ICEST_CV-011

DESIGN OF ROOFTOP RAINWATER HARVESTING FOR P. A. IBRAHIM HAJI MEMORIAL PHYSIOTHERAPY CENTER, NADUPADAVU, MANGALURU, DAKSHINA KANNADA DISTRICT, KARNATAKA

Palakshappa K.[1], Absana[1], Sunaina[1], Abdul Ashir[1], Dilhush Marjan[1]

[1]Department of Civil Engineering, P. A. College of Engineering, Mangaluru, Karnataka, India.

*Corresponding Author: Palakshappa K. Email: hod_civil@pace.edu.in

Abstract:

Water is known as the elixir of life due to its importance in the lives of living creatures. The rapid increase in population, changed climatic conditions, frequent occurrences of floods, draughts, etc., caused the scarcity of water in many regions of the world. So, to fulfil the requirements of water supply for domestic purposes, there is great demand and scope for rooftop rainwater harvesting. In the present work, an attempt is made to design the rooftop rainwater harvesting system for Dr. P. A. Ibrahim Haji Memorial Physiotherapy Centre, Nadupadavu, Mangaluru, with the objective of harvesting the rooftop rainwater and using it for domestic purposes and groundwater recharge. The annual volume of water to be collected to be collected from the rooftop is obtained using the area of the rooftop and the average annual rainfall in the region. The sizes of the gutters and downpipes are provided based on the rooftop area, rainfall and intensity of rainfall as per the guidelines of IS 15797:2008. A provision is made for the first flush system and filtration to remove substances causing pollution of the water. Excess water flowing out of the tank is directed to flow into the infiltration pit, which helps to induce the groundwater recharge. The storage tank is designed, and a cost analysis is done. It is evident from the study that rooftop rainwater harvesting is a very viable, reliable, and economical method to supply water for domestic and groundwater recharge. Also, it is one of the ways forward for sustainable utilization of water resources.

Key Words: Rooftop, Rainwater harvesting, Gutters, Downpipes, Storage tank, Infiltration pit.

ISBN-978-81-19905-39-3

1. Introduction

Water is the most essential element for the survival of every living being. For all of our daily tasks, we require water. Water is the mother, the foundation of life, and the medium whose consumption is always increasing. The need for water conservation has always been urgent, and there are various tools available. The uneven water budget equation has elevated the desire to conserve water to the next level in an effort to lessen the pollution and water shortage problems [1]. Rapid urbanization, development, the concentrated population density in many regions and changed lifestyle in many regions have resulted in excessive use surface water and groundwater has led to water scarcity and also the overexploitation of ground water resulted in decrease in the yield and degradation of quality. This has resulted in drought and drying up of river beds and defunct of wells. To alleviate these problems storm water harvesting from runoff would be an effective way [2],[3],[4],[5]. Storm water harvesting is a method of collecting water wherever it falls, rainwater, the purest form of water, may be immediately used to supplement the water supply for different uses. The practice by which the rainwater is collected from rooftop catchments is termed as rooftop rainwater harvesting [6]. Rainwater collected in natural ponds or artificial tanks can be used to recharge the groundwater and helped in the boosting of water levels in the wells [7]. Utilizing a roof, a land surface, or a rock catchment are examples of reasonably clean surfaces where rainwater collection technology is employed to collect and store rain for later use. The water is typically routed to recharge groundwater or stored in a rainwater tank. Another part of rainwater harvesting is infiltration, which is crucial for the management of stormwater runoff and replenishment of groundwater levels. In dry and semi-arid regions, rainwater gathering has been performed for over 4,000 years to provide residential water, drinking water, water for cattle, and irrigation. Today, rainwater harvesting has grown significantly in importance as an easy-to-use and cutting-edge technology. Though, rain water harvesting is vital for sustainable water resources development of 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],[9]. Rooftop rainwater harvesting has enhanced the groundwater recharge and improved quality of groundwater [10].

There are two major categories into which the process of collecting rainwater from rainfall events can be divided: roof-based and land-based. When runoff from land surfaces is gathered

