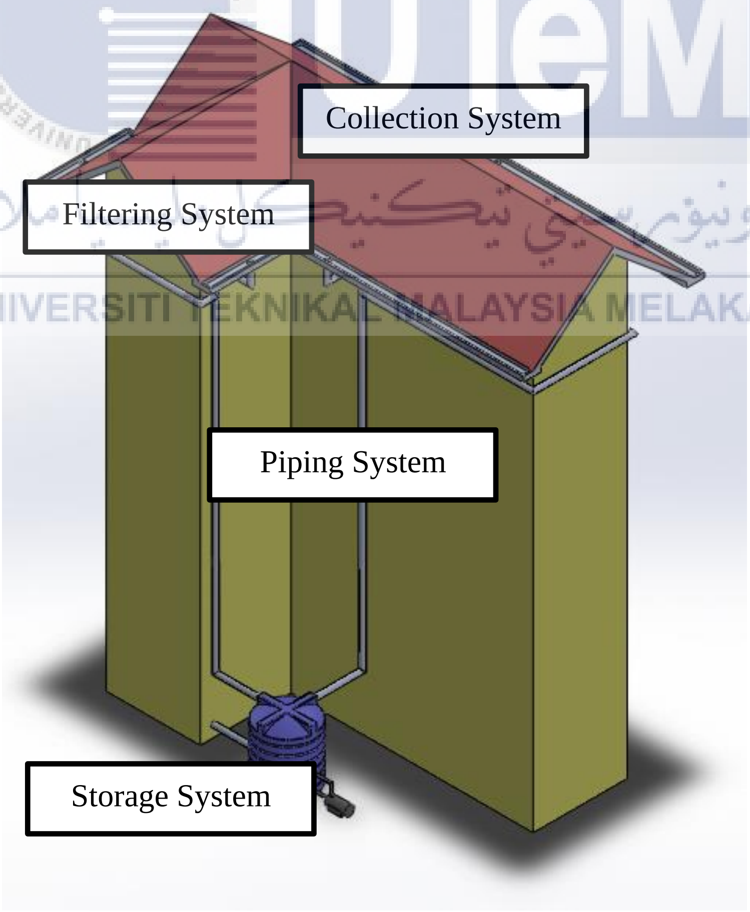

Figure 4.5: Isometric view of the RWH system.

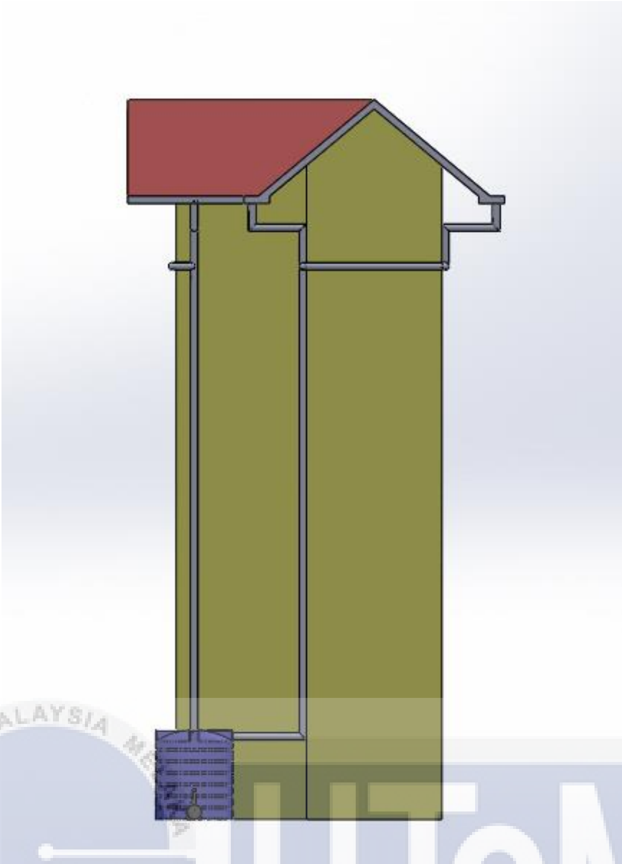

Figure 4.6: Side view of the RWH system.

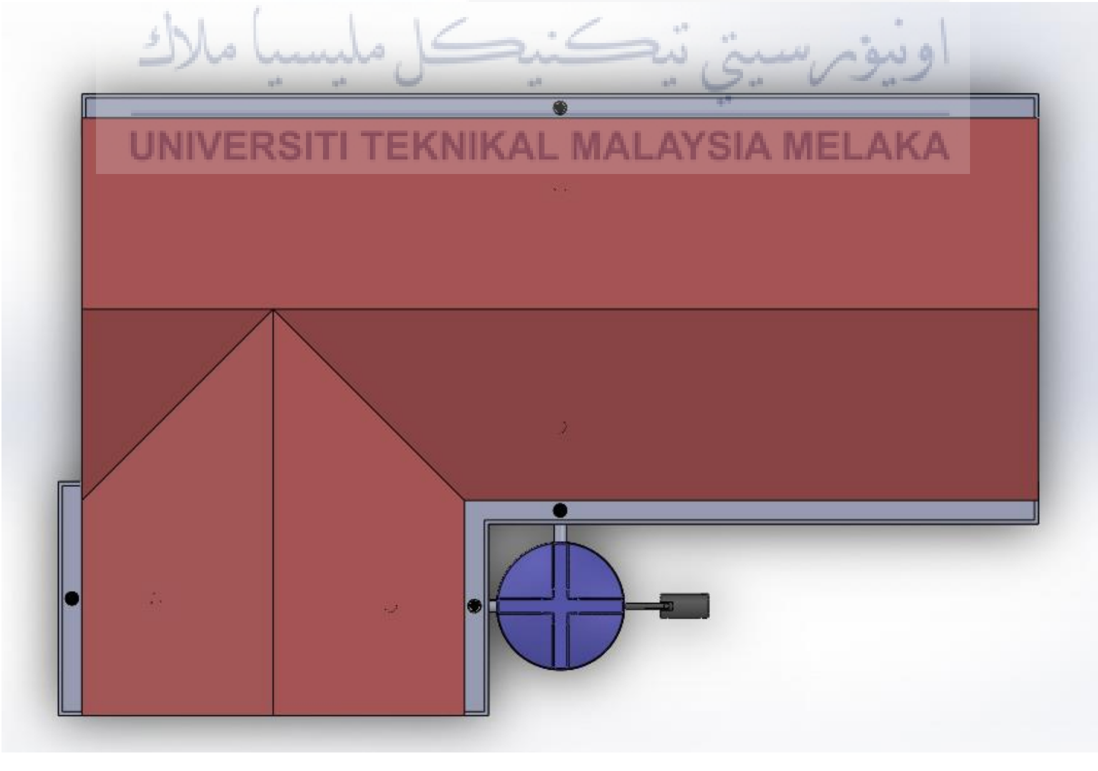

Figure 4.7: Top view of the RWH system.

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4.3.2 Rainwater Collection System Component

The collection system of the RWH system consists of the gutters that used to collect and channeled the rainwater to the pipes. When rain occurs, the rainwater will fall first on the rooftop of the selected building, which is the red colored area in Figure 4.8. After that, the rainwater will flow to the gutters and then the rainwater will be transferred to the pipes that connected to the water tank. Based on the rooftop and the building, the gutters are designed in two straight gutters and a L-shaped gutter for this RWH system as shown in Figure 4.9. Each of the gutters are rectangular in shape and has a depth of 0.10m. Figure 4.8 below shows the collection system of the RWH system. uPVC rain gutters is used for this RWH system because it eliminates the need to paint and lessen the chance of corrosion with time. It is also flexible and does not easily lose its shape. It is also less costly, lighter, convenient, and easy to install.

Figure 4.8: Collection system.

