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Design and Estimation of Roof top Rainwater Harvesting System for Rajiv Gandhi University of Knowledge Technologies (RGUKT), Andhra Pradesh, Srikakulam Campus

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ABSTRACT
Scarcity of water is one of the major global issues now days in most of the countries like India in non-monsoon season. The national water mission has initiated a campaign "Catch the Rain" with an objective to conserve water, minimize the wastage and ensure more equitable distribution both across and within the states. University Grants commission (UGC) has also requested to all the universities and institutions to take up appropriate Rain water Harvesting Structures (RWHS) in their establishments. Especially in residential educational institutions the usage and wastage of water by the student population is much high in hot climatic seasons. As the ground water is the only source of the water supply, it is very essential to implement water conservation techniques in the University campus. The objective of this study is to design a rooftop rainwater harvesting structure for Rajiv Gandhi University of Knowledge Technologies, located in Srikakulam district, Andhra Pradesh state of India. All the existing hostel blocks, dining halls and class room blocks were selected as catchment areas for harvesting of rainwater. Accordingly, the total demand for the university campus will be calculated and rainwater harvesting system could be provided for 13% of the total demand. The harvested rainwater could also potentially be used for gardening, construction work, development of landscaping and also in artificial recharge of ground water over the 200 acres university land.
Keywords - Roof top-Rain water harvesting structures-Water demand-RGUKT- AP-Residential University Campus-Artificial recharge of ground water table.

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I. Introduction

Unavailability of sufficient quantity of water in the rural and urban areas of the country due to over-exploitation of natural resources is becoming a one of the hindrances for the developing countries like India. The need for water is felt more and more for better living in modern times. The water demand has increased from few liters in the Stone Age to as much as 600 liters in developing countries. Only 10% of surface water and 90% of ground water are being used for drinking purposes. Only 12% of rain water is being used in the country. The rest flows into sea. The World Bank estimates that by the year 2025, 3.25 billion people in 52 countries will live in the conditions of water shortage. The issue of high scarcity of water is a global issue now and those countries whose primary revenue sector depends upon the proper distribution of uninterrupted water supply get standstill when their natural water sources dry out. Rainwater harvesting is the most promising solution for almost every country in the world. Rain water harvesting system is practically used from prehistoric period. This is a simple and viable technology.

II. Role of Indian Government in support of Rainwater Harvesting

RWH in India goes back to first century when conventional techniques for harvesting water in big rocks or manmade structures were in practice. Because of the change in climatic conditions in light

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of human mediation with characteristic assets, the current development in India is confronting a shortage of consumable drinking water and nature of water for water system purposes. The ordinary yearly precipitation in the nation is assessed to be 400 million hectare-meters of water (Mha-m). Out of this, 115 Mha-m enters surface streams, 215 Mha-m enters the ground, and 70 Mha-m is lost because of vanishing. This implies, just 25 Mha-m could at last be utilized through surface water system (6% of all water accessible through the downpour). This is a low figure for a nation whose income relies significantly upon horticulture.

To take this issue on the public level, the Administration of India partook in actualizing different water gathering procedures. This was finished by comprising focal specialists, laying some legitimate standards and strategies, spreading mindfulness with different state and town level projects and financing non-government associations to manage water collecting exercises at nearby levels.

1. Study Area

RGUKT Srikakulam, a constituent institute of Rajiv Gandhi University of Knowledge Technologies-AP, was established in 2016 by the Government of Andhra Pradesh. In the Year of 2017, Government of Andhra Pradesh allotted 200 acres of land for campus establishment. RGUKT campus is located in Srikakulam District of Andhra Pradesh. Lying within the geographic coordinates of 18º-20’ and 19º-10’ N and 83º-50’ and 84º-50’ E, the district is blessed with an average annual rainfall of 1154.6 mm. Large roof area is available in the existing hostel and academic and Hostel buildings in the campus to tap the rain water for augmenting the ground water resources.

