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RAINWATER HARVESTING STUDY AT MASJID JAMEK RIYAHDUS SOLIHIN, PINTAS PUDING, BATU PAHAT JOHOR MALAYSIA

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ABSTRACT

Harvesting rainwater contribute towards a sustainable living. It eliminate the wastage and reduce the dependency of potable water. The demand of potable water increases in accordance to the population. Rainwater harvesting is capable to combat water crisis and serves as an alternative water resources during water shortage. The present study proposed a rainwater harvesting system for the mosque and obtain the rainfall amount at study area. The method used for designing the rainwater harvesting system is referred to MSMA 2nd Edition. The system is consists of downpipe filter (4"/ Ø150 mm), Eaves gutter (16, 000 mm²) first flush diverter 150 mm (63 liter; 1.78 length) and: taper tank (600 liters). Rainfall data for study area was recorded by HOBO tipping rain gauge for four months. Rainwater was calculated and harvested 116.7% yield to the water demand for the study area. The rainfall for four months at the study area showed that the rainwater demand was sufficient to be collected and used for the mosque activities. The highest rainfall data collected was 75.2 mm. This study would help to initiate a starting point to create a green mosque concept into reality. Furthermore, this system applied the concept of green building that create environmental friendly surrounding as a stepping stone to educate and at the same time save the environment and minimize the energy wastage.

Keywords: Design of rainwater harvesting system, MSMA, Rainfall data

INTRODUCTION

The rainwater is a precious gift for us by nature. Since the creation of the Earth, rain has helped nourish the growth of myriad of flora and fauna and has provided precious drinking water for all creatures. Rainwater harvesting is as old as mankind. About 4,000 years ago in Rome, the Romans have been used rainwater for domestic purposes. Roman villages and cities of that time planned to take advantage of rainwater for drinking [1]

Clean water is a valuable and important source. Since clean water is important, it is seen as a waste for it to be used for flushing of toilets and watering plants. Rainwater is one of reliable source of clean water it can be used as a substitute by collecting and utilize it rather than let it go to waste. A part from that, by collecting rainwater from roof, flash flood affect can be reduced as few percentage of rainfall is retained and thus reduce the volume of surface runoff. Besides, by using rainwater as an alternative, clean water can be saved and used for other purposed and simultaneously decrease of demand of clean water resulted in lower cost of water bill and cost of operation in the water treatment plants. The use of untreated rainwater for non – potable uses that would otherwise be supplied by potable water ultimately conserves municipally supplied potable water [2].

Water shortage is becoming the number one problem in the world today. Moreover, the problem of water scarcity is strongly connected to the problem of water quality. Urban development, human activities and industrialization deteriorate the quality of water and, in some cases, make it unsafe for consumption [3]. Some effort has been made to reuse ablution water from mosques (masjid), which it has low contaminant and consist of high volume from the cleansing ritual [4] [5]. However, the utilization of the rainwater harvesting in mosque has not widely discussed in the case study.

Developing of region increase the water demand and reduce capability of drainage area to maintain overland flow judging the increasing of runoff coefficient. Fast growing development in Parit Raja especially at Pintas Puding area now has begun to increase of the water demand due to the rapid urbanization and dependence on main water supply.

In order to overcome the water crisis, domestic rainwater harvesting has been carried out which is an alternative solution for these problem. Rainwater harvesting is a simple ancient technique of collect water and storage. This technique has been practiced in Sri Lanka to meet the growing water demand on water supply; a good example is the sophisticated rainwater cum reservoir system in 5th century Sigiriya fortress complex. In Malaysia, a study on rainwater harvesting and utilization system (for non potable household use), coupled with detention storage (to reduce peak storm runoff), for double storey terrace house at Taman Wangsa Melawati, Kuala Lumpur was carried out. Therefore, all of the advantages of using rainwater harvesting will be combined in this further study to overtake the water crisis besides reducing water bills for the mosque.

Rainwater harvesting is a technology used for collecting and storing rainwater from rooftops, the land surface of rock catchments using simple techniques such as jars and pots as well as more complex techniques such as underground check dams and ponds. Commonly used systems are constructed of three principal components; which are the catchments area, the collection device and the conveyance system. The captured rainwater could be used for domestic usage such as drinking, cooking, toilet flushing, and other public facilities.

This study was conducted to propose a rainwater harvesting system at the study area with the collected data.

METHODOLOGY

Design of Rainwater Harvesting System

The study area is located at Masjid Jamek Riyahdus Solihin in Batu Pahat, Johor, Malaysia. This mosque is located nearby to Sekolah Kebangsaan Pintas Puding, and Kolej Jururawat Masyarakat Batu. Rainwater harvesting is a technique of collecting rainfall as a source of water supply for household, commercial and industrial premises. The planning and development of rainwater harvesting system shall be carried out adhering to the principles and guideline describes in MSMA (Urban Stormwater Management). The value of rainwater as the primary source of clean water is always ignored. Rainwater harvesting using roof catchments is the easiest and most common method.

