Scientific contribution
No: INCOH/SAR-27/2006

STATE OF ART REPORT

MANUAL FOR ROOF TOP RAIN WATER HARVESTING USING CISTERNS OR STORAGE TANKS FOR INDIVIDUAL HOUSEHOLDS, COMMUNITY AND INSTITUTIONS

Santosh Kumar Sharma

Publication of
Indian National Committee on Hydrology (INCOH)
(IHP National Committee of India for UNESCO)
National Institute of Hydrology, Roorkee - 247 667
INDIA

INDIAN NATIONAL COMMITTEE ON HYDROLOGY (INCOH)
(IHP National Committee of India for UNESCO)

Constituted by the Ministry of Water Resources in 1982

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- Hydrometeorlogical aspects of water resources development and flood forecasting.
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INDIAN NATIONAL COMMITTEE ON HYDROLOGY (INCOH)

(IHP National Committee of India for UNESCO)

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PREAMBLE

The Indian National Committee on Hydrology (INCOH) is an apex body under the Ministry of Water Resources (MoWR), Government of India entrusted with the responsibility of co-ordinating various activities concerning hydrology and water resources development in the country. The Committee has its members drawn from central and state government agencies as well as experts from academic and research organisations. INCOH provides technical support to MoWR in identifying the R&D schemes and studies for funding, publishing Hydrology Review Journal "Jal Vigyan Sameeksha" and supporting a number of activities including seminars, symposia, conferences, workshops, training courses, etc. The Committee is effectively participating in the activities of International Hydrological Programme (IHP) of UNESCO by organizing regional courses and workshops and conducting R&D work on various themes of IHP. In pursuance of its objective of preparing and updating the state?of?art in hydrology of the world in general and India in particular, INCOH encourages the experts to prepare these reports.

Roof Top Rain Water Harvesting is an important rain water harvesting process of capturing and storing rainfall utilizing the roof tops of the residential, industrial and other housing complex, thereby preventing run off, evaporation and seepage of rainfall; for efficient conservation and utilization. Roof Top Rainwater Harvesting is mainly used for drinking water supply. For many parts of India, Roof Top Rainwater is the cheapest form of water supply due to the availability of substantial rain-water. Roof Top Rain Water Harvesting techniques have an edge over other alternatives especially in hilly areas, islands, coastal and saline areas because of difficulties in construction of water supply schemes. The planning and designing of Roof Top Rain Water Harvesting system is guided by the volume of water that could be captured by the rooftop and subsequently stored. The extent and distribution of rainfall decides the volume of water available from the rooftops. Since the area of rooftops is by and large a fixed entity, the extent of rainfall and related climatic conditions decide the quantity of rainwater, which could be harvested and stored.

Realizing the importance of Roof Top Rain Water Harvesting on water resources, INCOH invited Dr.S.K.Sharma, Former Member, Central Ground Water Board, New Delhi for preparing a state-of-art report on the status of "Manual for Roof Top Rain Water Harvesting using Cisterns or Storage Tanks for Individual Households, Community and Institutions. It is hoped that this state-of-art report would serve as a useful reference material to practicing engineers, researchers, field engineers, planners, stakeholders and implementing authorities, who are involved in the estimation and optimal utilization of water resources in the country.

15/5/06

(K.D. Sharma)
Executive Member INCOH &
Director, National Institute of Hydrology, Roorkee

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Chapter - I
Introduction

Roof Top Rain Water Harvesting is a specific rain water harvesting process of capturing and storing rainfall utilizing the roof tops of the residential, industrial and other housing complex, thereby prevention run off, evaporation and seepage of rainfall; for its efficient conservation and utilisation. This is the best option to harvest rainwater in-situ and store it appropriately for eventual recovery and use during the time of need. Roof Top Rainwater Harvesting is an effective tool to utilize substantial quantity of high quality of water which otherwise goes waste creating numerous problems on its way.

Rain Water Harvesting is an age-old practice and traces its history to biblical time Archaeological evidence attests to the capture of rainwater as far back as 4000 to 6000 years. Ruins of cisterns built as early as 2000 BC for storing run off from hillsides are still standing in Israel. With the growing population and increasing demand of water, conservation and storage of clean water has become a prime necessity. Proliferation of constructional and housing activities have constricted the seepage surface for ground water recharge and accelerated surface run off with serious consequences. However, the houses and housing complexes in rural and urban areas provide easy receptacles for rainwater to flow in desired direction, which can be stored for use. Roof Top Rainwater Harvesting has therefore opened a new vista for providing supplementary source of higher quality of water for drinking water use.