As the campus is located in the hillock area, the available open area is maximum slope ground surfaces area. Hence it will be more advantageous to collect the rain water from the roof top catchment area. The main objective of this research is to install the roof top rain water harvesting system in the campus by utilizing the existing slope elevation ground levels to harvest, store and re use for drinking, domestic purposes, construction activities, gardening etc., in the campus. The excess water from rain water storage sumps can be utilized for the recharge of ground water through pits and shafts.

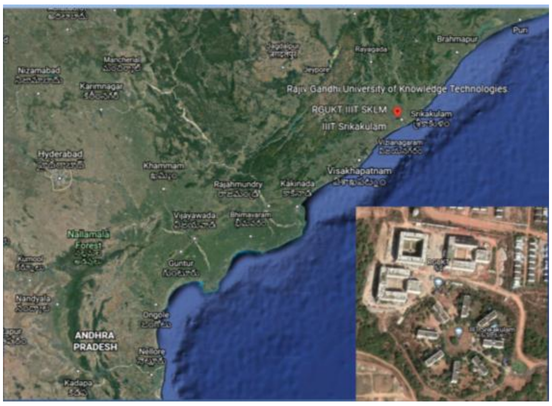

Fig. 1 Study Area- RGUKT IIIT, Srikakulam

2. Advantages of Rooftop Rainwater Harvesting System

Rooftop Rain Water Harvesting is the technique through which rain water is captured from the roof catchments and stored in reservoirs. Harvested rain water can be stored in sub-surface ground water reservoir by adopting artificial recharge techniques to meet the household needs through storage in tanks.

The following are the advantages with installing roof top rain water harvesting system:

- Gives independence to your water supply.
- Gives excellent water, delicate and low in minerals.
- Decreases the expense for siphoning of ground water.
- Improves the quality of ground water through dilution when recharged to ground water.
- Reduces soil erosion in urban areas.
- The rooftop rain water harvesting is less expensive.
- Rooftop rain water harvesting systems are easy to construct, operate and maintain.
- In hilly terrains, rain water harvesting is preferred.

III. Methodology

Here are the fundamental steps for appropriately estimating the capacity tank of a water harvesting system.

1. Determine how much water is accessible for collecting.

2. Estimate the application's water demand over a similar period. On the off chance that conceivable, decide the monthly demand for the application over an entire year.

3. Compare the measure of month-to-month precipitation that can be gathered to the monthly water request throughout the year. Is there by and large enough precipitation to gracefully a critical segment of the application's interest?

4. Determine optimum storage tank size that gives enough volume to store sufficient precipitation to fulfill the need while not over estimating the tank.

Note: If there are large variations in rainfall throughout the year, a larger tank may be necessary to store rainwater during wet months for use during drier months. Additional treatment may be necessary to maintain water quality. Also, it might be worthwhile to contrast week after week precipitation with week-by-week request to get a more exact image of the accessibility of precipitation to meet the water prerequisites of the application.

IV. Data

Rain fall data: The average rainfall at this location varies between 4.4 mm in the driest month (December) and 216.5 mm in the wettest month (October). The total annual rainfall in an average year is 987 mm.

Table1: Catchment Details

S No	Name of the block	Area in m^2	Roof type	Run off coefficient
1	Block-1	405.5	Tiles	0.8
2	Block-2	405.5	Tiles	0.8
3	Block-3	405.5	Tiles	0.8
4	Block-4	405.5	Tiles	0.8
5	Block-5	405.5	Tiles	0.8
6	Block-6	405.5	Tiles	0.8
7	Block-7	405.5	Tiles	0.8
8	Block-8	405.5	Tiles	0.8
9	Tutorial block	1246	Tiles	0.8
10	Boy's hostel	1718	Tiles	0.8
11	Girl's hostel	1718	Tiles	0.8
12	Boy's dining hall	525	Tiles	0.8
13	Girl's dining hall	525	Tiles	0.8
14	Dining hall-1	366	Corrugated metal sheets	0.8
		Total= 9342		

The runoff coefficients for the roof type were looked up from Table No.2 of the 'Rainwater Harvesting and Conservation Manual' published by the Central Public Works Department (CPWD).