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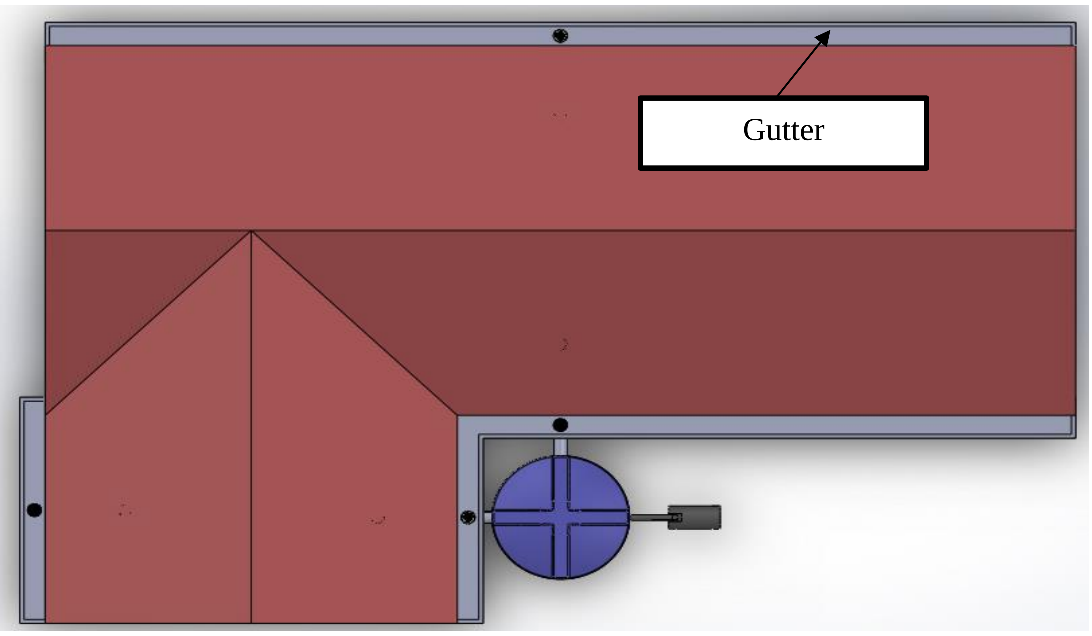

Figure 4.9: The two straight gutters and L-shaped gutter.

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4.3.3 Rainwater Filtering System Component

The filtering system consists of filters which responsible to prevent small debris or other substance to flow into the pipe. There are four filters that are located at the gutters. The rainwater must flow through these filters before it can flow through the pipes that connect to the water tank. Since it is a simple filter, the contaminated substances such as microorganism or bacteria cannot be filtered out. So, the harvested rainwater is only for non-potable purpose such as toilet flushing water. The harvested rainwater is not clean and may cause some diseases if consume by human being. To ensure the cleanliness of the harvested rainwater, a treatment system for the RWH system is required. The main function of treatment system is to treat the harvested water to a high-quality level so that human can drink the harvested water. Since the purpose of this RWH system is to supply the flushing water for the toilet, hence the treatment system is not needed in this RWH system. The filter has a diameter of 0.16m. Figure 4.10 shows the isometric view of the filter.

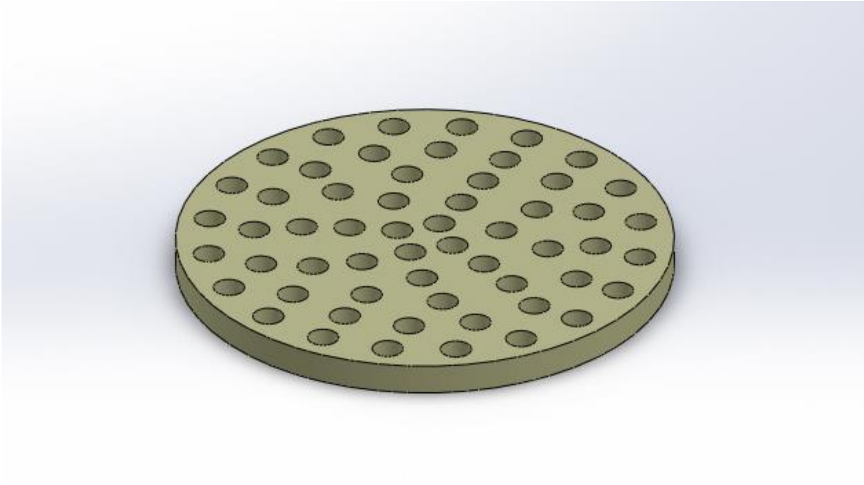

Figure 4.10: Isometric view of the filter.

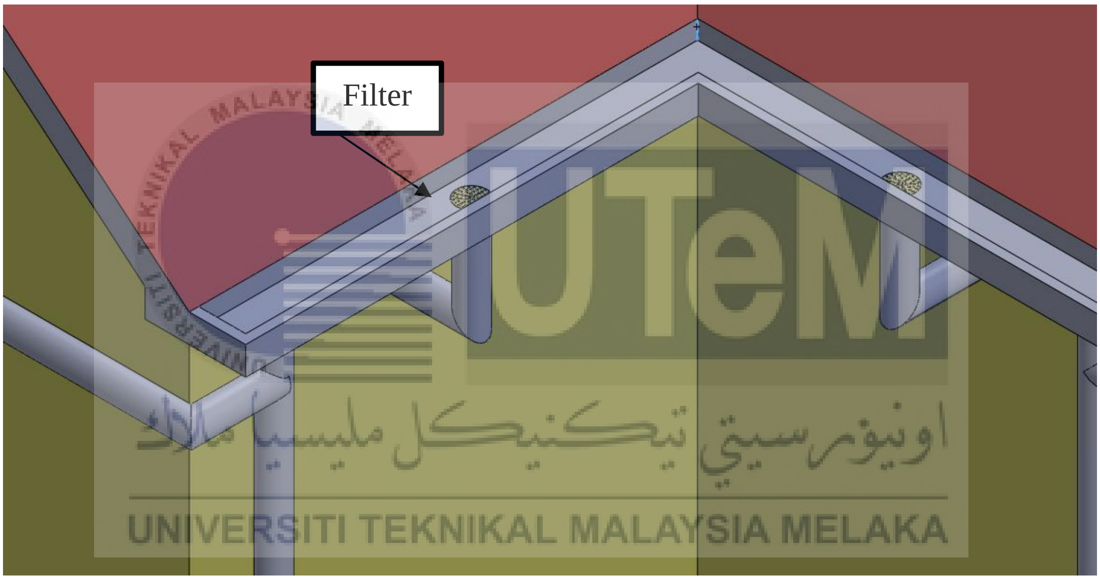

Figure 4.11: Filters in RWH system.

4.3.4 Rainwater Piping System Component

The piping system is functioned to connect the components of the RWH system together. The main parts of the piping system are the pipes that connect the collection system and filtering system which are the gutters and filters with the storage system which is the water tank. This connection is shown in Figure 4.12. Another pipe connection is the connection between the water tank and the toilet. The last pipe connection is the connection between water tank and the water pump. The pipe connection to toilet and water pump are shown in Figure 4.13. The pipes that connect between gutters and filters with storage tank is same with the pipe that connect the toilet with the water tank. These pipes have an external 0.16m. For the pipes connected to water pump, it has an external of about 0.07m. All the pipes are the uPVC pipes for water supply.

