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Design of Rooftop Rainwater Harvesting Structure in a University Campus

S. Sangita Mishra, Shruthi B. K., H. Jeevan Rao

Abstract*: *Rain water harvesting (RWH) is an excellent technique of water conservation for future needs and also to recharge groundwater. Due to the alarming population burden, climate change, uneven distribution of rainfall and abrupt variation of meteorological parameters, the surface and ground water resources are continuously depleting in India. Hence adoption of different water conservation techniques at individual, institute and community level has become imperative to cater to the needs. This study was aimed at designing a rooftop rainwater harvesting structure for the Amity University Mumbai, located in Maharashtra state of India. Out of the possible catchment areas, the main building was selected as the required catchment area for rainwater harvesting considering the water demand in university campus and the supply. Further, different parts of the RWH system were designed based on standard guidelines It was observed from the analysis that implementation of RWH system in Amity University Mumbai campus can resolve the water scarcity problems during non-monsoon season by storing a huge quantity of 6109.42 m^3 in a year in the university campus. This initiative can increase the water supply for construction work, gardening and also will help in artificial recharge of ground water thus enriching both the surface and the ground water resources.

Keywords: Rooftop rainwater harvesting, Amity University Mumbai, Sustainability, Water scarcity.

I. INTRODUCTION

Rapid urbanization has lead to concentrated population density in many regions which has resulted in surface water scarcity as well as uneven drying of ground water. This has resulted in drought and drying up of river beds in the regions where industrial and domestic consumption of water is high. In order to reduce the risk of scarcity of water to the future population, rain water collection and storm water harvesting from runoff would be an effective way. [4],[2],[3],[7].The best way for rainwater harvesting is to recharge the ground water and also, if rain water collected in natural ponds or artificial tanks is unused, the same can be used to charge the natural aquifer thus boosting the ground water level [5]. The technique by which the rain water is collected from rooftop catchments is termed as roof top rain harvesting [6]. In order to cater the domestic needs, harvested rain water can be stored in sub-surface ground water reservoir by using artificial recharge techniques by storing in tanks. Though harvesting rain water is vital for sustainable water saving system for both rural and urban regions, the major challenge in the design is to estimate the area for storing water. The required catchment area should be designed effectively to collect rainfall for required purpose [8], [1].

The Amity University Mumbai Campus, Panvel is a wide spread educational campus with a vast area of around 30 acres. There are around 3500 students studying in the main campus, whose daily requirement has to be served. Due to this fact there can be a possible water shortage in the future. The nearby water-tables are being exploited daily at a fast pace. And there are fields in the nearby area which require this water. So this create a situation here of the usage of the rainwater. This huge area can be utilized for the purpose of harvesting rainwater. Receiving an annual rainfall of around 3017 mm and an intensity of 20 mm per hour in this area of Panvel provides good opportunities to harvest the rainwater.

The study aims to design a roof top rainwater harvesting system for Amity University Mumbai Campus to overcome the water scarcity during non-monsoon season. The objectives of this study was

- To estimate the total water demand by students, teaching and non-teaching staffs of the University on working and non-working days.
- To estimate the rainwater harvesting potential of the catchment areas of the university campus.
- To design a suitable roof top rainwater harvesting system for the university campus.

II. STUDY AREA

Panvel is located in the district of Raigad in Maharashtra in Konkan Division, and is a node of Navi Mumbai city. It is densely populated due to its closeness to Mumbai. It is the first Municipal Corporation in the district of Raigad and the 27th Municipal Corporation of Maharashtra State. During monsoon in the months of June, July, August and September, the weather conditions are generally humid and wet. This area receives heavy rainfall during this season. The weather is pleasant and comfortable in the months of October and November.

Amity University Mumbai is located near the Panvel city and the weather conditions in the university campus are mainly characterized by high rainfall in the monsoon season and a prolonged dry period during rest months of a year.