1.1 Benefits and Advantages of Roof Top Rainwater Harvesting

The Roof Top Rain Water Harvesting has certain inbuilt advantages and benefits which are as follows :

- The water is free with relatively low cost for collection and use
- The in-situ collection of rainwater eliminate the need for complex and costly distribution system.
- It provides almost safe raw drinking water supply, which does not require costly treatment or purification process.
- The zero hardness of rainwater helps in prevention of scale on appliances extending their use. It eliminates the need for water softeners.
- Rainwater is sodium free and is good for persons on low sodium diets.
- Water available from Roof Top Rainwater Harvesting is free from faecal contamination responsible for most of the water borne diseases (mainly diarrhea, typhoid, selmovelloses, cholera, dysentery, etc.)
- It creates involvement of local community in the scheme and their contribution in form of man-power for construction and maintenance.
- No maintenance problems as beneficiaries can maintain these on their own.
- Zero electricity needs.
- Rainwater Harvesting reduces flow to storm water drains and reduces non point source pollution.
- Miseries of women and children for fetching water from long distance sources can be minimized.
- Less time required for implementation.

Chapter - II

Basic Frame of Roof Top Rain Water Harvesting

Roof Top Rainwater Harvesting is basically the capture, diversion and storage of rainwater mainly for drinking water use. For many parts of India, Roof Top Rainwater collection is cheapest form of water supply since the alternates are high cost. Further the availability of substantial rain water makes these schemes economically feasible. It is much easier to mobilize household for a family rainwater tank. These schemes have an edge over other alternatives especially in hilly areas; islands, coastal and saline areas because of difficulties in construction of water supply schemes.

The Roof Top Rainwater Harvesting can be planned in two ways;

i) Collection of rainwater from rooftop and storing it in suitable cisterns/ Storage Tanks.

ii) Directing the overflow from the system for ground water recharge in geologically favourable environment through suitable structures.

The second step is optional and is feasible in hydro - geologically favourable situations.

The basic steps in rooftop rainwater harvesting are :

2.1 Collection and Storage

During rainfall precipitation, rainwater falling on rooftop of houses can be collected and stored in storage for use during dry season. The rooftops of independent houses, flats, industrial complexes, schools, hospitals, etc. can be utilized for rainwater harvesting. This involves;

- Diversion
- Filtration
- Storage

2.1.1 Diversion

The rains falling on rooftops of house/housing complex have to be diverted towards the storage point/ cistern. The water from the rooftop can be directed towards an opening by providing mild slopes. This opening is connected with pipes to enable the rainwater to flow down to tank.

2.1.2 Filtration

Rainwater collected from roof has impurities like bird dropping, dust, leaves, etc. The water from roof has to be passed through a suitable designed filter to enable to harvest good quality of water.

2.1.3 Storage

The water collected from rooftop is stored in storage tanks constructed on the ground or below land surface. The storage tanks have suitable device to take out stored water without polluting it.

2.2 Recharge to Ground Water

The rain water harvested from roof top may be more than the capacity of storage tank/ cistern, hence a provision of excess flow from cistern is made which can be recharged to ground water through suitable structures. The most convenient would be to recharge this water through existing dug well/ hand pump/ tube well in the campus of house itself. Since the water from rooftop is already filtered, the same can be directly let into ground water reservoir through wells. Such a provision of recharging ground water from excess rainwater stored in cistern can further conserve the water resources.

Chapter - III
Rain Water Harvesting System Components

The domestic rooftop rainwater harvesting system consists of following basic elements :

3.1 Catchment Surface: This is the rooftop area on the houses, which is the collection surface for rainfall runoff. The rooftop surface can be of various shapes, size and make.

3.2 Gutters and Conduits or Downspouts: These are pipelines, drains which channelise the rainwater from rooftop to harvesting system.

3.3 Leaf Screen and First Flush Diverter: These are the components, which remove debris and dust from rooftop rainwater before it is stored in cisterns.

3.4 Storage Tank or Cistern: The storage tank is the most important and expensive component of the rooftop rainwater harvesting system. The size of the tank depends on several variables viz; amount of rainfall rooftop area, water needs etc. A number of variations of storage tank are in use and differ in design and make from area to area.

3.5 Delivery System: The mode of transferring water from tank to end - use makes delivery system. This can be gravity fed or manually/ mechanically pumped.

