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DESIGN OF A LOW-COST ROOF TOP RAIN WATER HARVESTING MODULAR SYSTEM

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Abstract*— At the rate in which the India population is increasing, it is said that India will surely replace China from its number 1 position of most densely populated country of the world after 20-30 years. The Urban water demand 3.3 billion in 2007 to 6.4 billion in 2050 (United Nations, 2008). These will lead to high rate of consumption of most valuable natural resource „Water" resulting in augmentation of pressures on the permitted freshwater resources. In order to conserve and meet our daily demand of water requirement, we need to think for alternative cost effective and relatively easier technological methods of conserving water. Rain water harvesting is one of the best methods fulfilling those requirements. The technical aspects of this study are rainwater harvesting collected from rooftop which is considered to be catchment areas at Bearys Institute of Technology Campus. In this study Two Areas are assumed to be consisting of a single residential building and multi-storey (Hostel) building, its serves about 4 and 240 inhabitants. The roof area of the buildings are 81.316 m2 and 772.25 m2. We selected Concrete Bed Roof and Galvanized steel Roof as roof material. In the year 2018 the average Monthly rainfall of 316.391mm respectively, The rainfall data are being taken from the India Meteorological Department, Mangalore. We design and Proposed modular Rain Water Harvesting System for Beary's Institute of Technology. After effectively implementation of proposed system has been tested and analyzed the design efficiency for Economic savings analysis. In all calculations for Runoff estimation, runoff coefficient is used to account for losses due to spillage, leakage, infiltrations catchment surface wetting and evaporation. Water collection efficiency is purely depended on roof material and found Galvanized steel Roof is best roof material for rainwater harvesting Construction cost of Proposed RWH modular system was estimated Rs.5710, Its indicate Low-cost roof top rain water harvesting. The highest Water Collection Efficiency obtained from Galvanized steel Roof 98.5 %. In the both roof top the highest Overflow found 46.26 % and 61.68%, was found in the 2KL and 10KL Tank size in the Area-1 and Area-2. In the Timebased reliability in Area-1 from the Concrete Bed Roof and Galvanized steel Roof was achieved 33.70 % and 36.71%, from the Area-2 the timebased reliability was achieved 7.12 % and 8.49 %.The benefit-cost ratio (BCR) for the 1% and 9% discount the benefit cost ratio was 3.07, 4.15 and 2.77, 3.72 from the Concrete Bed Roof and Galvanized Steel Roof for Area-1.The highest water saving was found from the Galvanized Steel Roof for the both areas around 81 & 2733 m3/ year.

***Index Terms*— Rainwater Harvesting, Timebased Reliability, Overflow, Benefit Cost Ratio**

I. INTRODUCTION

Water is a basic requirement of human which can be sourced from surface water, groundwater, or rainwater [11]. available water supply sources are diminishing resulting in the increased population, climate change, and pollution, which in turn causes a globally acknowledged situation of water scarcity, especially in developing countries [12], [13], [1]. In other words, changing climate has become an environmental threat which may result in additional pressure on hydrological systems and water resources which are already stressed (Kahinda et al., 2010). Demand for urban water is expected to increase drastically all over the world from approximately 3.3 billion in 2007 to 6.4 billion in 2050 (United Nations, 2008). The domestic use of freshwater accounts for approximately 10% of the total global freshwater consumption (Bocanegra-Martínezet al., 2014) [2]. The global population is tripled in 70 years while water use is grown in six-fold. In the next 25 years, one-third of the world's population will experience severe water scarcity, more than 1 billion people may suffer due to lack of access to safe drinking water (UNESCO 2000). Around 70% of our Earth's surface is covered by water, but still this means that the water is abundantly available but then the amount of fresh water available is the issue to be taken care of Around 97.5% of all water on Earth is salt water and remaining only 2.5% is fresh water (Encarta 2004). A large proportion of the world's population does not have access to safe sources of water. WHO/UNICEF has estimated that about 1.1 billion people doesn't have access to "improved drinking-water sources" (WHO/UNICEF 2000).

A. Impacts of Scarcity

Water security is defined as reliable and continuous access to safe drinking water for health, livelihood, and development [9]. The United Nations has estimated that 1.2 billion people do not drink safe water and at least 746 million people still doesn't have access to safe drinking water (World Bank, 2014). Continuous droughts and decreasing groundwater table are leading to water scarcity for agricultural irrigation in rural areas of Beijing. Both the amount of agricultural water consumption and the proportion of agricultural water consumption to total water consumption have decreased about 50% during the last 20 years in Beijing [2]; Wang and Wang, 2005; Webber et al., 2008; Yangand Zehnder, 2001).