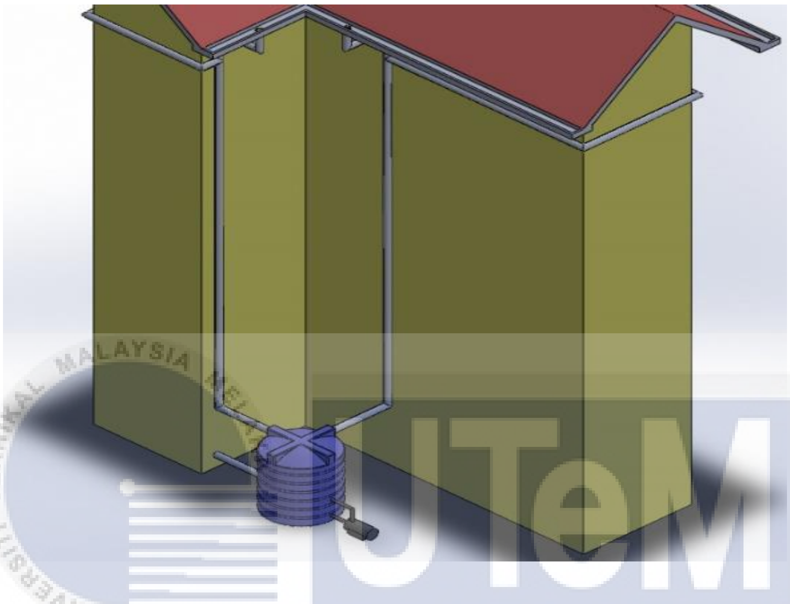

Figure 4.12: Pipes connection of gutters and filters with water tank.

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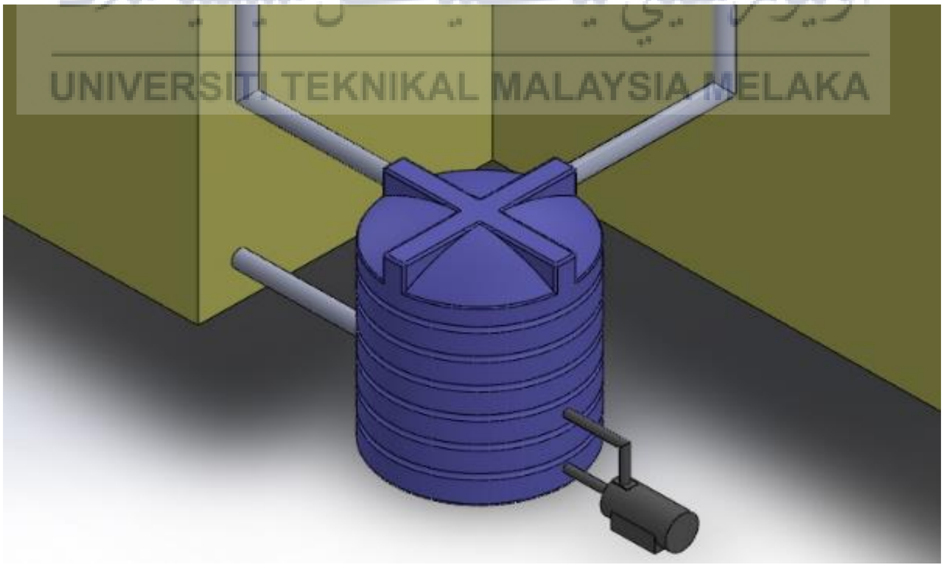

Figure 4.13: Pipes connection of water tank to toilet and pump.

4.3.5 Rainwater Storage System Component

The storage system is referring to the water tank and the water pump. The water tank is connected to a water pump so that the harvested water can be pressurized so that the harvested water can be supplied to the toilet efficiently. Centrifugal pump is used for this RWH system because it is efficient and had been used extensively water supply. The centrifugal pumps have the circular impellers mounted on a shaft inside a housing called volute. When the rotated at high speed, the impellers produces a vacuum and sucks the water in the volute. The circular motion of the impeller transfers the rotating dynamic energy to water which generates outlet pressure and can be transferred to a high level of water. It can pump large volumes of water and generate high pressure up to 200m and above. It can be installed in many ways and conditions. (Pump Systems for Rainwater Catchment n.d.).

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Figure 4.14: Centrifugal pump (Centrifugal Pump Brass Impleller CALPEDA NMM 2/A/A 1Hp 1x230V 50Hz Heavy Duty Z5. (n.d.).).

To select a suitable pump, the pump selection analysis is conducted. Pump selection is very important because it can help to make sure that the pump is not oversized and to avoid unnecessary spent of money (Rainwater Catchment System Pump Sizing, n.d.). By choosing a correct pump size, we can pressurize the water to our desirable water pressure and flow rate. When selecting a pump, we need to consider four important things, which is flow rate required, pressure or head required, the installation location or pump style and electrical requirements. The flow rate is a basic requirement for selecting a pump because an end application will require certain amount of flow (Rainwater Management Solutions, n.d.). The toilet would require about 2 to 3 gallons per minute (GPM) of flow rate (Drinking-Water, 2019). Pressure or Total Dynamic Head (TDH) is the height that the pump needs to overcome so that the water will reach the place. In this research, the total dynamic head is about 12.75m which is the height of the building as shown in Figure 4.15. So, now, by knowing the flow rate and the TDH, we can choose a suitable rating of pump by referring a pump curve as shown in Figure 4.16. As discussed earlier, the required flow rate is about 2 to 3 GPM, and TDH of 12.75m. By referring the pump curve, the closet suitable pump would be 1/2 HP 1SC51-F pump.

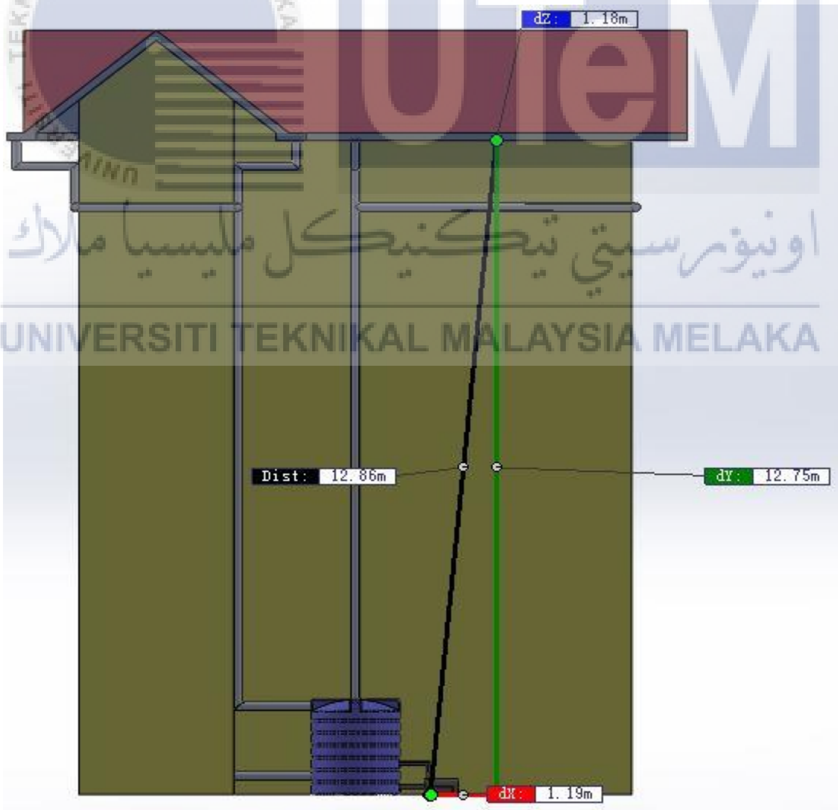

Figure 4.15: The height of the building.