3.6 Treatment / Purification: Filters and small measures like chlorination, adding chlorine tablets, boiling, etc. constitute the treatment of harvested rain water. Filters are used in the conduit before it enters the storage tanks. It is also sometime integral part of storage tank.

3.7 Ground Water Recharge Facility: The excess water from storage tank is recharged into the ground water aquifers through suitable structures like dug wells, bore well, etc.

A typical rooftop rainwater harvesting system is given in Fig. 1 & 2.

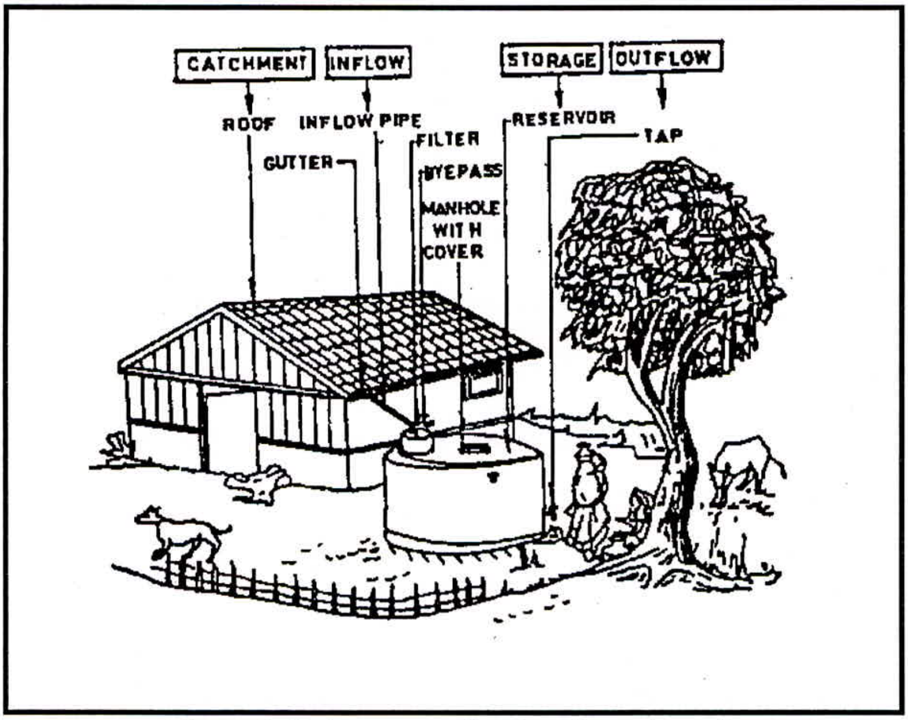


Figure 1: Rain water collection through roofs.

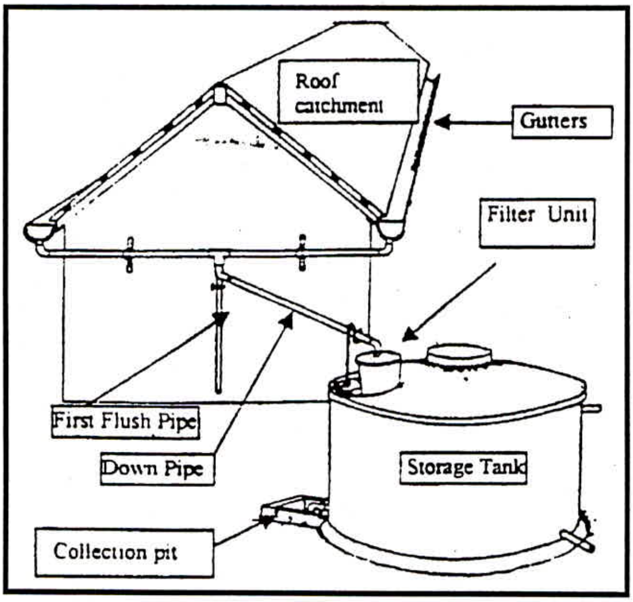


Figure 2: A typical rain water harvesting system

Chapter - IV

Planning and Design of Roof Top Rain Water Harvesting System

The planning and designing of Roof Top Rain Water Harvesting system is guided by the volume of water that can be captured by the rooftop and subsequently stored. This quantity must be equal to or exceed the volume of water to be used. The extent and distribution of rainfall decides the volume of water available from the rooftops. Since the area of rooftops is by and large a fixed entity, the extent of rainfall and related climatic conditions decide the quantity of rainwater, which can be harvested. The variables of rainwater and water demand determines the relationship between required catchment area (rooftop area being fixed) and storage capacity of cistern. The first step is, therefore, to determine the extent of collection surface (Rooftop area) and analyse the rainfall situation to arrive at the water balance of the catchment area.