Increased flooding in urban areas might result from CC and its impact on urban infrastructure, which will require significant financial resources to address [14], [15]. In Bangladesh, Due to variation in climate, excess groundwater extraction and increasing water stress with the rapid growth of urban population, water supply has become a major issue [17]; Mukherjee and Hyde, 2013). Like many other cities in the developing countries most of the cities in Bangladesh are also facing shortages of portable water due to decrease in groundwater as well as inappropriate water management (Akter and Ahmed, 2015). Water resources are being exploited to a large scale and the trend is increasing, For the year 2050, about 55% of increase in world water demand is expected, generating scarcity and competition among water uses (WWAP, 2015). From 1999 to 2008, the Barcelona area suffered from recurrent droughts which threatened domestic supply on various occasions. In addition to that precipitation deficits, urban and population growth, new urban consumption patterns, pollution of water bodies and inappropriate management of local resources have resulted in current water shortages (Saurí, 2003). Other countries which are having same problems, Spain has traditionally followed the so called “hydraulic paradigm” based on dams and inter-basin transfers to reduce the problem of water scarcity and to ensure the development in economy (Saurí and del Moral, 2001). The impacts of the change in climate are already visible, since the temperature and rainfall variability have increased and intensified all over the world in the last three decades (Hewitson and Crane, 2006; Chung et al., 2011). The scarcity of water resources in Jordan seems to be dictated by climatic conditions such as aridity and abundance of high solar radiation and by population pressure (E. Salameh and H. Bannayan 1993). Flooding in developed areas has so many threats to human wellbeing, these threats include risk to human health and the economic toll associated with loss of property and worker productivity (Moftakhari et al., 2018). Urbanization is a driver of flood risk, whereas features of an undeveloped catchment including floodplains, wetlands, and freely meandering stream channels provide high-flow attenuation to temper the effects of floods (Acreman and Holden, 2013). Domestic rainwater harvesting has potential to reduce hydrologic input at its source, otherwise it would have resulted in efficient delivery of water off impervious rooftops to a stormwater conveyance or directly to a surface stream (Askarizadeh et al., 2015 and 2008).

B. Conservation of Water

It is mandatory in India to have a rainwater harvesting system for a building plan so that the approval from the New Delhi and Chennai local authority is secured [7]. The selection of the size of optimum rainwater tank is a main factor to increase the efficiency of a rainwater harvesting system and also to reduce the payback period (Mun and Han, 2012). (Ward et al. 2012) have also investigated the performance of a rainwater harvesting system for a large building. The results indicated that about 87% water saving efficiency could be achieved for an office-based RWH system in an 8-month period. In the study conducted in several regions of Brazil with different precipitation amounts, water savings as a result of rainwater use in single storey buildings was 33.6%–35.5% (Ghisi& Oliveira, 2006), where as water saving as a result of rainwater use in multiple-storey buildings was 14.7%–17.7% (Ghisi& Ferreira, 2007). In office buildings with a bigger roof surface, water was saved by collecting and using of rainwater was about 62% (Ward, Memon, & Butler, 2012). Rainwater harvesting capacities of residential buildings with different roof areas in 5 different cities in South Brazil were evaluated (Ghisi&Schondermark, 2013). (Campisano and Modica, 2012) which developed a regression model which enables the evaluation of water saving and overflow discharge from domestic RWH sys-tems. By applying a minimum cost approach on the developed regression model, they evaluated the optimal tank size and concluded that the economic attractiveness of large tanks decreases with decrease in rain-water availability. In the UK, an average water saving efficiency (ET) of 87% in a period of 8 months was reported for the total toilet flushing demand of an office building using RRWH. ET is the percentage ratio of rainwater supplied to the total estimated demand [19]. Mun and Han (2012) [18] modeled RWH and incorporated operational parameters such as rainwater use efficiency, i.e. runoff capture, and water savings efficiency, and also design parameters such as the ratio of tank volume divided by catchment area and rainwater demand divided by catchment area. Stormwater is a valuable resource which is currently under use. The use of rainwater tanks is increasingly becoming popular with the persistant drought. Water from the tanks can be used for nonportable purposes such as garden use, toilet flushing, washing clothes and in the hot water systems. This constitutes about 80% of the water consumed within a residential property. In Australia, the major amount of water consumption is for outdoor use, hot water and toilet flushing (Coombes, 2002). Victorian Government policy supporting the use of rainwater tanks for portable substitution whilst meeting the Department of Human Services public health guidelines and the Plumbing Industry regulations is reflected in ‘‘Water Smart Gardens and Homes Rebate Scheme” which gives an opportunity to every household to save their water resources and also money (Department of Sustainability and Environment, 2007). Australia has one of the highest degrees of the implementation of RWH systems [10]. According to the results of a survey by the Australian Bureau of Statistics (ABS, 2015). An increasing trend is observed starting from early 1980s, adapted from MLIT, 2014.