ISBN-978-81-19905-39-3

in furrow dikes, ponds, tanks, and reservoirs, this is known as land-based rainwater harvesting. When rainwater runoff from roof surfaces is collected, it usually results in a considerably cleaner source of water that can also be used for drinking. This practice is known as "roof-based rainwater harvesting. Rainfall harvesting from highways, parking lots, and rooftops can enhance water availability for various domestic needs and assist to alleviate the country's persistent water shortages since most rural and urban areas in Jordan lack run-off sewer systems [11]. It is found that rainwater harvesting performs economically and in terms of saving water and energy in Pakistan's four major cities, Islamabad, Lahore, Peshawar, and Khanpur [12]. To increase system performance and the stability of the water supply, a rainwater harvesting (RWH) system must be properly designed and evaluated [13]. The study also showed that the selection of sloping smooth roofs implies a global rainwater harvesting potential greater than flat rough roofs by 50% [14]. The quality of harvested rain water on the basis of different roof materials used and to find the lichens/mosses on the roofing surface. Galvanized steel relatively have high water quality probably due to ultraviolet light and high [15]. Sustainability of roof captured rainwater for possible potable water production was investigated and with a goal to develop a cost-effective, long- term solution for rural communities' drinking water supply [16]. Rainwater harvesting's technical viability for Seven Iranian cities was studied and found that the rainwater harvesting has reduced the domestic portion of the demand for potable water by 15% to 30%, the average annual rainfall ranges from 523 to 1720 mm, and the potable water demand in the residential sector is from 152 to 242 litres per person per day [17]. It is found that on long-term environmental and potential effects of rooftop rainwater harvesting combined with shallow well infiltration, which is a less expensive solution that could help to ease water shortage problems [18].

From the literature, it is concluded that sloping roofs such as clay tiles, metal sheets and plastic sheets can be used for better quality. The different roof materials are used to quality of harvested rain water. It was found that galvanized steel will relatively have high water quality. It was concluded that composite asphalt shingle and metal roof were the most common roofing materials used for harvesting. When combining 50% traditional flat roofs and 50% extensive green roofs. It was concluded that combined solution can be feasible depending on the variability of rainfall. Use of rain water or toilet flushing reduces the amount of ground water recharge.

ISBN-978-81-19905-39-3

2. Materials and Methods

2.1 Location of the building

Mangalore is situated in the Dakshina Kannada district and the building is located at 12° 48' 30.9636" N and 74° 55' 54.9048" E and at an altitude of 219.00 metres above mean sea level. The satellite image of the building is as shown in Figure 1. The front view of the building is as shown in Figure 2.

Figure 1: Satellite image of Dr. P. A. Ibrahim Haji Memorial Physiotherapy Centre located in PAET campus Mangalore

Figure 2: Dr. P.A. Ibrahim Haji Memorial Physiotherapy Centre, Nadupadavu, Mangalore, D.K. District

P. A. Educational Trust established in the year 2000 and started many educational institutions in the PACE knowledge city Nadupadavu, 20 km from Mangalore city. Groundwater is the source of water for all uses of the campus. The excessive withdrawal of water caused scarcity of water during the months of March to June. To alleviate the problem a rainwater harvesting system was undertaken during the year 2016 to recharge the bore wells. However, still the scarcity of water persist. So, in the present work an attempt is made to design a rooftop

ISBN-978-81-19905-39-3

rainwater harvesting of Dr. P.A. Ibrahim Haji Memorial Physiotherapy Centre to fulfill the needs of the domestic water supply of the center, where the rooftop is already covered with galvolume iron profiled sheet.

2.2 Details of study area.

Mangalore, the headquarters of the Dakshina Kannada District of Karnataka, is a place of mixed cultures and lifestyles. People from different communities and neighboring states have moved here for business, jobs, education and many more. The current metro area population of Mangalore in 2024 is 763,000. Mangalore is also on the Smart Cities Mission list and among the 100’s of smart cities to be developed. It is now, both, Dakshina Kannada district’s largest city and administrative headquarters. The average ambient temperature remains 25.9°C, varies from 20.8°C to 32.6°C. The average relative humidity remains around 83%, varies from 33.8% to 98.5%. The average wind speed in Mangalore is 3 m/s with the maximum wind speed of around 9 m/s. Tropical weather prevails in Mangalore from June to September, when rainfall is heavy. The average annual rainfall for Mangalore is 3267 mm and the details of monthly distribution of rainfall is as shown in Table No. 1. The same data is used in the design of rooftop water harvesting of the present building located in the P. A. Education Trust, Mangalore campus.

Table 1. Average Annual Rainfall data

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Annual Rainfall (mm)	0	2.54	7.62	27.94	185.42	853.44	955.04	673.1	309.88	175.26	68.58	7.62

3. RESULTS AND DISCUSSIONS

3.1 Calculation of total rainfall.

It is observed from rainfall data that the runoff producing rainfall occurs between the months May to October. Hence the total rainfall is calculated between these months is used in calculation of total rainfall, as given below:

ISBN-978-81-19905-39-3

Total rainfall =185.4+853.44+955.04+673.1+309.88+175.26

Total rainfall = 3152.12 mm (Approximately 3000 mm)

3.2 Roof area calculation

The existing roof area covered with inclined/sloped G. I. sheets is used in the calculation. The details of the roof dimensions are given in the Figure 3.