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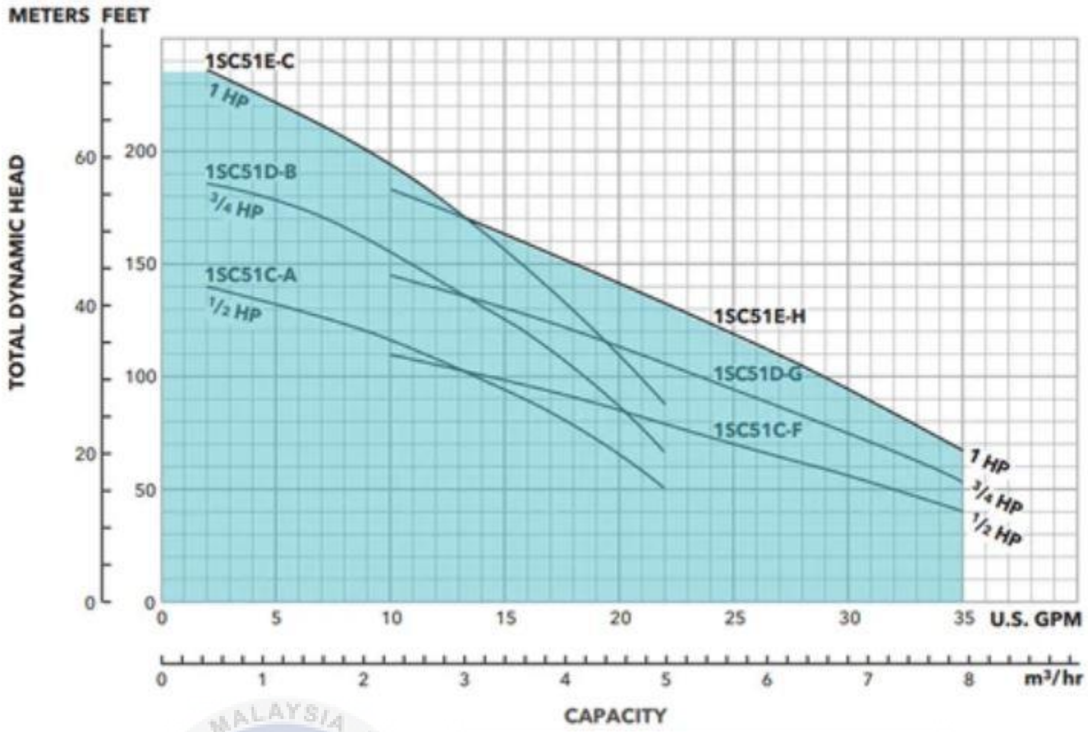

Figure 4.16: Pump curve (Rainwater Management Solutions, n.d.).

The next thing that we need to consider when selecting the pump is the installation location or pump style. The installation location typically refers to whether the pump is installed inside the water tank which is submersible type or outside the water tank which is booster or jet type. Each style has its own advantages. A submersible pump, for example, is also quieter as it is submerged in the water tank, it is out of sight / not in the floor space, enabling continuous pump access to water (as long as float switch is used for dry run protection). On the other side, however, it must be separated and removed in blizzard conditions, is more difficult to maintain, and usually involves long-term submersion of stainless-steel parts, which may affect costs. The booster / jet pump is easy to maintain, can be easily disconnected during freezing conditions, and can sometimes be more cost-effective with less expensive materials, as it is not submerged. They maybe sometimes noisy; however, they take up floor space and may lose prime if they are not in flooded suction condition. For this research, a booster or jet pump is selected. The last thing that we need to consider when selecting the pump is the electrical requirements. It is about the electrical characteristics available. Standard electric power for residential applications is chosen in this case. In short, the selected pump for this research is 1/2 HP of booster or jet pump (Rainwater Management Solutions, n.d.).

To select a suitable water tank, it is necessary to determine the storage tank capacity. There are two approaches that can used to determine the storage tank capacity, which is demand side approach and supply side approach (Law & Bustami, 2013). According to the research by Law & Bustami (2013), for the demand side approach, it can be assumed that every student is using the toilet only during the weekdays, the number of student is constant and the staff are not using the toilet since the staff are using the staff's toilet. It is assumed that all the students used once the toilet in a day. The amount of water per flush is assumed to be 5 liters (Sprague, G. 2016, October 7). The demand for toilet flushing used by students for the selected building is calculated in Table 4.1. According to data, the total number of the students at SJK(C) Ayeh Keroh was 407 students (Sekolah Jenis Kebangsaan (Cina) Ayer Keroh, Melaka. (n.d.)).

Table 4.1: Total Demand

	Total	Amount in m^3
No. of students	407	
Toilet capacity (Liters)	5	0.005
Times of flushing Toilets	1	
Daily Water Demand (L)	2035	2.035
Weekly Water Demand (L)	10175	10.175
Monthly Water Demand (L)	40700	40.7
Yearly Water Demand (L)	488400	488.4

The supply side approach, on the other hand, the water harvested is calculated by

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multiplying the roof catchment area to the rainfall intensity. The roof catchment area of the selected building can be estimated by summing up the total area of the base area of the building. From Figure 4.17, the roof catchment area was estimated to be 35.56m^2.

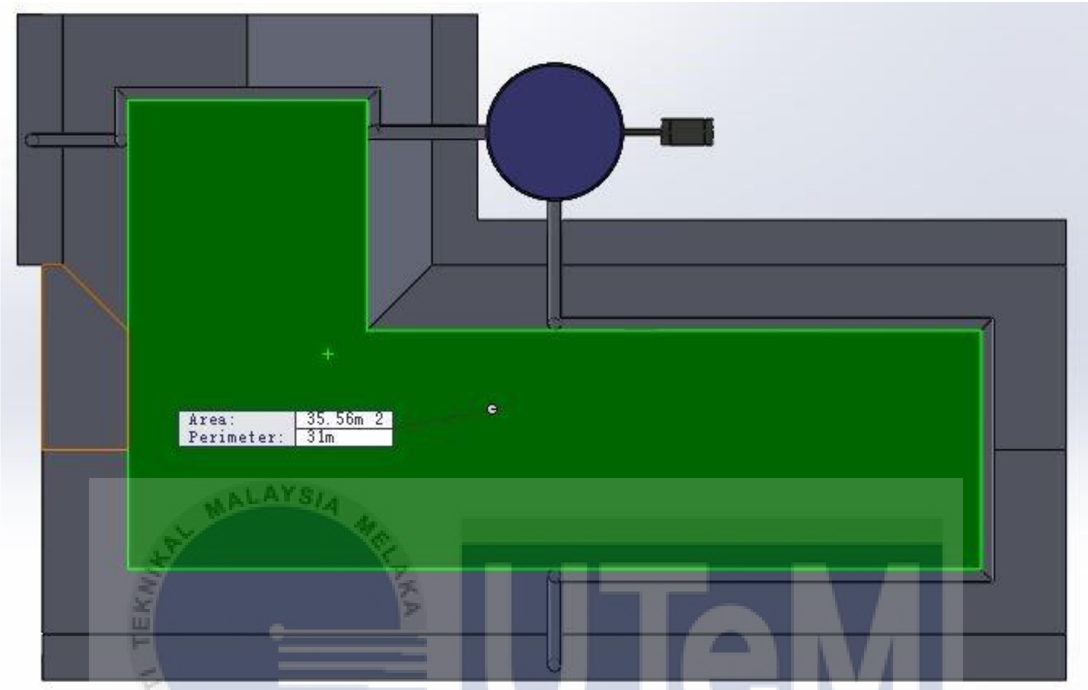

Figure 4.17: Bottom view of the selected building.

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According to Yu Media Group. (n.d.). Malacca, Malaysia - Detailed climate information and monthly weather forecast, throughout the year, in Malacca, there are 138 rainfall days, and 1950.3mm of precipitation is accumulated.