C. CHALLENGES FOR RAINWATER HARVESTING

These trends accentuate the need to adapt water management to new and challenging environmental and socio-economic conditions. among other options, rainwater harvesting may play a vital role in widening water security and to reduce the impacts on the environment (el-sayed et al., 2010). Drastic decrease in minimum monthly precipitation (32 – 61 %) especially during the dry season from May to August associated with climate change in certain regions, could cause the RWH system ineffective if precipitation falls below a minimum threshold or not sufficient to hold a reliable supply (che-ain et al., 2009; shaaban, 2009). According to (Hashim et al. 2013), 58% of water supply can be provided by RWH and 41% must be supplied by the water utility. The Optimization of the RWH system design is crucial to meet the supply and demand network at optimal reliability. In addition, the lack of incentives also makes Malaysian slow in accepting RWH system [3], as practised in japan and elsewhere the government may need to provide subsidies to encourage the public to install RWH (Shawahid et al., 2007). It is certainly a right step to make it mandatory despite the fact that there is 211 still lack of robust policy to promote the installation of RWH in Malaysia.

D. SCOPE OF THE STUDY

This Project is under planning stage to build a fully functional rain water harvesting (RWH) system for Beary's institute of technology, Mangalore. as it is mandatory and important to have a compulsory rain water harvesting system for any institutional area for conservation of water. hence, Beary's institute of technology Mangalore is planning to complete RWH system by 2020-2021. However, this is a preliminary step to design rwh system to understand the cost effectiveness study and economic savings of water. the Scope of the Present study are as follows.

A. Conservation of water.
B. Ground water recharge.
C. Preventing urban floods.
D. Water-shed management.
E. Tackle the scarcity of water.

II. LITERATURE REVIEW

A Brief review on the various analysis, techniques, water Qultitys for rainwater harvesting has been considered in the present study. An attempt was also made to understand how rainwater harvesting efficiency is varying in different roof material. In the statistical analysis study showing that, If the RWHS with larger storage capacities can achieve the water supply time reliability and more water saving efficiency, for economic viability of RWHS. The amount of rainwater collected on a building depends not only yield coefficient and precipitation but also depends on rainwater catchment area. The average annual rainfall is major factor is to increase the average annual water savings from rainwater tanks. The very Higher Net benefit value is found in the Polyester–fibreglass material. If reducing the investment cost and if increasing the Both water prices and of water production costs then the RWH can achieve the economic feasibility. The initial abstraction is high in flat rough roofs compare to the sloping roofs. The roofs have different slopes, the roof angle could not be considered and runoff coefficients were used based on the material for 0.9 for iron, 0.8 for Tile and Concrete, 0.85 for the Clay tile and Fiber cement roof taken, Due to spillage, leakages, infiltration, roof surface wetting and evaporation which is reduce the amount of roof rainwater collection. The Rooftop runoff water quality is based on the roof type material and the environmental condition. To achieve the water demand in good quality water in sufficient quantities, The galvanized steel was most suitable for roof top rainwater harvesting, Because of the lower concentrations. high water quality is found in galvanized steel, Due to high temperature and the ultraviolet light with physical and chemical water quality parameters results are found satisfied with the drinking water quality. In ground water recharge MODFLOW technique was use to evaluated base flow, stream flow and stream leakage. to predict the groundwater system behaviour like groundwater flow and transport model by using SEAWAT-2000 for pumping well Ground Water Recharge Technique was selected. the potentiality of rainwater for recharging shallow Groundwater with two recharge shafts, by injecting rainwater into unconfined and confined aquifer, obtained The linearly increasing groundwater levels are recorded by piezometers so that the groundwater levels are improved.

III. MATERIALS AND METHODS

As discussed earlier in the section of introduction importance of rainwater harvesting at Beary's Institute of Technology (BIT) Campus, Mangalore. as it is Mandatory and important to have a compulsory rain water harvesting system for any institutional area for conservation of water. Hence, Beary's Institute of Technology Mangalore is Planning to complete RWH system by 2020-2021 [3]. we clearly came to know the all the advantages which we can draw out by implementing this small but highly efficient technique in the campus. Thus to increase the potential, benefits of this system and draw maximum advantages from it, we need to have rooftop areas which will be going to act as catchment areas. More the catchment areas more will be the surface runoff and thus more will be the amount of harvested water. This study was carried out at Beary's Institute of Technology (Boys Hostel), Mangalore. BIT Boys hostel presently has capacity of 285 students including staff. For experimental part our project we took area as 100 ft^2. The Proposed system has been tested and analyzed the design efficiency on a different Case [16]. In this study Two Areas are assumed to be consisting of a single residential building and multi-storey (Hostel) building, its serves about 4 and 240 inhabitants. The roof area of the buildings are 81.316 m^2 and 772.25 m^2. The average Monthly rainfall of 316.391 mm respectively. To examine the effect of roofing materials on the Physicaly and Chemical quality of rainwater harvested for Domestic use. It also provides guidelines for the selection of roofing materials that will aid in the harvesting of clean rainwater.

Fig. 1 Data Collection

Beary's Institute of Technology (boys hostel), Mangalore is located at 74057'10.41"E longitude and 12050'44.26"N latitude in Dakshina kannada district of Karnataka at an elevation of about 364 ft above mean sea level. Mangalore has a tropical climate and receives high rainfall during June to September.