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* Correspondence Author
S. sangita Mishra*, Civil Engg., Amity School of Engineering and Technology, Amity University Mumbai, Panvel, Maharashtra, India. Email: dr.sushreemishra80@gmail.com
Shruthi B.K., Civil Engg., Amity School of Engineering and Technology, Amity University Mumbai, Panvel, Maharashtra, India. Email: shru28.leo@gmail.com
H. Jeevan Rao, Aerospace Engg., Amity School of Engineering and Technology, Amity University Mumbai, Panvel, Maharashtra, India. Email: hjrao@mum.amity.edu

This leads to water scarcity in the campus during the summer months which can be taken care using roof top rain water harvesting techniques in the campus. The University constitutes four main buildings viz. Main building, New building, New Boys' hostel and Architecture building that can be used as the catchment areas for this purpose.

The picture shown below shows the majority of the buildings for rain water harvesting system under study at Amity University Mumbai Campus, Panvel. (Fig. 1)

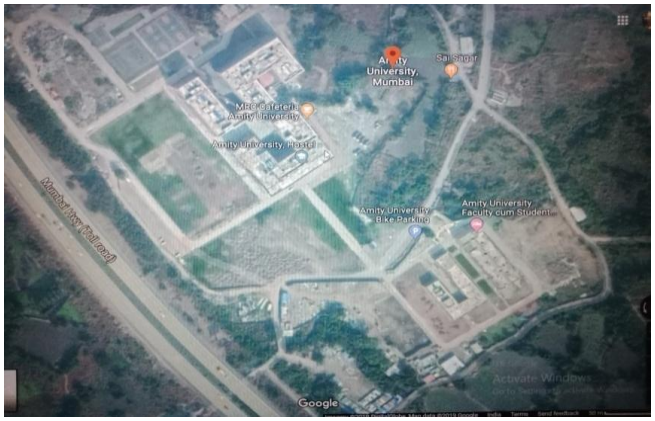

Fig 1: Amity University Mumbai Campus, Panvel (Source: www.googlemap.com)

III. METHODOLOGY

For this study, rainfall data for a period of (2002-2019) of the study area was collected from the Indian Meteorological Department and analyzed. It was observed that the average of annual rainfall of the area under study was 3017 mm. The step wise procedure adopted to design rainwater harvesting structure is mentioned here (Fig. 2).

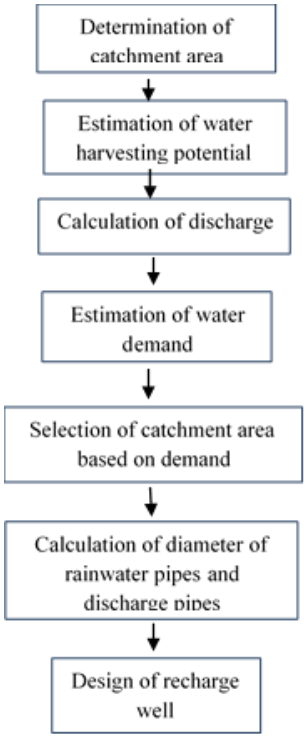

Fig 2 Methodology flow chart

In this study, the main building, new building and new boy's hostel are selected as catchment areas. The total area and height of the buildings were calculated from the building plan details. The total rainwater harvesting potential was estimated using rational formula and total water demand was calculated. Based on these two parameters final catchment area was selected for design purpose.

IV. RESULTS AND DISCUSSIONS

A. Determination of Catchment Area

The rooftop surface area is the catchment area that receives the incident rainfall. The rooftop areas of 3 buildings i.e the main building, new boys' hostel and new building are selected as catchment areas in the study. The rooftop area and heights of the selected buildings are mentioned in table I.

Table I: Roof Area of all Buildings in Amity University Campus

S.No	Building Name	Roof Area (m^2)	Height (m)
1.	Main Building	2250	16
2.	New boys hostel	2520	27
3.	New Building	4577	22

B.Estimation of water harvesting potential

The quantity of water that is received from rainfall over an area is called the rainwater potential of that area. And the quanity that can be effectively harvested is called the rain water harvesting potential. Rain water harvesting potential can be calculated using the following formula.

Rainwater Harvesting potential(m^3) = Area of Catchment (m^2) X Amount of rainfall (mm) X Runoff coefficient

C.Runoff coefficient

In this study, runoff coefficient value was taken from the manual of artificial recharge of ground water, **Government of India Ministry of Water Resource Central Ground Water Board**, the tables II and III represents the runoff coefficient values to be adopted for design purpose.