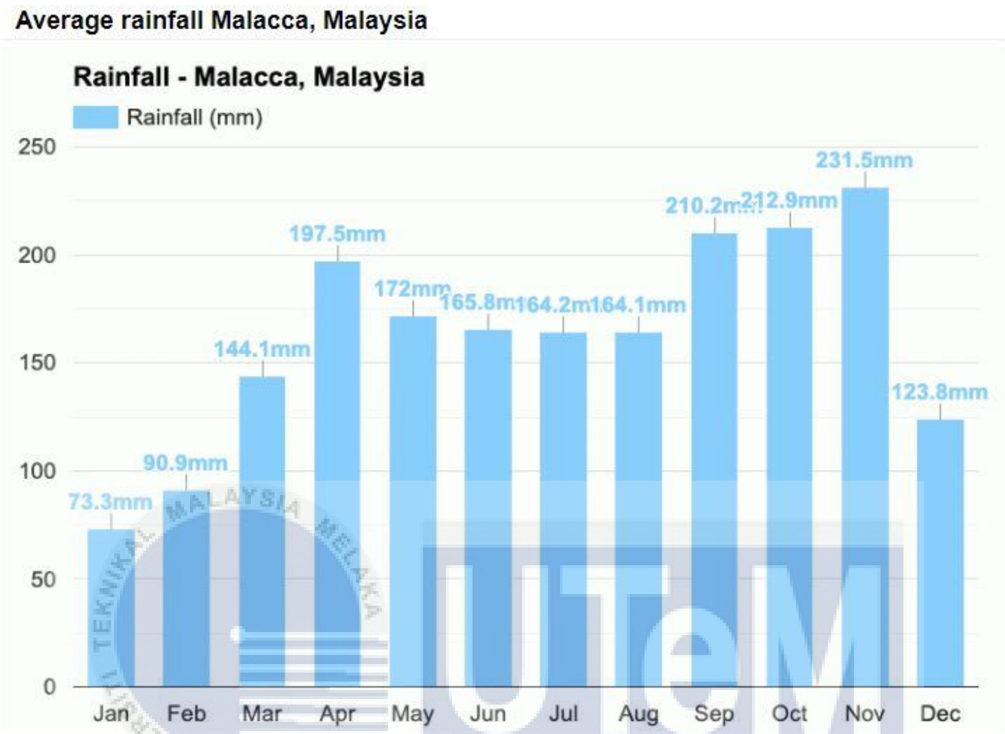

Figure 4.18: Average rainfall of Malacca (Yu Media Group. (n.d.). Malacca, Malaysia - Detailed climate information and monthly weather forecast).

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The Potential Volume of Rainwater Harvested are calculated as below:

$$Catchment\ area = 35.56m^2$$

$$Average\ annual\ rainfall = 1950.3mm(1.9503m)$$

$$Runoff\ Coefficient = 0.8(typical\ value\ for\ rooftop)$$

$$Volume\ of\ Rainwater\ Harvested = Catchment\ area \times Average\ annual\ rainfall \times Runoff\ Coefficient$$

$$Volume\ of\ Rainwater\ Harvested = 35.56m^2 \times 1.9503m \times 0.8$$

$$= 55.482m^3$$

From the monthly average rainfall in Malacca, a potential harvested rainwater amount calculated is presented in Table 4.2.

Table 4.2: Amount of Water Harvesting Potential & Water Demand

Month	Precipitation (mm)	Potential Rainwater Harvesting (m^3)	Demand ($m^{3)}$
January	73.3	2.085	40.7
February	90.9	2.586	40.7
March	144.1	4.099	40.7
April	197.5	5.618	40.7
May	172	4.893	40.7
June	165.8	4.717	40.7
July	164.2	4.671	40.7
August	164.1	4.668	40.7
September	201.2	5.724	40.7
October	212.9	6.057	40.7
November	231.5	6.586	40.7
December	123.8	3.522	40.7
Total	1941.3	55.226	488.4

According to the study by Law & Bustami (2013), the design in storage tank should be for one day usage. So, for the demand side approach, the value used in designing the storage tank is based on $2.035m^3$ or 2035 Liter. For supply side approach, due to the small roof catchment area and the low monthly precipitation in Malacca, the calculated potential rainwater harvesting is very small and did not meet the demand. Hence, this RWH system merely works as a backup toilet flushing water supply system for the selected building. The supply side approach is not suitable to be chosen as the approach to determine the storage

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tank capacity because the value of the potential rainwater harvesting is too small if compare to the storage tank capacity that available in the market. Moreover, this RWH system will not replace the municipal water supply and it is act as a backup flushing water supply system for the toilet only. In general, the potential harvesting rainwater will not be able to meet the water demand due to the inconsistent rain pattern. Thus, it is not relevant to determine the storage tank capacity by based on the supply side approach. Hence, the demand side approach is chosen as the approach to determine the storage tank capacity for this study. For this approach, the capacity of the storage tank must larger than the daily water demand. Based on the survey from the market, the suitable water tank is a R3000 liter water tank. This storage tank has a capacity of 3000 liters which is more than the daily water demand of 2035 Liters (Table 4.1). The function of the water tank is to temporarily store the harvested rainwater for the flushing toilet purpose.

In terms of the tank material, the five most common water tank materials are plastic, sheet steel, stainless steel, concrete and fiberglass. The material used in the tank should decide both how suitable it is for a given site and easy tank maintenance. There are three water tank materials that are chosen to be compared. The three materials are plastics, which is Polyethylene (PE), Steel and Stainless Steel. These three water tank materials were compared by some important criteria such as density, prices, tensile strength, etc. The result is presented in Table 4.3. Polyethylene tanks are built using roto molding or plastic welding. The welding of polyethylene tanks is a process in which two parts of heat-softened polyethylene are joined by applying pressure. Hot air welding and extrusion welding are examples of this process (Polyethylene Water Tanks: Rainwater Tanks Direct: Water Tanks Blog. 2018, June 19). Many water tanks in steel are made of galvanized steel — a zinc coating that protects the steel from corrosion. Such tanks can be designed to accommodate water capacities ranging from about 30 000 liters to millions of liters. This makes them an

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acceptable solution for highly challenging storage requirements. The type of Polyethylene and steel that compared are High Density Polyethylene (HDPE), Rotating Molding Grade and ASTM A525 Galvanized Steel, respectively.

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Table 4.3: Comparison table for Polyethylene, Steel and Stainless-Steel water tank

	ASTM A525 Galvanized Steel	High Density Polyethylene (HDPE), Rotating Molding Grade	Stainless-Steel
Density (g/cc)	7.80	0.939 – 0.952	0.190 – 9.01
Tensile Strength, Ultimate (MPa)	-	-	34.5 – 3100
Tensile Strength, Yield (MPa)	-	17.9 – 26.6	25.0 – 2500
Elongation at Break (%)	-	350 – 1000	0.000 - 160
Elongation at Yield (%)	-	9.00 – 20.0	0.000 – 62.0
Modulus of Elasticity (GPa)	200	-	5.50 – 310
Flexural Modulus (GPa)	-	0.600 – 1.15	-
Bulk Modulus (GPa)	160	-	166
Poissons Ratio	0.29	-	0.220 – 0.346
Shear Modulus (GPa)	80.0	-	62.1 – 86.5
Specific Heat Capacity (J/g-°C)	0.470	-	0.200 – 0.850
Thermal Conductivity (W/m-K)	52.0	-	10.0 – 34.3
Melting Point (°C)	-	126 – 133	1230 – 1530
Coating	Yes	No	No
Price (RM) (3000 liters)	5827.23	3561.08	6084.00

Note: The Online Materials Information Resource. (n.d.), Quality Rainwater Tanks Brisbane & Sydney. (n.d.) and Lazada (n.d.).

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From the Table 4.3, galvanized steel and stainless-steel tank has a higher density than the polyethylene tank. Nevertheless, galvanized steel still rusts and corrodes over time, and zinc will leak into your water leaving metallic smelling for your stored water. Most steel rainwater tanks come with liners is made from food grade polyethylene to help resolve this problem. These can be very costly to make and may need repair over time. Stainless steel tanks do not have all these problems, but then they are much more costly which also makes them less feasible. From the Table 4.3, the price of the polyethylene tank has a lowest price among the three type of water tank that had been compared, which has a price of RM3561.08 and a 3000 liters tank capacity. For the comparison between the polyethylene tank and stainless-steel tank, one of the benefits of the stainless-steel tank is its high resistance towards corrosion. Chromium is a corrosion-preventing base material used in stainless steel. The chemical element molybdenum also needs to be added to combat the corrosive effects of salty sea water, harsh acids, and the like. Molybdenum is found in 316 Stainless Steel and is used in surgical instruments and in implants made of stainless steel. In terms of ease of installation, for all tanks firm foundations are ideal but bases can often consist of crusher dust for poly tanks. Due to their construction, Stainless Steel tanks require more compact and strong foundations. It is crucial for us to ensure that the foundations are protected from erosion. Once stainless-steel tank is installed however, we do not want to move it again. Not only because of it is heavy, but also will risk compromising its structural integrity and having leaks develop. Poly tank on the other hand are much lighter and easier to set in place. If we also decide to re-locate the tank later, then a poly tank is much easier to move. In terms of longevity, poly water tanks can last for long periods, up to 20 years or longer. Thanks to added UV-stabilizers to the molding mix, the material can withstand the harsh effects of the Sun. Just as the addition of chromium to steel will protect it against corrosion, so the application of UV-stabilizers to a polymer mix stops the material from being brittle and