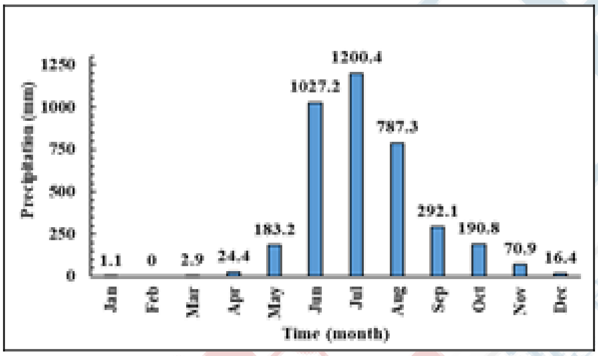


Fig. 2 Amount Precipitation for each month of Mangalore for 2018

The rainfall data are being taken from the India Meteorological Department, Mangalore. Thus rainfall data of the Mangalore city is given below in the Graph, which is assumed to be same for the BIT campus.

IV. METHODOLOGY

Below framework shows the methodology for this present study involved the following key steps.

- Select the study area. Observed precipitation, climate and water-demand data are required to calculate the exact storage capacity of an RWHS.
- Design of RWH System components based on the collected data.
- Compare the design efficiency of RWH Systems to optimization of RWH Model.
- To estimate the cost & specification for RWH module and installation of optimized RWH modular system in the study area.
- Calculate the rainwater harvesting potential and future scenario analysis (economic savings analysis).
- If the RWH collection efficiency is more then the excess of water [8] is using for increasing the ground water recharge with the suitable techniques.

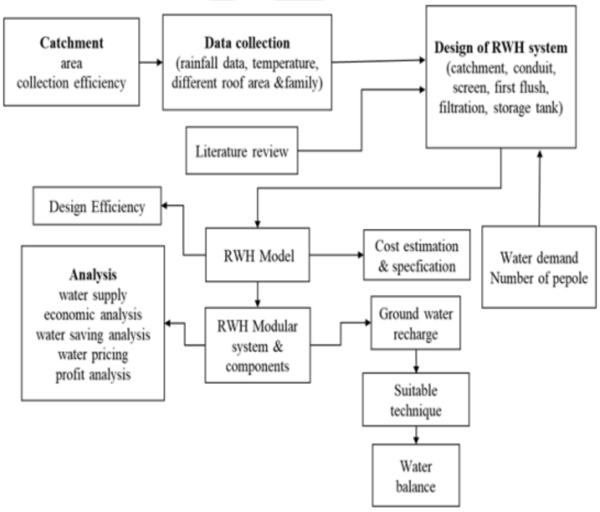


Fig. 3. Proposed Methodology For Rain water harvesting system for economic savings and conservation of water

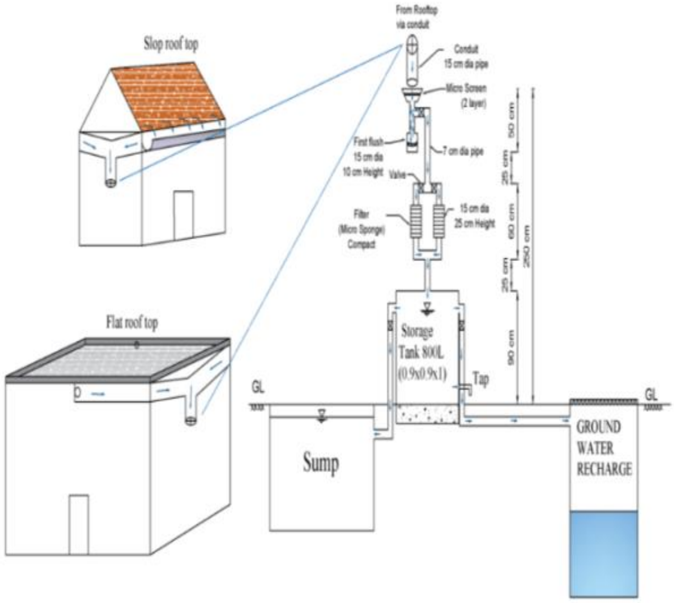


Fig. 4. Proposed Rain Water Harvesting System for Bearys Institute of Technology

A. Cost and Estimation

Table 1 COST AND ESTIMATION DETAILS

Sl No	Component	Cost (Rs)	Application
1	**Coarse Mesh**	**60**	**To prevent the entry of leaves and other debris in the system**
2	**Double layer screen**	**250**	**it avoid the entry of leaves and other debris in the system. provided to collect and divert the rain water to downspout or conduits.**
3	**First flush**	**650**	**to avoid this contamination a first flush system is incorporated in the roof top rain water harvesting system.**
4	**Filtration Chamber**	**1650**	**The filter is used to remove suspended pollutants from rain water collected over roof.**
5	**Storage tank**	**3100**	**the rain water collected from roof top is used directly for various purposes, storage tank is required.**

B. FORMULA

The total amount of water that is received from rainfall over an area is called the rainwater legacy of that area. And the amount that can be effectively harvested is called the water harvesting potential. Regarding the financial aspects and viability of RWH systems, we identify the most important determinants for the development of projects. It is provides useful information for making decisions, financial studies to choose among several investment projects. The below formulas are used to brief calculation for Hydrological analysis and economic analysis [21].