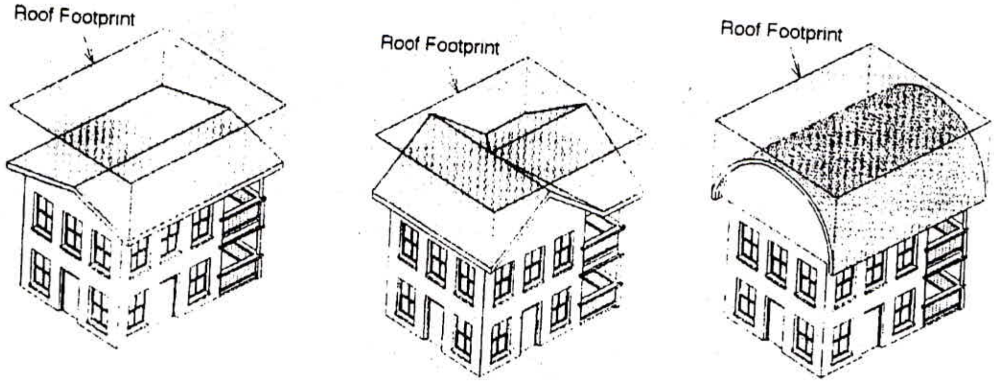
4.1 Catchment area or Collection Surface Area

The collection surface is the footprint of the roof. The effective collection area, regardless of the pitch of roof is area of the roof i.e. length times width of the roof. If one side of roof is guttered, only area drained by the gutters is used for computing the area. The catchment area or roof foot print of four different roofs is given in Fig. 3. Determination of roof area: The catchment area of roof is a simple calculation. The width X length of the house gives the roof area. This is given in Fig. 4.

4.2 Rainfall Distribution and Availability for Designing Harvesting System

In large part of the country, rainfall occurs seasonally i.e. during monsoon period. Hence the roof top rainwater harvesting system has to be so planned as to have sufficient storage in the tanks during rainy days to last through the dry spells.

The extent of rainfall decides the quantity of water that would be available from the area of catchment available from roof. The annual rainfall data of the area is normally available from the State Government or India Meteorological Department. The mean rainfall is calculated for the longest period for which the data is available. For computing the water available from the roof, the average rainfall data of last 10 to 15 years is normally considered. For safe calculation it has also been recommended that rainfall data of a dry year in the past 10 years may be considered and 80% of it should be considered as available for collection. This indicates that shortage may occur one in 10 years. This can be illustrated by following example;



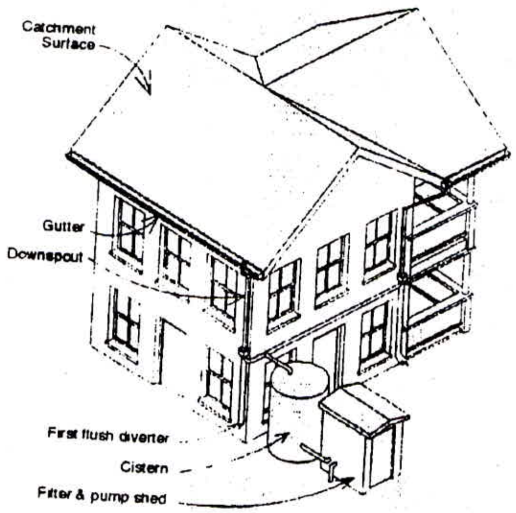


Figure 3: Different type of roof top

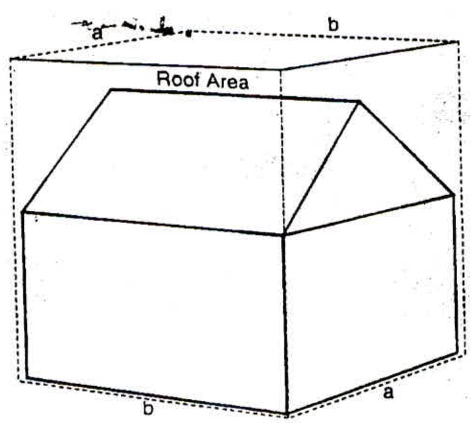


Figure 4: Roof area

Year	*Rainfall in mm*	*Year*	*Rainfall in mm*
Year 1	320	Year 6	280
Year 2	360	Year 7	335
Year 3	311	Year 8	380
Year 4	290	Year 9	355
Year 5	330	Year 10	340

Arranging the rainfall in descending order give the following ;
380, 360, 355, 340, 335, 330, 320, 311, 290, 280

The maximum rainfall of 380 mm is equaled only once in 10 years which means this quantity of rainfall is expected to occur only once in 10 years. The minimum rain is 280 mm, which is equaled or exceeded in all the ten years. As such this figure of rainfall is most reliable and should be used for assessing rainwater harvesting potential and designing the system.