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decomposing. For stainless steel tanks, keeping them clean with a cloth and fresh water is important. Keep away solvents that may cause corrosion, such as salt sea water or chlorine found in pools. In terms of maintenance, poly tanks need much fewer ongoing maintenance costs, and can be equipped with a self-cleaning tank system. A special easy-to-install pipe with special holes is placed inside the tank and connected to the water tank overflow. Whenever the tank is full of water, all the debris is drawn into the pipe at the bottom of the tank and removed from your tank. To keep the rainwater fresh in a stainless-steel tank, a more costly two-tank system is often needed. Rainwater falls into the first tank with a coarse filter panel inside. The water falls through the screen, and the debris gets trapped and the tank side discharged. Instead, this filtered water is pumped into a finer filter before being pumped into a second water tank in stainless steel. This means that the water is still smooth. (Water Tanks Compared: Poly Tanks versus Stainless Steel Tanks: Team Poly Water Tanks: Water Solutions for Life. (2018, August 30)). Hence, from the discussion above, we can conclude that the polyethylene tank is the most suitable water tank to be installed.

The water tank that is used in the proposed RWH system has a volume of 3000 liters ($3m^3$), round shaped, polywater tank. It has a dimension of 1600mm diameter, 1850mm height, 1800mm inlet height and a 75kg slot weight. (R3000 Liter Rainwater Tank. (n.d.).).

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Figure 4.19: The R3000 Liter Rainwater Tank.

4.4 STRESS ANALYSIS

To analyze the performance of the RWH system, we need to do analysis on the components of the RWH system. In this research, the tank component has been chosen for the performance analysis. To do this, we can study the overall impact on the stress of the water tank. To study the overall impact on the stress of the water tank, a stress analysis has been done in Solidworks simulation. The tank material is defined as high density PE (Polyethylene). The pressure that acting on the water tank can be determined by the Equation 4.1.

$$P = \rho g h + L P_L \qquad \text{(Equation 4.1)}$$

$$where\ \rho = density\ of\ water\ \left(1000\,\frac{kg^3}{m}\right)$$

$$g = gravitational\ acceleration\ (9.81ms^{-2})$$

$$h = height\ (m)$$

$$L = total\ length\ of\ pipes\ (m)$$

$$P_L = pressure\ loss\ per\ metre\ (\frac{Pa}{m})$$

The h in this case would be 12.75m, as shown in Figure 4.15, the total length of pipes is approximately equals to 40m, and the pressure loss per meter is assumed to be 35 Pa/m, by substituting these values, the value of pressure (P) are obtained, as shown as calculations below:

$$P = (1000)(9.81)(12.75) + (40)(35)$$

$$= 126477.5\ Pa$$

Hence, a pressure of 126477.5 Pa is acted onto the inlets of the water tank and the simulation result are shown in the Figure 4.20. The bottom face of the water tank is set as the fixture of the water tank. From Figure 4.20, we can observe a maximum von Mises stress of 106986.1 N/m^2 and a minimum von Mises stress of 32.0 N.m^2. The red arrows in the Figure 4.20 represent the places where the pressure acted.

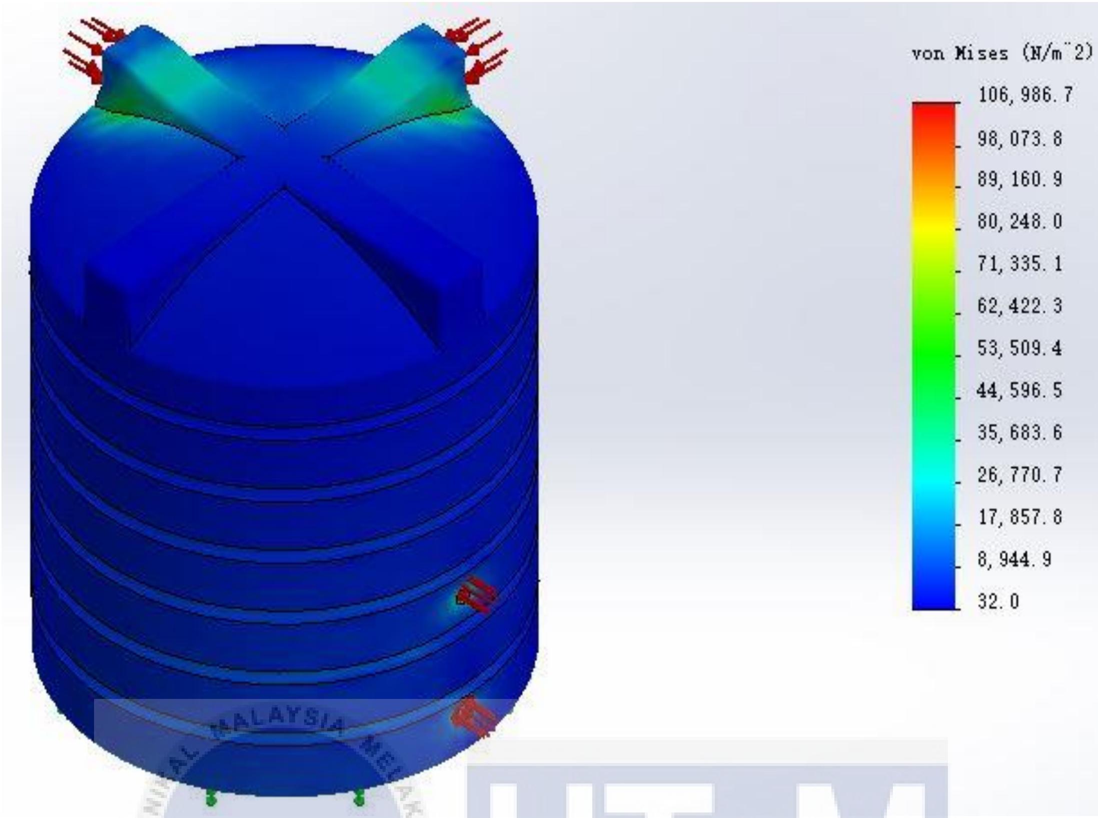

Figure 4.20: Stress analysis of the water tank.

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The performance of the RWH system is also affected by the water tank material. As discussed earlier, there are many types of water tank material available in current market, such as plastic, sheet steel, stainless steel, concrete and fiberglass. Also, from the discussion earlier, the water tank selected was the poly or plastic tank. In this part, we will further discuss about the benefit of poly water tanks. As we know, polywater tanks are now rising in its popularity because of its numerous advantages. There are four benefits of using polywater tanks, which are high durability, easy installation, easy to maintenance and variety. In terms of durability, polywater tanks can last very long and even outlast us with proper care and maintenance. On average, a good quality polywater tank from trusted company can last for more than 20 years. This is because some company add UV stabilizers into the material so that the water tanks are safe from the harsh effects of the sun and prevent the water tanks from deteriorating over the time. Next, the polywater tanks are also very easy to install compare to other type of water tank. It normally does not require a lot of efforts. We can also install it at anywhere that we want. It is also very easy to relocate if we wished to because it is made up from a very lightweight material. Polywater tanks are also comparatively easy to maintain from other materials. The materials such as fiberglass and steel require extra care, but for polywater tanks, we can easily remove all dirt and debris whenever the tank reaches full capacity by installing a self-cleaning system in the polywater tanks. Unlike steel water tanks, polywater tanks also does not rust. Also, polywater tanks are more affordable than other materials such as stainless steel or concrete. The best advantages of the polywater tanks is its variety. Polywater tanks can be molded into various shapes and sizes so that we will have a lot of options according to our own preferences. Polywater tanks are also come in various colors, and we will not worry that the polywater tanks will not fit into the RWH system design. Based on these benefits, the performance of the RWH system can be assured, since a good RWH system require a good water tank. If the water tank is not good, it requires us to put more efforts on the maintenance and consecutively will cost us more in money, and hence leading a bad performance of RWH system (What Are the Benefits of Poly Water Tanks? 2019).