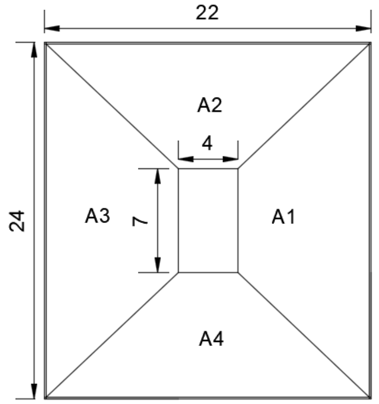

Figure 3: Dimensions of rooftop area covered with G.I sheets

Area of the catchment (Rooftop) = 22*24=528 m^2.

3.3 Volume of rainwater calculated from rooftop area

Volume of water available from rooftop area is calculated using area of rooftop, average rainfall and runoff coefficient

Volume V=area of the catchment x average annual rainfall calculated x runoff coefficient.

Area of the Catchment = 22*24 = 528 m2

Average annual rainfall = 3000 mm

Runoff coefficient (k) = as per recommendations of IS 15797:2008 for inclined rook k= 0.85 is taken.

Volume of water available from rooftop water harvesting.

Va= area of the catchment x average rainfall calculated x runoff coefficient

= 528 * 3000 * 0.85

ISBN-978-81-19905-39-3

= 13, 46, 400 litres.

3.4. Volume of storage required (Vs)

The volume of storage tank can be determined using the following formula recommended by IS 15797:2008

Vs= T x N x Q

Where

Vs= volume of tank in litre

T = length of dry day season days= 200

N = number of people using the tank and= 80

Q= Consumption in litres per capita per day= 20

Vs= 200 x 80 x 20

Vs= 3,20,000 Litres

3.5. Storage tank requirements

It is proposed to provide reinforced cement concrete underground water tanks to store the water. The size of each tanks and total number of tanks are calculated based on total demand/volume of water. The details of calculations are as given below.

Volume required = 3,20,000 Litres

Provide tank of 6m x 4m x 3.5m

Assume free board = 150 mm or 0.15 m

Therefore, Water depth = 3.5 – 0.15 = 3.35

Volume (Provided) = 6 x 4 x 3.35 = 80.40 m^3 = 80,400 litres= Say 80000 litres

Number of tanks = 3,20,000 /80000= 4

The reinforced cement concrete (R.C.C) water tanks and the tanks are designed as per limit state design of R.C.C structures. The details of the storage tank is shown Figure 4. The storage tank to be provided 3.0 m below ground level with 0.35 m projected above the ground level.

ISBN-978-81-19905-39-3

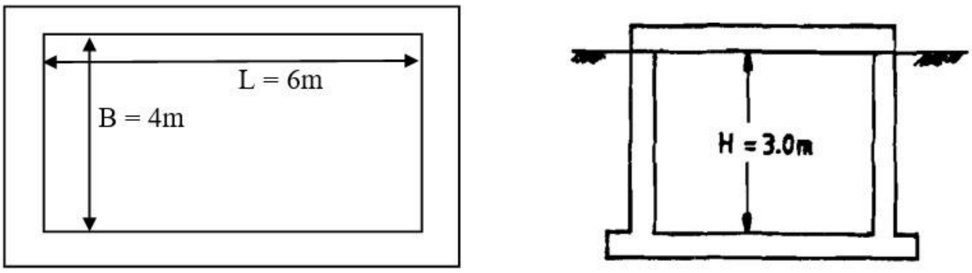

Figure 4: Details of the storage water tank

3.6 Design of Gutters and Pipes

A channel that encircles the edge of a sloping roof and is used to collect and convey rainwater to a storage tank is referred to as a gutter. Gutters can be semi-circular or rectangular in shape, and they are typically made of PVC or galvanised iron sheet. The efficiency of a gutter is greatly impacted by the size, width, and location of those elements in relation to the edge of the roof and the slope of that edge. Consequently, care was taken in selecting this parameter. So, building a gutter with enormous dimensions is essential if you want to gather the most water possible. The value of the water collected from it, however, is far greater than the cost of building the gutter, so it is cost-effective to create huge gutters with suitable dimensions. The gutter width was reduced to account for the throwing wind and pulsating effects. In the present work the diameter 125 mm for the gutters and 210 mm width of GI sheet and down pipe of diameter 90 mm are selected as per the IS 15797:2008 (Table 3) based on area of rooftop and rainfall intensity.