V. Data Analysis

5.1 Total Harvestable Rainfall:

Maximum volume of rainfall that can be harvested from the available rooftop area:
Area of rooftop = 8910 m^2
Average Annual Rainfall = 1154.6 mm = 1.11546 m
Runoff coefficient for catchment surface = 0.8
Coefficient for evaporation losses, spillage, first flush, etc. = 0.8 (Para 2.9 CPWD Manual)
Harvestable rainfall on an average year = 9342 m^2 * 1.11546 m * 0.8 * 0.8 = 6669.2 m^3

5.2

5.3 Water demand:

Total number of students = 2000
Water demand = 19 lpcd (Exclusively for cleaning of the mess and miscellaneous washing)
Total annual water requirement = 2000*19*365 = 13870 m^3
Water requirement being met by RWH = (6360.799/13140) *100 = 46% (approximately)

5.4 **Optimum Dimensions of Sedimentation Tank**:

Criteria for Volume Determination:
Detention period for plain sedimentation must be a minimum of 3 hours
Velocity of flow should not greater than 30cm/min (Horizontal flow)

Tank dimensions =L: B= (3 to 5):1 (For Rectangular)
Slope for rectangular= 1% towards inlet
Data Available:
Mean rainfall for August month (peak month) =207.5mm =0.2075m (per month)
Rainfall intensity per day = (0.2075/30)
= 0.0069 m/day
Rainfall intensity is rounded off to 0.01m/day (Assuming the rain is concentrated in 1 hour) = 0.01 m/hour
Total catchment area=8910 m^2
Surface runoff calculation is given by:

$$Q = C \times I \times A$$

Where,
Q = peak flow (m^3/s); C = runoff coefficient (unit less); I = rainfall intensity (mm/hr); A = catchment area (m^2)
Q = 57.024 m^3/hr
Volume = Flow x Detention period =57.024m^3/hours x 3 hours =171.072 m^3
Assigning depth of tank =3 m
Area of tank = 171.072 m^3/3 m = 57.024 m^2
L/B=3 (Assumed from the minimum required ratio for L:B for sedimentation tanks)→ L=3B
Depth (H) = 3m, Length (L) = 13.1m, Breadth (B) = 4.4m.
The storage tank's dimensions are determined by the Rapid Depletion Method here. We assume that the rainwater being collected are deleted shortly after being stored in this method. We thus don't have to build huge storage structures but a tank of nominal dimensions would suffice. The two months that receive the highest rainfall, August and September were considered in the calculation as they receive the highest rainfall.
Average rainfall in August and September = 207.5 + 196.2 mm = 403.7 mm
Harvestable rainfall in August and September = 403.7mm *9342² * 0.8 * 0.8 = 2413.67 m³
Water requirement in two months = 19 l.p.c.d * 2000 students * 60 days= 2160 m³
Optimum Tank Volume = Harvestable Rainwater – Consumption
= 2413.67 – 2280 = 133.67 ≈ 150 m³
Therefore, a tank of **150** m³capacity would serve the rain water harvesting purpose well all year round.
The height of the tank was fixed to be 4m.
Area of tank = 150m³/4m = 37.5 m²
Assigning L = 9.5 m and B = 4.5, we get total volume of tank = **171**m³
For practical reasons, it would be wise to have a storage unit of around **150 m³** with facility for excess water being directed to a recharge pit.

VI. Design of Individual components of RWH System:

6.1 Sedimentation tank:

Height of tank= 4m
Area of base = $\frac{150}{4}$ = 37.5 m^2
Saturated unit weight of soil = 22 Kn/m3
M30concrete, HYSD bar (Fe 415)
Unit weight of water, γ_w = 10 KN/m
Volume required =**150 m^3**
So, we provide tank of 9.5 x 4.5 x 4 m
Consider free board = 0.1m
Water depth = 4-0.1 = 3.9 m
Volume provided = 9.5x 4.5 x 3.9 **=166.72m^3**
Taking subsoil consists of sand, angle of repose = 35^0
There are four components of design: -