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4.5 COST ESTIMATION

The cost of components for the RWH system is calculated and presented in the Table 4.4 below. All the cost of the components for the RWH system is referring JKR Standard 2010. All the calculated cost below is just a rough estimation for the cost to install the whole system, it is subjected to be changed and it may be not accurate.

Table 4.4: Cost of installation for the proposed RWH system

Component	Unit	Quantity	Rate (RM)	Amount (RM)
Storage Tank (3000 liters)	No.	1	3561.08	3561.08
Gutter (uPVC) (1m)	No.	25	23	575
uPVC pipes (1m)	m	40	12.72	508.8
Booster Pump (1/2 HP)	No.	1	265	265
Installation	LS	1	200	200
Total Amount				RM5109.88

Note: Law & Bustami (2013).

Hence, we need roughly about RM5109.88 to install this RWH system.

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4.6 PRACTICE AND IMPLEMENTATION ISSUE

According to Lani et al., 2018, there are some future challenges to install the RWH system, which including the cost, application, treatment system, rainfall characteristics, policy, and public perception.

4.6.1 Cost

In terms of cost, the RWH system requires about RW5109.88, which is a huge amount of investment, and the maintenance cost is not even included. The initial cost and maintenance are still debatable with regards to how the RWH system can be affordable for all societies. This limitation is associated with national income and the low awareness of the community about this RWH system. Hence, to maximize the benefits, it is very important to have an optimum RWH system design. Material selection need to be done to reduce the initial installation cost. Designing the system with gravity concept also has the potential to reduce the operation and maintenance cost compared to the system with pumping operation. In addition, the government can encourage the school authorities by subsidy the school to install the RWH system. Training and awareness campaigns can also be held from time to time or enhancing the interest of the community (Lani et al., 2018).

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4.6.2 Application

The application of RWH system in Malaysia is still limited to government buildings only. The exploration of other commercial buildings such as school is interesting since they normally have larger rooftop catchment area. The saving from implementing of RWH system are less rewarding for the building with small roof catchment area such as residential building because the commercial water tariff is higher, and the water consumption is bigger. The benefits of installing RWH system are more attractive when it is implemented early during the design and construction phase as opposed to during the retrofitting of the existing building. Therefore, implementation of RWHS in the foreseeable future should be more intensively applied for large buildings (Lani et al., 2018).

4.6.3 Treatment System

In this study, the RWH system is for non-potable uses, in which the water is used directly from the water tank. Although rainwater in Malaysia is relative clean from major contaminants, minimum treatment is still needed to be done before it can be used for portable uses. Hence, a simple treatment system needs to be included to maximize the economic benefit of RWH system. Many methods of treatment can be used but we also need to consider the implementation and installation cost of this treatment system. The selection of rainwater treatment method has implications for the installation and maintenance costs. Therefore, research need to be done on the treatment system if the RWH system is designed for potable uses. To maximize the investment benefits, a clear goal of constructing RWH system should be considered prior to installation (Lani et al., 2018).

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4.6.4 Rainfall Characteristics

The success of an RWH system is greatly dependent on the quantity and temporal pattern of the rainfall. The development of RHWS in Malaysia should consider their rainfall quantity to optimize its advantage. The higher rainfall depth would be more appropriate for a same roof area and water consumption rate. In addition, the number of rainy days in Malaysia is high, being in the humid tropic region (138 days to 181 days / year). Then the use of RWHS should be maximized to allow the greatest water savings in the reservoir to be used during the dry season. Given the spatial variability of rainfall in Malaysia, assessment of the RWHS potential for various rainfall regions is crucial (Lani et al., 2018).

4.6.5 Policy

Although the Malaysian government has launched RWH system policy, the implementation has been mostly confined to public buildings, bungalows, and semi-detached houses. The RWH system policy should be extended to all buildings with large roof area such as commercial building like school. However, the existing policy is still quite loose (Lani et al., 2018). There is no mention of the minimum requirement of tank size in relation to roof area. The commercial buildings are still not subjected to this policy. Therefore, a comprehensive study that considering an optimum tank size according the various roof sizes and climatic conditions in Malaysia need to be carried out for foreseeable future as a scientific judgement before issuing a legal policy (Lani et al., 2018).

4.6.6 Public Perception

The acceptance among Malaysians towards the RWH system is still unsatisfactory although various initiatives have been done by government to promote the RWH system. The main reason for the poor acceptance is because of low water tariff. Now, the Malaysians are paying only between RM0.96 and RM3.05 depending on the water supply service provider. In addition, the average water tariff in Malaysia is among the lowest in the world (0.20 USD/m^3) compared to neighboring country of Singapore (2.39 USD/m^3) and developed countries such as Tokyo (2.0 USD/m^3), Dubai (2.4 USD/m^3), and Copenhagen (7.3 USD/m^3). Malaysia is also having rare occurrences of significant drought and is blessed with abundant rainfall. This makes the public feel that there is no necessary to explore other alternative water resources. Ultimately, the public is also inadequately educated on the importance of rainwater utilization withing the context of water demand management. To solve this issue, Malaysia government can offer incentive by providing rebate to premises owner who install RWH system. Moreover, a proper awareness program is also necessary to educate the public on how RWH system can be implemented to reduce the dependency on municipal water supply (Lani et al., 2018).

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5. CHAPTER 5

CONCLUSION AND FUTURE WORKS

5.1 CONCLUSION

The main objective of this study is to overview the practice and implementation issues of RWH system in SJK(C) Ayeh Keroh and to design and develop a feasible RWH system for application in school. This study also needs to provide an overall analysis on the designed RWH system in SJK(C) Ayeh Keroh. The main purpose of installing this RWH system is to provide backup flushing water for the toilet at SJK(C) Ayeh Keroh. The RWH system is comprising components such as water tank, pipes, gutters, filters, and pump. The RWH system can be divided into four systems, which are collection system, filtering system, piping system and storage system. Since the system is designed for non-potable uses that is to flush the toilets, the treatment system is not necessary in this study. By using material selection analysis, the polywater tanks are found out to be the most suitable material of the water tank or storage tank. The analyze the performance, stress analysis has been done for the tank component and found that the tank can withstand a maximum von Mises stress of 106986.1 N/m^2 and a minimum von Mises stress of 32.0 $N.m^2$. The total cost to install this RWH system is estimated to be RM5109.88 without considering the maintenance cost. Lastly, for the practice and implementation issue, there are some future challenges to install the RWH system, which including the cost, application, treatment system, rainfall characteristics, policy, and public perception.

5.2 FUTURE WORKS

In the future, a comprehensive study about the RWH system need to be conducted in proposing the RWH system. This is because various factors such as cost, application, rainfall characteristics, purposes of RWH system and implementation issues need to be considered in the designing phase of the RWH system. When facing a series of dry season, the RWH system should be capable to solve the water shortage problem by storing enough rainwater during the rainy season. Hence, it is important to observe the rainfall characteristics of the place where the RWH system is installed. By knowing the rainfall pattern, we can select when to use the harvested rainwater to maximize the benefits of RWH system. The rainfall pattern would be different for different places, this can be studied by observing the hydrological data of a certain place. In addition, modifications such as changing the pumping operation to gravity concepts will also help to improve the performance of the RWH system, this is because the pumping operation may require some maintenance through the years after the RWH system is installed. Abundant research and study are required to design a optimum and feasible design of the RWH system.