Determine Average Rainfall Intensity

Average rainfall intensity determined by referring to the intensity – duration – frequency (IDF) curves at study area city or the nearest. Basically, to obtain the most accurate amount of the rainfall intensity, Eq. (1) can be used.

$$\boldsymbol{i} = \frac{\lambda T^{k}}{(d+\theta)^{\eta}} \quad 3 \qquad \text{(Eqn. 1)}$$

Where,
i = Average rainfall intensity (mm/hr);
T = Average recurrence interval–ARI (0.5 ≤ T ≤ 12 month and 2 ≤ T ≤ 100 years)
d = Storm duration (hours), 0.0833 ≤ d ≤ 72; and
λ, K, θ and Ƞ = Fitting constants dependent on the rain gauge location

Determine the Catchment Area

The rooftop act as the catchment area for this study. Rooftop dimension such as width, base and slope was taken by measure at the study area. The total catchment area can be determined by using Eq 2.

$$Total\ catchment\ area = Ah \times Ar \qquad \text{(Eqn. 2)}$$

Where,
Ah= plan area (m^2)
Ar= rise vertical area (m^2)

Gutter and RWDP Sizing

Gutter and downpipe size was determined by referring to the design chart from MSMA 2nd Edition (Chapter 6) [6]. The size determine by considering the rooftop gradient and the total flow of the rainfall.

First Flush Diverter

First flush diverter is a must component in rainwater harvesting. It separate debris from entering the storage tank to control the quality of the rainwater. First flush diverter was determined according to standard as stated in MSMA 2nd Edition (Chapter 6) [6]. First flush volume requirement are based on the roof area or the catchment area. Figure 1 shows the illustration of the first flush diverter.

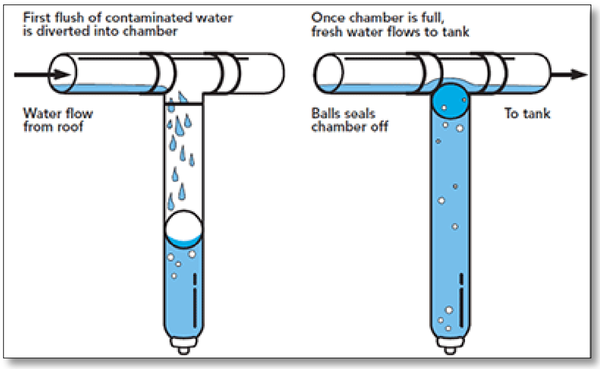

Fig 1 Illustration of first flush diverter

Tank size Estimation

There are various types of rainwater harvesting tank. In general, the rainwater tank can be divided into either above – ground tank or below – tank. The tank shapes can be circular, or rectangular. The tank sizing was determined based on the Yield Before Spillage (YBS) model. Tank size of 1 m^3 is for roof area of 100 m^2. Tank size (m^3) can be determined according to Eq. 3.

$$\boldsymbol{St = 0.01\,Ar} \qquad \text{(Eqn. 3)}$$

Where,
St = Tank Size (m^3)
Ar = Rooftop Catchment Area (m^2).

Determine the Water Demand

Water demand was determined based on the average consumption, and average total rainwater demand at the study area. Total use per day and the annual rainwater demand need to be determined in unit of m^3 and in percentage. Water demand determination is important to determine whether the rainwater supplied is sufficient to fulfill the water demand at study area. Table 1 shows the estimation amount of water used for different application.

Table 1 Amount of Water Uses for Different Applications (DID, 2009)

Use (Appliance)	Type	Average Consumption	Average total Rainwater Demand
Indoor			
Toilet	Single Flush	9 litres per flush	120 litres per day
	Dual Flush	6 or 3 litres per flush	40 litres per day
Washing Machine	Twin Tub (semi – auto)		40 litres per wash
	Front Loading		80 litres per wash
	Top Loading		170 litres per wash
Dishwasher	-		20 – 50 litres per load
General Cleaning	-	10 – 20 litres per minutes	150 litres per day
Outdoor			
Sprinkler or handheld hose		10 – 20 litres per minute	1000 litres per hour
Drip System			4 litres per hour
Hosing Paths/ Driveways		20 litres per minute	200 litres per wash
Washing car with a Running hose		10 – 20 litres per minute	100 – 300 litres per wash

Collection of Rainfall Data

Collection of rainfall data at the study area is taken for almost four months at the study area. The rainfall data collected using the rain gauge that was installed a few meters from the location of the RWH system. The rainfall data and temperature for every 3 minutes from 28th August 2016 were recorded until 20th November 2016 using HOBO tipping rain gauge.