1. Runoff for Catchment area

Run off is nothing but the amount of water can effectively harvest from the respective catchment area is called potential rainwater harvesting. There many empirical or Semi-Empirical formulae used to estimate the runoff discharge from catchment area. semi-empirical bases are preferable and have a wide use by the designer. The Rational method Consider a rainfall of uniform intensity and duration occurring over a basin in a time taken for a drop of water from the farthest part of the catchment to reach the outlet that calledtc = time of concentration, the runoff will be constant and at the peak value. The peak value of the runoff is computed by Eq (1).[22]

$$Q = C \times I \times A \quad \text{----------} \ (1)$$

Where,

Q= Runoff (Potential rainwater harvesting), C = Coefficient of runoff . A = Area of the catchment. I = Intensity of rainfall.

2. Water collection efficiency

The collection efficiency of the rainwater harvesting system. Not all the water will be captured due to system inefficiencies [17]. For example, some of the water gets trapped in the gutters or simply evaporates before reaching the storage container or water barrel [20]. Rainwater collection efficiency was estimated using Eq (2). (Abdulla et al,2009)

$$\eta_C = \frac{RAINWATER\ COLLECTION}{POTENTIAL\ RAINWATER\ HARVESTING} \times 100 \quad \text{----------} \ (2)$$

3. Demand

Monthly domestic household water demand dt is the total amount of non-potable water needed, thus can be expressed as Eq (3). (Okoye et al,2015)

$$dt = Wd \times n \times Nt \quad \text{----------} \ (3)$$

Where,

Wd = The water usage in m3/day/capita, N = The number of residents Nt= The number of days in month t.

4. Reliability (Time and Volume)

Two types of reliability equations; time based and volume based reliability equations were used in this study. time-based reliability is defined as Eq (4). (Bashar et al,2018)

$$R_{e(t)} = \frac{N - X}{N} \times 100$$

Where, Re(t) = The reliability of the RWH system to be able to supply the intended demand (%). X = indicates the number of days in a year (when rainfall runoff failed to meet the daily water demand) of a residential building. N = The total number of days in a that year. Volumetric reliability is also known as efficiency as Eq (5). (Bashar et al,2018)

$$R_{e(v)} = \frac{Volume\ of\ rainwater\ supplied\ in\ a\ year}{Total\ water\ demand\ during\ a\ year} \times 100$$

Where, Re(v) = The efficiency or volumetric reliability of a RWH system (%).

5. Water saving efficiency

To obtain potential annual water savings, water demand was compared to the volume of rainwater that could be harvested in each governorate. The annual potential for potable water savings was determined using Eq (6). (Abdulla et al,2009)

$$APPWS = \frac{VR}{PWD} \times 100 \qquad \text{---------- (6)}$$

Where, APPWS = The annual potential for potable water savings in each governorate (%). VR = The annual volume of rainwater that could be harvested(m3/y). PWD =The annual potable water demand (m3/y) [23].

6. The overflow ratio (OFR)

The overflow ratio (OFR) is defined as the volume of rainwater exceeding storage capacity to the inflow to the system during an evaluation period by using Eq (7). (Bashar et al,2018)

$$OFR = \frac{\sum_{i=1}^{n} SW_i}{\sum_{i=1}^{n} V_i} X100 \qquad \text{---------- (7)}$$

Where,

SWi= The volume of spilled water (L) in a day ‘i’.
Vi= The volume of the harvested rainwater (L) in the day ‘i’.
‘n’ = The number of days in an evaluation period.

7. Benefit-cost ratio

The economic benefit can be evaluated by benefit-cost ratio, which compares the present value of benefits (TB) to the present value of costs (PV) of RHS. The benefit-cost ratio (RBC, dimensionless) can be calculated asEq (8). (Zhang et al,2017)

$$R_{BC} = \frac{TB}{PV} \qquad \text{---------- (8)}$$

$$PV = I + C\frac{(1+i)^n - 1}{i(1+i)^n}$$

$$TB = B\frac{(1+i)^n - 1}{i(1+i)^n}$$

where RBC= The ratio between the present values of benefits and costs of a project. I = The fixed investment of the project. C = The operational cost of the project. B = The annual average total benefit generated from the project. i= The discount rate. n = The design lifetime of the project.