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REFERENCES

Anang, Z., Padli, J., Abdul Rashid, N. K., Alipiah, R. M., & Musa, H. (2019). Factors Affecting Water Demand: Macro Evidence in Malaysia. Jurnal Ekonomi Malaysia, 53(1), 17-25. doi:10.17576/jem-2019-5301-2

Centrifugal Pump Brass Impleller CALPEDA NMM 2/A/A 1Hp 1x230V 50Hz Heavy Duty Z5. (n.d.). Retrieved July 12, 2020, from https://www.tomeiwatersolutions.com/en/home/water-pumps/calpeda/centrifugal/centrifugal-pump-brass-impleller-calpeda-nmm-2-a-a-1hp-1x230v-50hz-heavy-duty-z5.2.5.145.gp.31996.uw

Chiang, V. C., Kao, M. H., & Liu, J. C. (2013). Assessment of rainwater harvesting systems at a university in Taipei. Water Science and Technology, 67(3), 564– 571. doi: 10.2166/wst.2012.592

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Clean India Journal. (2012, January 9). Rooftop: rainwater harvesting systems in Schools. Retrieved from https://www.cleanindiajournal.com/rooftop_rainwater_harvesting_systems_in_schools/.

Climate - Malaysia. (n.d.). Retrieved from https://www.climatestotravel.com/climate/malaysia

Drinking-Water. (2019, August 23). What is the water flow rate to most fixtures in my house? Retrieved June 17, 2020, from https://drinking-water.extension.org/what-is-the-water-flow-rate-to-most-fixtures-in-my-house/

Education – School Rainwater Harvesting Systems. (n.d.). Retrieved from https://www.rainharvesting.co.uk/school-rainwater-harvesting/.

Farreny, R., Morales-Pinzón, T., Guisasola, A., Tayà, C., Rieradevall, J., & Gabarrell, X. (2011). Roof selection for rainwater harvesting: Quantity and quality assessments in Spain. Water Research, 45(10), 3245–3254. doi: 10.1016/j.watres.2011.03.036

Halim, Z., Din, A., Tokit, E., & Rosli, M. (2019). Development of Rainwater Harvesting System for Sekolah Menengah Kebangsaan Iskandar Syah Melaka. IOP Conference Series: Earth and Environmental Science, 268, 012024. doi: 10.1088/1755-1315/268/1/012024

Lani, N. H. M., Yusop, Z., & Syafiuddin, A. (2018). A Review of Rainwater Harvesting in Malaysia: Prospects and Challenges. Water, 10(4), 506. doi: 10.3390/w10040506

Law, B. K., & Bustami, R. A. (2013). A Study on Potential of Rainwater Harvesting System in SJK Chung Hua No. 2, Kuching. Journal of Civil Engineering, Science and Technology, 4(2), 28–33. doi: 10.33736/jcest.116.2013

Lazada (n.d.). Retrieved from https://www.lazada.com.my/products/deluxe-dp60k-

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

3000l660g-round-bottom-with-stand-316-stainless-steel-water-tank-i101952960-s102547731.html?laz_trackid=2:mm_150030489_51201076_2010201089:clk5hjhu11e7fusrsocbin

Madaan, S. (2016, December 26). What is Rainwater Harvesting, its Importance and Various Methods to do it. Retrieved from https://www.eartheclipse.com/energy/importance-methods-rainwater-harvesting.html.

Maxwell-Gaines, C. (2018, May 6). The Many Benefits and Advantages of Rainwater Harvesting. Retrieved from https://www.watercache.com/faqs/rainwater-harvesting-benefits.

Mwamila, T. B., Han, M. Y., & Kum, S. (2016). Sustainability evaluation of primary school rainwater demonstration project in Tanzania. Journal of Water, Sanitation and Hygiene for Development, 6(3), 447–455. doi: 10.2166/washdev.2016.186

Polyethylene Water Tanks: Rainwater Tanks Direct: Water Tanks Blog. (2018, June 19). Retrieved from https://rainwatertanksdirect.com.au/blogs/about-polyethylene-water-tanks/

Pump Systems for Rainwater Catchment (n.d.). Retrieved from http://www.harvesth2o.com/pump_systems.shtml

Quality Rainwater Tanks Brisbane & Sydney. (n.d.). Retrieved from https://www.watertankfactory.com.au/

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

R3000 Litre Rainwater Tank. (n.d.). Retrieved from https://www.watertankfactory.com.au/water-tanks/r3000-litre-round-rainwater-tank

Rainwater Catchment System Pump Sizing (n.d.). Retrieved June 17, 2020, from http://www.harvesth2o.com/pump-sizing.shtml

Rainwater Management Solutions. (n.d.). Rainwater Harvesting 101: Pump Selection. Retrieved June 17, 2020, from https://rainwatermanagement.com/blogs/news/rainwater-harvesting-101-pump-selection

Renew. (n.d.). Rainwater tank buyers guide - Renew Magazine. Retrieved from https://renew.org.au/renew-magazine/buyers-guides/rainwater-tank-buyers-guide/

Sekolah Jenis Kebangsaan (Cina) Ayer Keroh, Melaka. (n.d.). Retrieved from https://www.apac.com.my/mbc2077-sjkc-ayer-keroh.html

Sprague, G. (2016, October 7). How Many Gallons of Water Does It Take to Flush a Toilet? Retrieved from https://homeguides.sfgate.com/many-gallons-water-flush-toilet-88812.html

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Steel vs Concrete vs Fibreglass vs Poly Tanks. (2018, August 30). Retrieved from https://www.nationalpolyindustries.com.au/2018/06/15/steel-vs-concrete-vs-fibreglass-vs-poly-tanks/

Sung, M., Kan, C. C., Wan, M. W., Yang, C. R., Wang, J. C., Yu, K. C., & Lee, S. Z. (2010). Rainwater harvesting in schools in Taiwan: system characteristics and water quality. Water Science and Technology, 61(7), 1767–1778. doi: 10.2166/wst.2010.107

Sung, C. T. B., Soo, M. H., Sung, C. T. B., Francesca, Jia, Christopher Teh, & Kondi, K. (2015, July 20). Water consumption and crop water use in Malaysia. Retrieved from http://www.christopherteh.com/blog/2011/09/cropwateruse/.

Yu Media Group. (n.d.). Malacca, Malaysia - Detailed climate information and monthly weather forecast. Retrieved from https://www.weather-my.com/en/malaysia/malacca-climate

Water Tanks Compared: Poly Tanks versus Stainless Steel Tanks: Team Poly Water Tanks: Water Solutions for Life. (2018, August 30). Retrieved from https://www.teampoly.com.au/2018/06/15/water-tanks-compared-poly-tanks-versus-stainless-steel-tanks/

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

What Are the Benefits of Poly Water Tanks? (2019, November 21). Retrieved June 17, 2020, from https://rainwatertanksdirect.com.au/blogs/what-are-the-benefits-of-poly-water-tanks/

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APPENDIX

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APPENDIX A

GANTT CHART FOR PSM 1:

Weeks / Activities	PSM 1															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Research Title Selection	■	■	■													
Backgroud Study			■	■	■											
Literature Review				■	■	■	■	■	■	■	■	■	■	■	■	
System Comparison								■	■	■	■	■	■	■	■	
Drafting Chapter 1						■	■									
Submission Progress Report							■									
New Design Sketching															■	
Methodology								■	■	■	■	■	■	■	■	
Mechanism Analysis								■	■	■	■	■	■	■	■	
Cost Analysis											■	■	■	■	■	
PSM 1 Report Writing													■	■	■	
Submission Report PSM 1															■	
PSM 1 Seminar																■

GANTT CHART FOR PSM 2:

Weeks / Activities	PSM 2															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Literature Review	■	■	■	■	■	■	■	■	■	■	■	■	■			
Drafting in Solidworks	■	■	■	■												
Simulation					■	■										
Analysis					■	■										
Submission Progress Report							■									
Result and Discussion								■	■	■	■	■	■			
Improvement and Justification								■	■	■	■	■	■			
Conclusion and Recommendation													■			
PSM Report Writing								■	■	■	■	■	■			
Draft Submission														■		
PSM 2 Seminar															■	
Final Report Submision																■

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