RESULTS AND ANALYSIS

Average Rainfall Intensity

In order to maximize the error in estimating the amount of rainfall intensity values from the IDF curves, the empirical equation 1 was applied. The fitting constants dependent on the rain gauge location (Table 2)

The system designed using the average recurrence interval – ARI, T is for 10 years with 10 minutes of storm duration, d.

Johor	Λ	κ	θ	η
Stor JPS Johor Bahru	59.972	0.163	0.121	0.793
Pusat Kem. Pekan Nenas	54.265	0.179	0.1	0.756
Johor Silica	59.06	0.202	0.128	0.66
Balai Polis Kg. Seelong	50.115	0.191	0.099	0.763
SM Bukit Besar	50.554	0.193	0.117	0.722
Setor JPS BatuPahat	64.099	0.174	0.201	0.826
Ladang Ulu Remis	55.864	0.166	0.174	0.81
Simpang Masai K. Sedili	61.562	0.191	0.103	0.701
Emp. Semberong	60.568	0.163	0.159	0.821
Pintu Kaw. Tg. Agas	80.936	0.187	0.258	0.89
JPS Kluang	54.428	0.192	0.108	0.74
Ladang Chan Wing	57.188	0.186	0.093	0.777
Ladang Kekayaan	53.457	0.18	0.094	0.735
Ibu Bekalan Kahang	52.177	0.186	0.055	0.652
JalanKluang–Mersing	56.966	0.19	0.144	0.637
LadangLabis	45.808	0.222	0.012	0.713
Rmh. Tapis Segamat	45.212	0.224	0.039	0.711
Kg Peta Hulu Sg Endau	59.5	0.185	0.129	0.623
Setor JPS Endau	62.04	0.215	0.103	0.592

Table 2 Fitting constants dependent on the rain gauge (MSMA 2nd Edition)

$$i = \frac{(64.099)(10)^{0.174}}{(0.1666 + 0.201)^{0.826}}$$

$$i = 218.71 \text{ mm/hr}$$

Catchment Area

Plan area, Ah = 25 m×22 m= 550m^2

Rise Vertical area, Ar =25×0.5 m=12.5m^2

Total catchment area = Ah×Ar (Eqn. 2)
= 550 + (12.5/2)
=556.3m^2

Calculation of Gutter and Downpipe Size

As the gradient of the rooftop surface is flatter than 1:500, with the calculated value of average rainfall intensity and total catchment area, the sizing of the eaves gutter is able to be identified as 15.75 m^2 with 4.0L/s total flow. Therefore, 150 mm diameter of circular downpipe was taken from Table 3.

Table 3 Required Size of Downpipe for Eaves Gutter (AS/NZS 3500.3, 2003)

Eaves Gutter Size(mm^2)	Minimum Nominal Size of Downpipe (mm)	
	Circular	Rectangular
4,000	75	65 x 50
4,200		
4,600		75 x 50
4,800	85	
5,900		100 x 50
6,400	90	
6,600		75 x 70
6,700	100	
8,200		100 x 75
9,600	125	
12,800		100 x 100
16,000	150	125 x 100
18,400		150 x 100
19,200	Not applicable	
20,000		125 x 125
22,000		150 x 125

This study determines the size of the down pipe by using the size of the gutter. However, it is different for other researcher. Study by Villarreal and Dixon (2005)[7] determine the size of the downpipe by referring to the material of the downpipe itself. Villarreal and Dixon (2005) [7] use concrete pipe with diameter of 300 mm compare to other researcher with the use PVC pipe with diameter of 65 mm. The pipe size for this study is within the range from the previous study which shows that the size is suitable to be used.

First Flush Volume

The first flush need to install with suitable volume according to its standard as suggested in the MSMA 2nd Edition (Chapter 6). This is important to prevent the contaminants and debris collected from the roof surface from entering the storage tank.

Table 4 First Flush Requirement According To Roof Area (DID, 2009)

Roof Area (m^2)	First Flush Volume (m^3)
Less than 100	0.025 – 0.05
100 – 4356	0.05 – 2.5
Greater than 4356	2.5

Note: Adopt first flush of 5 m^3 if surface contains excessive soil, dust or debris.

Tank Size Estimation

Based on the Yield Before Spillage (YBS) model suggested for the procedures in estimating the rainwater availability, the estimation of the Average Annual Rainwater Yield (AARY) was carried out by using the water balance model for the selected towns in Malaysia and summarize that tank size for Malaysia regardless of location is 1m^3 for roof area of 100m^2. With the 10 mm of rainfall is equivalent to be stored from 100 m^2 of rooftop area. The tank size was determined by using Equation 3.

$$St = 0.01Ar \qquad \text{(Eqn. 3)}$$

Where,
St = Tank Size (m^3); and
Ar = Rooftop Catchment Area (m^2).
St = 0.01 (556.3)
St = 5.563m^3

Water Demand

The rainwater demand depends on the number of people using the water, average consumption and also the range of uses by the consumer. The water demand for the rainwater influences the effectiveness and availability of designed rainwater storage tank.