1. Design of long wall
2. Design of short wall
3. Design of roof slab
4. Design of base slab

A) General Considerations

Design of wall be done under two conditions: -
a) Tank full with water, with no earth fill outside
b) Tank empty with water, with full earth pressure due to saturated earth fill.
The base slab will be designed for uplift pressure and the whole tank is to be tested against floatation.
Taking size of the base of tank =9.5×4.5m
$\frac{L}{B} = \frac{9.5}{4.5}$ =2.11 >2
h = $\frac{H}{4} = \frac{4}{4}$=1
Hence long wall be designed as a cantilever.
Bottom H/4 =4/4 = 1m of the walls will be designed as cantilever, while the top portion will be design as slab supported by other walls.

B) Design Constants:

For M 30 concrete, $\sigma_{cbc=}$ 10 N/mm^2 σ_{st} = 130 N/mm^2
modular ratio (m) = $\frac{280}{3\sigma cbc} = \frac{280}{3\times10}$ = 9.33
k = $\frac{m\sigma_{cbc}}{m\sigma_{cbc} + \sigma_{st}} = \frac{9.33 \times 10}{(9.33\times10)+130}$ = 0.418

$j = 1 - \frac{k}{3} = 1 - \frac{0.418}{3} = 0.861$

$Q = \frac{1}{2} \times \sigma_{cbc} \times k \times j = 1.80$

The working stress method in conformation to the IS Code 3370 was used for the design of all four components of the storage tank. The details of the tank are summarized below.

Table 2: Summary of Design of Storage Tank

COMPONENT	**THICKNESS (mm)**	**INNER REINFORCEMENT**		**OUTER REINFORCEMENT**	
		Main	**Distribution**	**Main**	**Distribution**
Long wall	320 with 40mm clear cover	20 mm Ø bars at 90 mm c/c	10 mm Ø bars @ 210 mm c/c	30 mm Ø bars at 150 mm c/c	10 mm Ø bars @ 210 mm c/c
Short wall	320 with 40mm clear cover	16mm Φ @ 100mm c/c	25mm Φ @ 90mm c/c	16mm Φ @ 100 mm c/c	25mm Φ @ 90mm c/c
Top slab	160 with 40mm clear cover	16mm Φ bars with 130 mm c/c	10mm Φ bars with 160 mm	16mm Φ bars with 130 mm c/c	10mm Φ bars with 160 mm
Base slab	310 with 50mm clear cover	24mm Φ bars with 110 mm c/c	8 mm Φ bar at 120 mm c/c	24mm Φ bars with 110 mm c/c	8 mm Φ bar at 120 mm c/c