V. RESULTS AND DISCUSSION

The Proposed system has been tested and analyzed the design efficiency on a different Case. In this study Two Areas are assumed to be consisting of a single residential building and multi-storey (Hostel) building, its serves about 4 and 240 inhabitants. The roof area of the buildings are 81.316 m^2 and 772.25 m^2. The average rainfall of 316.391mm respectively. To examine the effect of roofing materials on the Physicaly and chemical quality of rainwater harvested for domestic use. It also provides guidelines for the selection of roofing materials that will aid in the harvesting of clean rainwater.

A. RUNOFF

Runoff from a particular area is dependent on various factors i.e. rainfall pattern and quantity, catchment area characteristics etc. For determining rainfall quantity, the rainfall data preferably for a period of one year rainfall data was taken, In the year 2019 the average rainfall of 316.391 mm, In the month of July the average rainfall of 38.722 mm, The maxium rainfall in day of July month is 153mm respectively. which has Taken Runoff coefficient is Consider has 0.81 and 0.9 for Concrete Bed Roof and Galvanized steel Roof. we can easily calculate by using Eq-1 the potential rainwater harvesting.

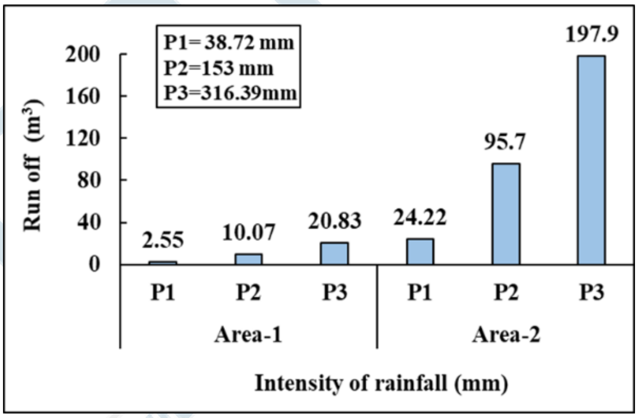


Fig. 5. Potential rainwater harvesting of Concrete Bed Roof for different Intensity of rainfall

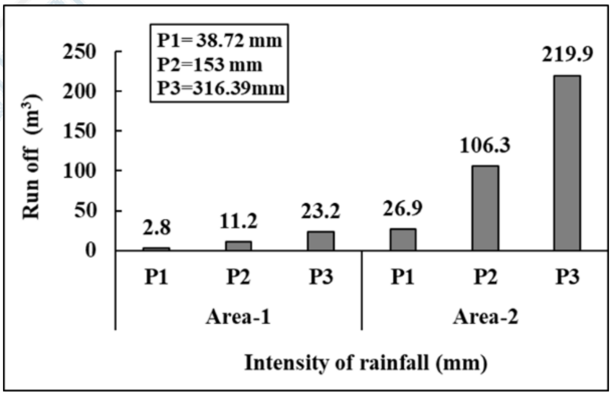
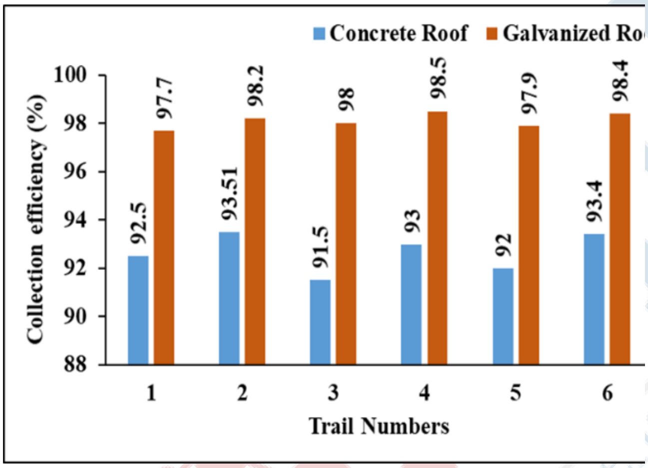


Fig. 6. Potential rainwater harvesting of Galvanized Steel Roof for different Intensity of rainfall

In all calculations for Runoff estimation, runoff coefficient is used to account for losses due to spillage, leakage, infiltrations catchment surface wetting and evaporation, which will ultimately result into reduced runoff. The above graphs are shows the how much of Potential rainwater that can be harvested in the present catchments. It was estimated from both Concrete Bed Roof and Galvanized Steel Roof catchment areas. In the Fig:5 the Computation of annual Runoff for Area-1 and Area-2 of Concrete Bed Roof is around 20.83 m^3 and 197.91 m^3. In the Fig:6 the Computation of annual Runoff for Area-1 and Area-2 of Galvanized steel Roof is around 23.2 m^3 and 219.9 m^3

B. WATER COLLECTION EFFICIENCY

To obtain Water collection efficiency, the collected water was compared to the volume of rainwater that could be harvested in each catchment with the respective rainfall data. Observed the below Fig:7 out of 6 trails results, the highest Water Collection Efficiency for Concrete Bed Roof is 93.5 % and 98.5 % for Galvanized steel Roof we obtained. Water collection efficiency is very important to reach our water demand. It is purely depended on roof material. All the water which is falling over an area cannot be effectively harvested, due to various losses on account of evaporation, spillage etc. because of these factors the quantity of rain water which can effectively be harvested is always less than the rain water endowment. The collection efficiency is mainly dependent on factors like runoff coefficient and first flush wastage etc.