Table 5 Rainwater Demand for Domestic Application (DID, 2009)

Use (Application)	Type	Average Consumption	Average Total Rainwater Demand
Toilet	Single Flush	9 litres per flush	120 litres per day
General washing	-	10-20 litres per minute	150 litres per day

Total use per day = 120 l/day + 150 L/day
= 270 l/day

The annual rainwater demand = 365 days × 300 L/day =98.55 m

Compute the Average Annual Rainwater Yield for town (m^3)

From Table 5, take the nearest Kluang, The AARY for 1m3 tank size = 1 x 115 = 115m^3

Compute the percentage of water yield over rainwater demand

Percentage of rainwater yield over rainwater demand = (115/98.55) x 100 = 116.7%

Rainfall Data

The rainfall data was collected for almost four months (August until November) using the rain gauge that installed few meters from the location of the RWH system. The rainfall data and temperature for every 3 mins from 28^{th} August 2016 were recorded until 20th November 2016 using HOBO tipping rain gauge. Figure 6 shows the rainfall amount and temperature collected at study area.

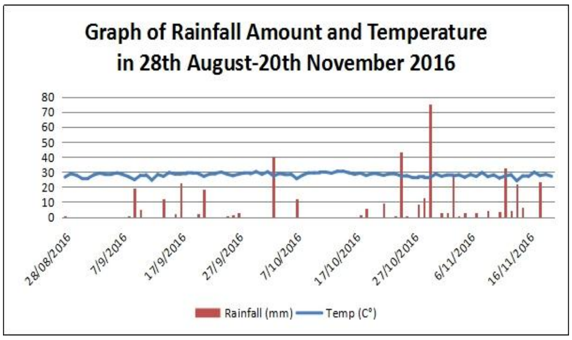

Fig. 2 Rainfall amount and temperature collected

According to website from the Department of Irrigation and Drainage Malaysia (DID), http://infokemarau.water.gov.my/realtime.cfm, 2017), the rainfall data that were recorded at Sri Medan show that the highest rainfall data recorded is 77.00 mm which is the same as the rainfall data in Figure 3. The data are comparable due to Malaysia's equatorial climate. Equatorial climate can be defined as the climate where there is a constant temperature, high moisture content and generally high rainfall intensity. Figure 3 shows the rainfall amounts that were obtained from infokemarau website http://infokemarau.water.gov.my/realtime.cfm, 2017),

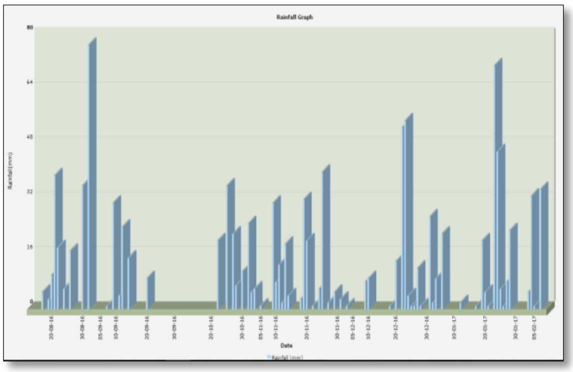

Fig. 3 Recorded rainfall data from infokemarau (2017)

CONCLUSION

From the study, it is promising if the rainwater harvesting is practices in mosque, it serves as a substitution for non – potable water usage for domestic activities such as flushing and irrigation and supplying freshwater in the face of increasing water scarcity and escalating demand. The component that needs to be used for this RWH system is design based on the MSMA 2^{nd} Edition. The components proposed Downpipe filter (4"/ Ø150mm), Eaves gutter (16, 000mm²), First flush diverter 150mm (63 liter; 1.78 length), : taper tank (600liters) and Outgoing Distributions Pipe from RWH Tank Main Discharge Point to Nearest Irrigation Tap or Usage Points (Ø35mm). The rainwater is calculated 116.7% yield to the water demand for the study area. The rainfall for four months at the study area shows that the rainwater demand is sufficient to be collected and used for the mosque activities. The highest rainfall collect is recorded to be 75.2 mm.

By using rainwater, many benefits can be seen economically and environmentally where water can be saved and can reduce impacts from flash flood phenomena respectively. It is important that mosque would take rainwater harvesting system seriously in realizing its objectives to become a green mosque that creates an environmental friendly surroundings and the same time save the environment and minimize the energy usage.

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