Table II :Runoff Coefficient values for Surface Areas (type 1)

Type of area	runoff coefficient (k)
Residential	0.3-0.5
Forests	0.5-0.2
Commercial and industrial	0.9
Parks & Farms	0.05-0.3
Asphalt or Concrete Paving	0.85
Road Surfaces	0.8-0.9

Table III: Runoff Coefficient values for Surface Areas (type 2)

different surfaces	runoff coefficient (k)
Roof Conventional	0.7-0.8
Roof Inclined	0.85-0.95
Concrete /Kota paving	0.6-0.7

Gravel	0.5-0.7
Brick Paving	0.7

The annual rainwater harvesting potential of the three catchment areas viz. main building, new boy's hostel and new building was estimated using the guidelines. The value of runoff coefficient was taken as 0.9 from table III. It was observed that the new building has maximum rainwater harvesting potential of 12,427.92 m^3. Rainwater harvesting potential of other catchment areas are summarized in table IV.

Table IV: Annual rainwater harvesting potential

Building Name	K	I (m)	A (m^2)	Volume(m^3)
Main Building	0.9	3017	2250	6109.42
New Boys' hostel	0.9	3017	2520	6842.55
New Building	0.9	3017	4577	12,427.92
Total Volume				25,379.89

D.Estimation of water demand

The Total water demand of the University was estimated considering the per capita consumption of water for domestic use as per the norms of Central Public Health and Environmental Engineering Organization mentioned in table V.

Table V: Per capita consumption of water for domestic use

Activities	Liters/Person
Drinking purpose	3
Cooking purpose	4
Bathing purpose	20
Flushing purpose	40
Washing Cloths purpose	25
Washing Utensils purpose	20
Gardening purpose	23
Total demand of water needed liters/person/day	135 liters/person/day

Demographic data of the campus was collected from the University Admin and HR departments to estimate the total water demand by different consumers and considering their daily requirement as per the norms. The information collected regarding the same is mentioned below.

Total number of students in campus:- 3283

Number of students in hostel: 1720

Number of security guards: 56

Number of teaching staff: 180

Number of Non-teaching staff: 137

Number of staff staying within campus: 15

Total number of day scholars: 1563

The total water demand was calculated for hostellers, day scholars and also considering miscellaneous use. The total water demand of the University was estimated to be 316.05 m^3/d.

E.Selection of catchment area for roof-top water harvesting structure

The total water demand by the University is 316.05 m^3/d. Based on the above calculations, the main building catchment area is sufficient to serve the purpose by comparing demand and supply.

F.Calculation of discharge

To find out the required diameter of the pipe to be used for draining the rainwater down from the roof, first we need to calculate the discharge Q i.e. given by:-

$$Q = CIA \qquad (1)$$

Where, Q= Discharge from roofs due to rainfall in (m^3/s)
C= Coefficient of runoff by rational method taken as 0.8 for this case
I= Intensity of rainfall i.e.20mm/hr.
A= Area of catchment, m^2

Discharge from different catchment areas were estimated to calculate the required diameter of rainwater harvesting pipes and summarized in table VI.

Table VI:Calculation of discharge

Building Name	Constant (C)	I (mm/hr)	A (m^2)	Q (m^3/sec)
Main Building	0.8	20/3600000	2250	0.01
New Boys' hostel	0.8	20/3600000	2520	0.0112
New Building	0.8	20/3600000	4577	0.020
Total Discharge				0.0412

G.Calculation of number of rainwater pipes (R.W.P)

Assuming the diameter of pipe as 10 cm, the total number of required pipes was calculated in this study.

$Q = C \times I \times A$

$$= n \times \frac{\pi}{4} \times d^2 \times v \qquad (2)$$

Where;
Q=Discharge

I=Intensity of rainfall

A=Area of catchment

n=Minimum no. of pipes

d=Diameter of rainwater pipe i.e. R.W.P

v=Velocity of water on the roof when it is at the verge of entering in the pipe due to the slope available at the roof. As the roofs are flat or having 0-2% slope so;

v=0.1m/s (as per CGWB guidelines)

So, no. of pipes are calculated as:

$n = Q / (0.785 d^2 \times v)$ (3)

Using the above formulae the total number of required RWP were calculated and summarized in table VII.