- **Fig:7 water collection efficiency of harvesting systems for different roof material**.

C. OVERFLOW RATIO (OFR)

The overflow ratio (OFR) is defined as the volume of rainwater exceeding storage capacity to the inflow to the system during an evaluation period. Overflow ratio relations with varying different tank sizes under different conditions. The tank sizes are considered for Area-1 is 2KL, 3KL, 4KL and 10KL, 15KL, 20KL tank sizes for Area-2 respectively. Overflow ratio relations with varying tank sizes for different Area under two roof conditions are shown in above Tables. It is evident that in Area-1 the Tank size 2KL,3KL,4KL was consider in the during 42, 27, 11 Days of Evaluation Period the over flow are 45.53 %, 31.70%, 23.77 % for Concrete Bed Roof and in the during 51, 31, 22 Days of Evaluation Period the over flow are 46.26%, 33.43%, 20.61% for Galvanized Steel Roof. In the both roof top the highest over flow was found in the 2KL and 10KL Tank size in the Area-1 and Area-2 By observing the results. Graphical representation of Overflow. it indicating that if increase the tank size the overflow ratio will be reduced. The analysis also indicated that overflow losses tend to decrease with the increasing storage capacity and only an insignificant amount of spilled water was found for tank sizes exceeding 4KL and 20KL.

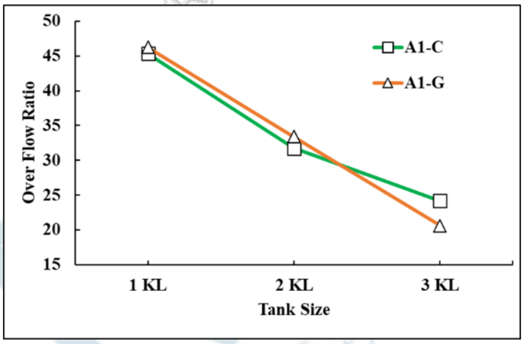


Fig. 8. Overflow Ratio of Area-1 for different Storage Tank size

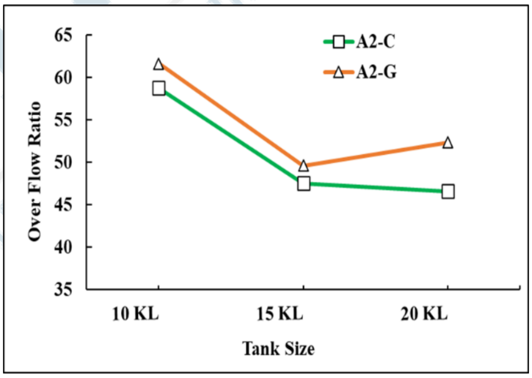
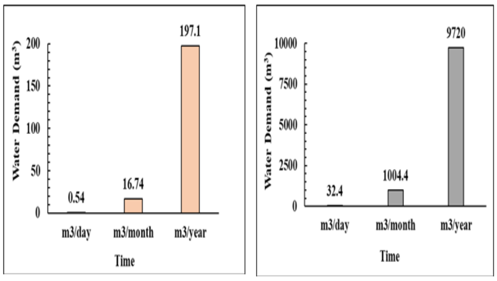


Fig. 9. Overflow Ratio of Area-2 for different Storage Tank size

Thus rainwater harvesting in the multi storied building can play an important role in controlling water logging in urban areas caused by storm runoff, if the storage tanks are designed with appropriate capacity.

D. WATER DEMAND

Water Demand is the measure of the total amount of water used by the customers within the water system. In this study two areas are assumed to be consisting of a single residential building and multi-storey (Hostel) building, its serves about 4 and 240 inhabitants.



(a) (b)

Fig. 10. Water Demand for different Building (a) single residential building (b) Multi-storey (Hostel) building

The Water consumption rate is considered has 135 LPCD. The water demand was calculated for Per Capita Demand in litres per day per head, litres per Month, litres per year. the water demand is helpful to check the water demand met and also to obtain the economic analysis results. the water demand for different Building. 197.1 m^3 per year and 9720 m^3 per year for single residential building and Multi-storey (Hostel) building.

E. RELIABILITY ANALYSIS

The reliability means RWH system to be able to supply the intended demand. In this study Two types of reliability equations were used That is time based and volume based reliability equations. To obtain the time based reliability the total number of days in a that year compered to the number of days in a year rainfall runoff failed to meet the daily water demand.