3.7 Filtration unit

When rainwater is harvested in a large rooftop area, the filtering system should accommodate the excess flow. A system is designed with three concentric circular chambers in which the outer chamber is filled with sand, the middle one with coarse aggregate and the inner-most layer with pebbles. This way the area of filtration is increased for sand, in relation to coarse aggregate and pebbles. Rainwater reaches the centre core and is collected in the sump where it is treated with few tablets of chlorine and is made ready for consumption.

3.8 First flush system

The roof of a structure or another collection area will gather debris, dirt, dust and animal droppings. This undesired material would be swept into the tank with the first rains. The water will become contaminated as a result, lowering its quality. Because of this, many RWH systems

ISBN-978-81-19905-39-3

include a mechanism for directing this "first flush" water away from the tank. First flush devices are the name given to these systems. The most basic concepts rely on a manually operated system in which the intake pipe is physically moved away from the tank inlet and then replaced once the initial first flush has been redirected. This approach has apparent disadvantages in that someone must be there who will remember to relocate the object.

3.9 Infiltration Pits:

Infiltration pits are provided to allow the excess water flowing out of the storage tank to flow down and improvement of groundwater recharge. Five infiltration fits each of size 3 m x 2 m x 1.5 m are recommended for the at the downstream of water tanks

3.10 Abstract of Estimated Cost of the Project

The details abstract of estimated cost is shown in Table 2.

Table 2: Abstract of Cost of Estimation

SL NO	PARTICULARS	QUANTITY	UNIT	RATE PER UNIT	TOTAL AMOUNT (Rs.)
1	**Materials**				
i	90 mm 4 kg/cm2 PVC Downpipe	110	m	Rs. 350/metre	38500
ii	Bend Pipe	16	No.	Rs. 100 /piece	1600
iii	T pipe	16	No.	Rs. 130 /piece	2080
iv	Valves	16	No.	Rs. 150 /piece	2400
v	Gutter pipe	100	m	Rs. 210 /metre	21000
vi	Filtration Tank	1	No.	Rs. 38000/-	38000
vii	First Flush Tank	1	No.	Rs. 8500/-	8500
viii	Concrete M30	240.00	m^3	Rs.8000/m3	1920000
2	**Excavation**	10	Hours	Rs. 1000/hour	10000
3	**Infiltration Pit**	5	Nos	Rs. 5000/unit	20000
4	**Transportation, Labour & Miscellaneous**				35000
TOTAL					**Rs. 20,99, 080** **Say Rs. 21,000,00**

ISBN-978-81-19905-39-3

4. CONCLUSION

- The average rainfall of Mangalore region is about 3000 mm and the quantity of roof water from the roof area of 528 m^2 is quantified as 13, 46,400 litres.
- Total water requirements of the inhabitants of the building is estimated as 3,20,000 litres. Four R.C.C. underground tanks are designed each 80,000 litres capacity.
- A provision is made for filtration of rooftop harvested before collection in the storage tank.
- The total estimated cost of the project is Rs. 21,00,000 (Rupees twenty one lakhs only). In long run of the project it is very economical.
- This project will cater the needs of the Dr. P.A. Ibrahim Haji Memorial Physiotherapy Centre to overcome the water scarcity.

Also in the present scenario of water scarcity this project not only fulfil the water scarcity but also brings sustainability in various aspects in rural as well as in urban areas.

References

[1] Gireesh Kumar Pala, Abhirami Priyanka Pathivada, Sasi Jyothishma Himaja Velugoti, Chandrika Yerramsetti, Shalini Veeranki (2020)"Rainwater harvesting - A review on conservation,creation & cost-effectiveness". Journal: Materials Today: Proceedings. Materials Today: Proceedings 45 (2021) 6567-6571.

[2] J M. W. Kimani, A. N. Gitau and D. Ndunge, “Rainwater Harvesting Technologies in Makueni County, Kenya”,Research Inventy: International Journal of Engineering and Science, vol.5, issue 2, Feb 2015, pp 39-49, ISSN (e): 2278-4721, ISSN (p):2319-6483.

[3] E. Hajani and A. Rahman, “Reliability and Cost Analysis of a Rainwater Harvesting System in Peri-Urban Regions of Greater Sydney, Australia”, Water, vol.6, Apr 2014, pp.945-960, doi:10.3390/w6040945, ISSN 2073-4441.

[4] J. Hammerstromand T. Younos, “Single-family home rainwater-harvesting system demonstration project for stormwater-runoff control and utility-water saving”, The Cabell Brand Center Special Report No. 100-2014.