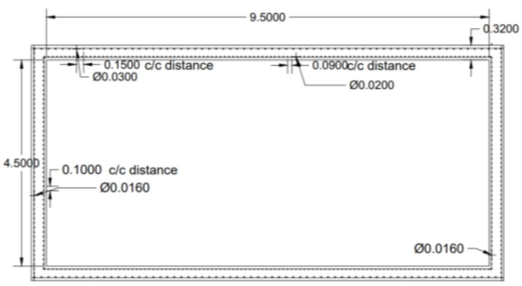

Fig. 2 Sectional Top View of Storage Tank

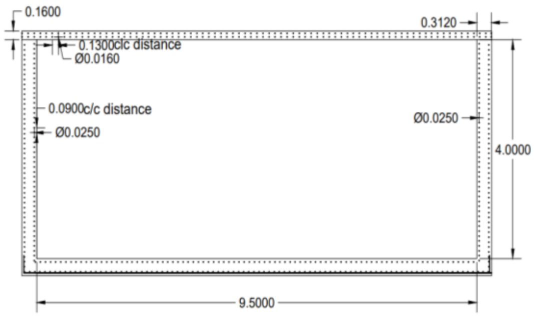

Fig. 3 Sectional Front View of Storage Tank

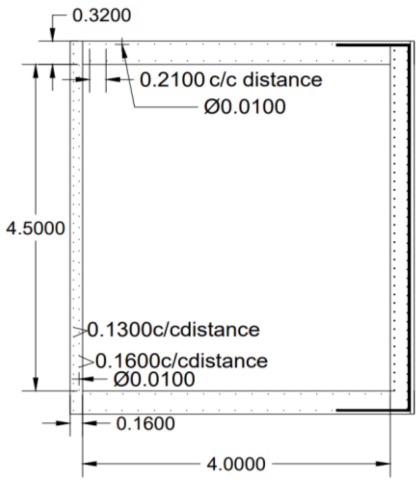

Fig. 4 Sectional Side View of Storage Tank

6.2 Design of Filtration Unit:

In the context of the RGUKT Srikakulam Campus, we are not using rainwater for drinking purposes. So, filters like microscopic filters, disinfection filters, and carbon filters etc. do not need not be used.

Sand Gravel Filter: These are commonly used filters, constructed by brick masonry and filleted by pebbles, gravel, and sand. Each layer should be separated by wire mesh.

In a simple sand filter that can be constructed domestically, the top layer comprises coarse sand followed by a 5-10 cm layer of gravel followed by another 5-25 cm layer of gravel and boulders. This filter is to be installed before the storage tank and after the sedimentation tank.

An area of 1m * 1m of filter media is recommended for current project.

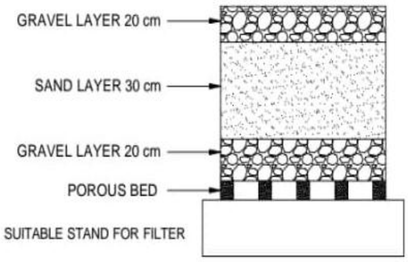

Fig. 5 Sectional View of Filter Unit

6.3 Design of Pipe:

For the expected flow from rainfall, PVC pipes of 100mm diameter are recommended to be used for all connections between catchments and RWH components, with the exception of any special circumstances where a deviation in the size of the pipe is admissible.

The minimum required gradient of the pipe is calculated using the Manning's formula, while trying to ensure that the minimum self-cleansing velocity is maintained. This needs special attention as the rainwater is bound to have leaves, twigs and other medium sized particles that might clog the pipes and screens in the rainwater harvesting system, drastically affecting its efficiency.

Calculation of the Size of the Pipes:

Let us assume that the initial velocity of Rainwater entering the R.W.P. to be 0.10 m/sec.

The water flowing under the influence of gravity will have an acceleration of 9.81m²/sec.

We know that $V^2 = U^2 + 2aS$

Substituting all the values in above equation, we get V=18.60 m/sec.

The Discharge pipe has to be designed for the worst condition as it has to carry all the discharge of building collected from even starting of collection.

The discharge **Q** of the Building = 0.004846 m^3/sec.

The velocity of water= 18.60 m/sec.

We know that Q= π/4×d2×V

Substituting known values, d = 18.21 mm which is not available in standard sizes.

We will therefore provide Discharge pipes of 110 mm diameter.

We will provide P.V.C. pipes of 110 mm diameter for both discharge as well as for R.W.P. Both of them will be connected by the "T" joints and Discharge pipes will be provide "S" joints at required corners.

Calculation of the Gradient of the Pipes:

Diameter of pipe = 0.11 m

Minimum self-clearing velocity = 0.75 m/sec (Recommended minimum velocity for stormwater)

Manning's Equation $V = (1/n) * R^{2/3} * S_o^{1/2}$

Where,

N= Manning's coefficient

R= Hydraulic radius = Area/Perimeter

S_o= Slope or gradient

V = Velocity

The value of 'n', manning's coefficient for PVC pipes is between 0.009 and 0.011. Let us assume the manning's coefficient to be 0.01.

Assuming circular pipe to be running half full,

Radius, r = D/2 = 0.11/2 = 0.055 m

Hydraulic Radius = $\frac{\pi * 0.055^2}{2 * \pi * 0.055}$ = 0.0275 m

Substituting velocity, manning's coefficient and hydraulic radius in Manning's equation to get minimum gradient:

$V = (1/n) * R^{2/3} * S_o^{1/2}$

$S_o = 0.007766 = \frac{1}{147}$

The range of gradient for water carrying pipes lies between (1/40) to (1/110).