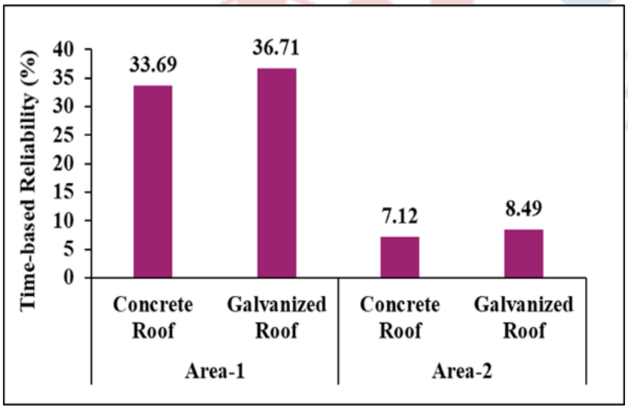


Fig. 11. Time based reliability of different Area for different Roof material

The results are indicating that in Area-1 from the Concrete Bed Roof and Galvanized steel Roof the time based reliability was achieved 33.70 % and 36.71% it means in year the % of days daily rainfall was satisfying the our water demand. The Concrete Bed Roof and Galvanized steel Roof was achieved 7.12 % and 8.49 % of time based reliability from the Area-2. The time based reliability Results are Shown in Graphical representation

F. BENEFIT-COST RATIO (BCR) ANALYSIS

A benefit-cost ratio (BCR) is a ratio used in a cost-benefit analysis to summarize the overall relationship between the relative costs and benefits of a proposed project.The economic benefit can be evaluated by benefit-cost ratio, which compares the present value of benefits (TB) to the present value of costs (PV) of RHS. The design lifetime of RHS consider as 4 years. The benefit-cost ratio will vary with respect to discount rate.

Observe the above result table for the 1% and 9% discount the benefit cost ratio was 3.07, 4.15 and 2.77, 3.72 from the Concrete Bed Roof and Galvanized Steel Roof for Area-1. It is indicating that when the discount rate is less the benefit cost ratio is more and vice versa.

Table 2. Computation of Benefit-Cost Ratio Analysis

Benefit-Cost Ratio Analysis				
Discount Rate (%)	Area-1		Area-2	
	Concrete Bed Roof	Galvanized Steel Roof	Concrete Bed Roof	Galvanized Steel Roof
1	3.07	4.15	8.33	8.03
3	2.99	4.04	8.06	7.83
5	2.93	3.93	7.81	7.69
7	2.84	3.82	7.56	7.52
9	2.77	3.72	7.33	7.36

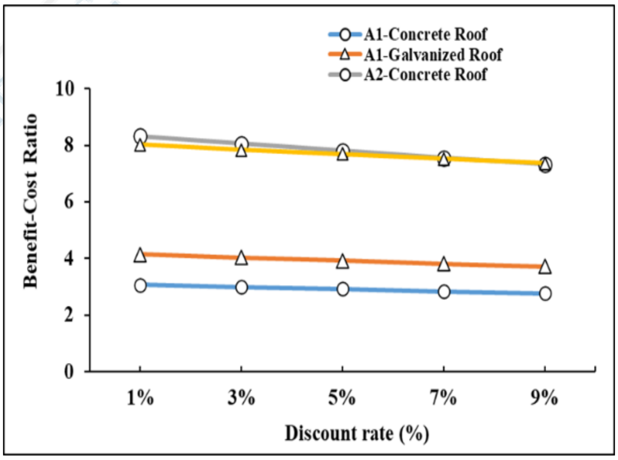


Fig. 12. Benefit-Cost Ratio Analysis for different Discount Rate

the Graphical representation of BCR results are shown in the Fig:12 If the BCR is equal to 1.0, the ratio indicates that the NPV of expected profits equals the costs. If it is larger than 1.0, the benefits provided by the system is greater than its costs, which suggests that the system is economically feasible. If a project's BCR is less than 1.0, the project's costs outweigh the benefits, and it should not be considered.

VI. CONCLUSION

In all calculations for Runoff estimation, runoff coefficient is used to account for losses due to spillage, leakage, infiltrations catchment surface wetting and evaporation. Water collection efficiency is purely depended on roof material and found Galvanized steel Roof is best roof material for rainwater harvesting. Construction cost of Proposed RWH modular system was estimated Rs.5710, its indicate Low-cost roof top rain water harvesting. The highest Water Collection Efficiency obtained from Galvanized steel Roof 98.5 %. In the both roof top the highest Overflow found 46.26 % and 61.68%, was found in the 2KL and 10KL Tank size in the Area-1 and Area-2. In the Timebased reliability in Area-1 from the Concrete Bed Roof and Galvanized steel Roof was achieved 33.70 % and 36.71%, from the Area-2 the timebased reliability was achieved 7.12 % and 8.49 %. The benefit-cost ratio (BCR) for the 1% and 9% discount the benefit cost ratio was 3.07, 4.15 and 2.77, 3.72 from the Concrete Bed Roof and Galvanized Steel Roof for Area-1. The highest water saving was found from the Galvanized Steel Roof for the both areas around 81 & 2733 m^3/ year.

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