ISBN-978-81-19905-39-3

[5] S.S. Mishra, "Rainfall Analysis and Design of Water Harvesting Structure in Water Scarce Himalayan Hilly Regions", International Journal of Civil and Structural Engineering, vol. 5, issue 1, August 2014, pp. 29-41. International Journal of Recent Technology and Engineering (IJRTE) ISSN: 2277-3878, Volume-8 Issue-5, January 2020 3595 Published By: Blue Eyes Intelligence Engineering & Sciences Publication Retrieval Number: E6519018520/2020©BEIESP DOI:10.35940/ijrte.E6519.018520 Journal Website: www.ijrte.org

[6] S. Jain, P. Thakur, S. Singh, M. Srivastava, "Design of Rooftop Rainwater Harvesting Tank for Katpadi Region, Tamil Nadu", SSRG International Journal of Civil Engineering (SSRG-IJCE), vol. 2, issue 7, Jul 2015, pp. 6-8, ISSN: 2348 – 8352.

[7] R. Ganguly, A. Bansal, M.Mishra and A. Kumar, "Application of Rainwater Harvesting Scheme in Shimla Region", Hydrology: Current Research, vol. 5, issue 3, Sep 2014, ISSN: 2157-7587 HYCR. Available:http://dx.doi.org/10.4172/2157-7587.100018.

[8] U. R. Patel, V. A. Patel, M. I. Balya, H. M. Rajgor,"Rooftop rainwater harvesting (rrwh) at spsv campus, Visnagar: Gujarat - a case study", International Journal of Research in Engineering and Technology, vol. 3, issue 4, Apr 2014, pp.821-825, eISSN: 2319-1163, pISSN: 2321-7308.

[9] E. Awuah, S.F. Gyasi, H. M. K. Anipa and K. E. Sekyiamah, "Assessment of rainwater harvesting as a supplement to domestic water supply: Case study in Kotei-Ghana", International research journal of public and Environmental health, vol. 1, issue 6, Aug 2014, pp.126-131, ISSN 2360-8803.

[10] G. K. Viswanadh (2014) "Rooftop Rainwater Harvesting Structures Design at JNTUH Hyderabad Campus" International Journal of Creative Research Thoughts (IJCRT)| Volume 2, Issue 3 August 2014 | ISSN: 2320-2882.

[11] Fayez A. Abdulla, A. W. Al-Shareef (2008) "Roof rainwater harvesting systems for household water supply in Jordan". JOURNAL: ScienceDirect. Desalination 243 (2009) 195-207.

ISBN-978-81-19905-39-3

[12] Shahbaz Ali, Yan-Fang Sang (2022) " Implementing rainwater harvesting systems as a novel approach for saving water and energy in flat urban areas".JOURNAL : Sustainable Cities and Society. Sustainable Cities and Society 89 (2023) 104304.

[13] A.S. Mun, M.Y. Han (2011) " Design and operational parameters of a rooftop rainwater harvesting system: Definition, sensitivity and verification". JOURNAL: Journal of Environmental Management. Journal of Environmental Management 93 (2012) 147-153. James P. Gibb, et al (1994): He researched on Effective porosity of geological materials. ISWS Contract Report 351.

[14] \Ramon Farreny,Tito Morales-Pinzón, Albert Guisasola, Carlota Tayà, Joan Rieradevall, Xavier Gabarrell (2010) "Roof selection for rainwater harvesting: Quantity and quality assessments in Spain" JOURNAL : SCIENCE DIRECT. Water Research 45 (2011) 3245-3254.

[15] Ju Young Lee, Gippeum Bak , Mooyoung Han (2011) "Quality of roof-harvested rainwater Comparison of different roofing materials" JOURNAL: Environmental Pollution. Environmental Pollution 162 (2012) 422-429.

[16] Mohammad A. Alim, Ataur Rahman, Zhong Tao, Bijan Samali, Muhammad M (2019) Suitability of Roof Harvested Rainwater for Potential Potable Water Production" JOURNAL: Pre-proof S0959-6526(2019)34096.

[17] Narges Jalili Kolavani, Nasrin Jalili Kolavani (2019) "Technical feasibility analysis of rainwater harvesting system implementation for domestic use". JOURNAL: Sustainable Cities and Society. Sustainable Cities and Society 62 (2020) 102340.

[18] Zsóka Szabó, Daniele Pedretti, Marco Masetti, Tibor Ridavits, Endre Csiszár György Falus, László Palcsu, Judit Mádl-Szönyi (2022) " Rooftop rainwater harvesting by a shallow well-Impacts and potential from a field experiment in the Danube-Tisza Interfluve, Hungary". JOURNAL: Groundwater for Sustainable Development. Groundwater for Sustainable Development 20 (2023) 100884.

ISBN-978-81-19905-39-3