Therefore, a minimum gradient of **1 in 110** is recommended for adequate self-cleansing velocity to be achieved in the pipes.

6.4 Location of Tanks

The location of the tank is to be determined with caution as it has a direct impact on the efficiency of the entire rainwater harvesting system. The obvious choice for the location of the sedimentation and storage tank would be a low lying area so that the rainwater collected in the roofs could reach the storage unit by gravity, thus minimizing the operating cost of the system. The storage unit also shouldn't be too far from the catchment area as it would lead to longer pipe lengths, increasing chances of contamination and leaks.

With these in consideration, we have decided to recommend the open area between Blocks 1 and 2 of the campus as the best location for the sedimentation and storage tank as the location is relatively close to the catchment area and in proximity of the mess.

Fig. 6 Location of Tanks

9.Abstract Estimate The following table presents the abstract cost estimate for the sedimentation and storage units of the rooftop rainwater harvesting systems with respect to the rates in the SOR of the corresponding year. The approximate lengths of the pipes were calculated from the Master Plan AutoCAD drawing of the campus.

Table 1 Abstract Estimate

S.no	Particulars	Quantity	Rates	Cost (Rs)
1	Earth work in excavation	240.8 m^3	130 Rs/m^3	31,304
2	Lean/PCC (1:3:6)	7.72 + 9.94 m^3	3600 Rs/ m^3	63,576
4	1^{st} class brick work in 1:4 cement mortar	37.48m^3 + 25.9m^3	3000 Rs/ m^3	1,90,140
5	R.C.C work for slab	40.5 m^3	9100 Rs/ m^3	3,68,550
6	12mm plastering inside with 1:2 cement mortar Long wall Short wall	112m^2 + 105 m^2	350 Rs/m^2	75,950
7	Steel	3815.1 kg	61000 Rs/ton	2,30,422
8	PVC Pipe (110 mm)	2560 meters	243 Rs/Rm	6,22,080
			Total	**15,82,022**
9	Contingency + work charges establishment	(3% + 2 % = 5 %)	---------	79101.1
10	Contractor profit	10%	---------	158202.2
		GRAND TOTAL		**18,19,326 ≈ 18.2 Lakhs**

VII. Conclusion:

This paper dealt with all aspect of improving the water sustainability in the RGUKT Srikakulam campus by implementing ancient old technique of Rainwater Harvesting (RWH). Two alternatives have been suggested for tank design, which take separate approaches towards the consumption of harvested rainwater. The calculated results are given clearly in the Chapter 4. We can draw out a conclusion that a huge amount of water got collected from the rooftop surfaces of all the considered buildings. Our campus has a huge harvesting potential, and if installed properly, it would yield very good results. This reservoir will have to build for the storage of 150 m^3 of water. This tank has the capacity to accommodate the rainwater collected from the catchments and meet the requirement in the monsoon of every year for about 2000 consumers having a consuming rate of 18 liter/day as calculated by rational depletion method.

It is concluded that RCC tank which is to be constructed should be an underground one, so that upper surface of the tank can be utilized economically for any land purpose such as playground or cycle stands or any such small structure. Cost analysis has been done for both sedimentation and storage tanks. Although the cost might seem a little high, it is to be kept in mind that it is only a one-time investment, and that it will alleviate problems which will be faced by the students and staffs inside the campus if the indiscriminate use of conventional sources of water is continued. The other component of the harvesting systems such as Sedimentation unit, and Filtration mechanism and Infiltration pit have also been reviewed and designed for the hostels and all other building in details.

It was finally concluded that implementation of "ROOF TOP RAINWATER HARVESTING SYSTEM" project in the campus of RGUKT SRIKAKULAM will be the best approach to fight with present scenario of water scarcity in all aspects, whether it is from financial point of view or from optimum utilization of land surface, and also serve as an example to the students and guide the towards a more sustainable future. Water is a limited natural resource which is always in high demand. The RGUKT Srikakulam campus would greatly benefit from a RAINWATER HARVESTING SYSTEM (RWHS), and this thus strongly recommended to be implemented.

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