Table VII: Calculation of Number of Rainwater Pipes (R.W.P) to be installed

Building Name	d (m)	v (m/sec)	Q (m^3/sec)	Number of Pipes
Main Building	0.1	0.1	0.01	13
New Boys' hostel	0.1	0.1	0.0112	15
New Building	0.1	0.1	0.020	26
Total no of Pipes				54

H.Calculation for the Diameter of the Discharge Pipe

The discharge pipe was designed considering the selected catchment area i.e. the main building. Initially the velocity of water entering the horizontal discharge pipe is calculated using the formula

$V^2 = U^2 + 2aS$ (4)

Where;

V= Velocity of water entering the horizontal Discharge pipe
U = Velocity with which Rainwater enters the R.W.P. = 0.1 m/sec.
S= Height of the building = 16 m.
a = Acceleration due to gravity= g = 9.81m^2/sec.
The velocity of water in the mail building was calculated to be 17.71 m/sec.
The discharge Q of the Building = 0.01 m^3/sec.
We know that Q= $\pi/4 \times d^2 \times V$
On putting all the values we get;
d = 26.81 mm (27 mm approximately)
Which will not available in standard sizes. Hence 50 mm diameter discharge pipes can be used.

I.Design of Recharge Well

The design of recharge well is done on the basis of two criteria

1. Time of Concentration of water
2. Maximum water to be stored at the longest rainfall with chocked filters.

J.Time of Concentration

In this study, the roof top area and the length of drain were considered for calculation of time of concentration.

$T_C = 0.0195\ L^{0.77} S^{-0.385}$ (5)

where:
Tc = Time of concentration, minutes
L = overland flow length, m
S = average slope of the overland area.

Table VIII : Design of Recharge Well to find T_C(Minutes.) & T_C(Hours.)

Blocks	L (m)	S (Slope)	T_C(Minutes.)	T_C(Hours.)
Main Building	54	0.005	3.235	0.053
New Boys' hostel	126	0.005	6.209	0.103
New Building	199	0.005	8.829	0.14

Volume of the Recharge Well considering main building as the catchment area = Q X T_C = 0.01x3600x0.053 = 1.908 m^3 or 2 m^3.

V. CONCLUSION

This study was aimed at designing a rooftop rainwater harvesting structure for the Amity University Mumbai campus. This will help in artificial recharge of groundwater in this area in addition to fulfilling water scarcity conditions. The main building was selected as the required catchment area for rainwater harvesting considering the water demand in university campus and the supply. Further, different parts of the RWH system were designed based on standard guidelines It was observed from the analysis that implementation of RWH system in Amity University Mumbai campus can resolve the water scarcity problems during non-monsoon season by storing a huge quantity of 6109.42 m^3 in a year in the university campus. This initiative can increase the water supply for construction work, gardening and also will help in artificial recharge of ground water thus enriching both the surface and the ground water resources.

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AUTHORS PROFILE

Dr. S. Sangita Mishra, has obtained her PhD degree from Indian Institute of Technology Bombay, India in Geo-informatics and Natural Resources Engineering and is working as Associate Professor in the Department of Civil Engineering, Amity School of Engineering and Technology, Amity University Mumbai, Maharashtra, India. She is the author of a book and several articles published in national and international journals of repute. She is reviewer of many reputed journals and life member of ISTE, ISRS, ISH, International association of engineers, CBEES and member of IEEE and IEEE-GRSS. Her research interests are: water resources management, watershed management, drought vulnerability assessment using GIS and Remote sensing techniques.

Ms. Shruthi B.K, is an Assistant Professor in Amity University Mumbai. Received Master's in civil Engineering in Construction Technology from Bangalore University, pursuing PhD in Civil Engineering from Amity University Mumbai. Her current research includes High performance concrete, steel fibre reinforced concrete, Nano materials, composite materials, smart materials.

Mr H.Jeevan Rao, M.Tech (PhD) in Aerospace engineering and he is a researcher, currently working as an assistant professor in an Aerospace engineering (ASET) Amity University Mumbai. He published Journal papers in various journals and attended reputed conferences. He is also an associate member of Institute of Engineers India(IEI),Life member of Society for Small Satellites and Systems (SSSS) He is currently working Natural Nano composite materials and their applications.