The entire rainfall on the rooftop cannot be taken as availability of water. The likely losses of water from rooftop are;

a) Evaporation
b) Rain blown away from roof by wind
c) Water lost in depression in roof or improperly sloped gutters
d) Water lost in first flush device.

These losses are expected varying from 10 to 30% hence these are to be considered for calculation of water harvesting potential.

Alternatively a term Runoff Coefficient for roof catchment depending on the material used for roof is taken to calculate the quantum of rainwater availability for harvesting. This is as follows;

Type of Roof Catchment	Runoff Coefficient
❖ GI Sheets	0.9
❖ Asbestos	0.8
❖ Tiles	0.75
❖ Concrete	0.7

For designing of roof top rainwater harvesting system the meteorological data needed are;

1. Average Annual Rainfall
2. No. of dry season days

4.3 Water Requirement/ Drinking Water Needs

For designing storage tank, data about average annual rainfall number of dry season days and per capita drinking water requirement are needed. Considering a dry season of about 100 days during which there is no rainfall available for storage, the average drinking water requirement of a five-member family can be calculated as follows;

No. of family members	--	5
Per capita drinking water requirement	--	10 lpcd
No. of Dry Season Days	--	100

Average Water Requirement = No. of family members x Drinking water needs per capita per day x No. of dry season days = 5 x 10 x 100 = 5000 Litres

4.4 Computation of Roof Top Rainwater Harvesting Potential

Considering the following ;

a)	Annual Rainfall	-	400 mm
b)	Roof Top Area	-	25 m2
c)	Runoff Coefficient	-	75%

Rooftop Rainwater Harvesting Potential = Area x Rainfall x Runoff Coefficient = 25 x 0.4 x 0.75 = 7.5 m3

Hence reservoirs/ storage tank of 5.0 m3 capacity will remain full with the available water. This tank can meet the basic drinking water requirement of a 5-member family for dry period.

In real life situation the size of collection and storage system is controlled by the available roof area and the rainfall. Both these attributes are fixed except that some modification can be done in the type of roof to improve runoff. Hence the water harvested from the available roof area is by and large fixed.

As a guide the water availability for a given roof top area can be found from the following Table-1 :

Table 1 : Water Availability for a given Roof Top Area and Rainfall

Roof Top Area (sq.m)	Rainfall (mm)												
	100	200	300	400	500	600	800	1000	1200	1400	1600	1800	2000
	Harvested Water from Roof Top (cum)												
20	1.6	3.2	4.8	6.4	8	9.6	12.8	16	19.2	22.4	25.6	28.8	32
30	2.4	4.8	7.2	9.6	12	14.4	19.2	24	28.8	38.6	38.4	43.2	48
40	3.2	6.4	9.6	12.8	16	19.2	25.6	32	38.4	44.8	51.2	57.6	64
50	4	8	12	16	20	24	32	40	48	56	64	72	80
60	4.8	9.6	14.4	19.2	24	28.8	38.4	48	57.6	67.2	76.8	86.4	96
70	5.6	11.2	16.8	22.4	28	33.6	44.8	56	67.2	78.4	89.6	100.8	112
80	6.4	12.8	19.2	25.6	32	38.4	51.2	64	76.8	89.6	102.4	115.2	128
90	7.2	14.4	21.6	28.8	36	43.2	57.6	72	86.4	100.8	115.2	129.6	144
100	8	16	24	32	40	48	64	80	96	112	128	144	160
150	12	24	36	48	60	72	96	120	144	168	192	216	240
200	16	32	48	64	80	96	128	160	192	224	256	288	320
250	20	40	60	80	100	120	160	200	240	280	320	360	400
300	24	48	72	96	120	144	192	240	288	336	384	432	480
400	32	34	96	128	160	192	256	320	384	448	512	576	640
500	40	80	120	160	200	240	320	400	480	560	640	720	800
1000	80	160	240	320	400	480	640	800	960	1120	1280	1440	1600
2000	160	320	480	640	800	960	1280	1600	1920	2240	2560	2880	3200
3000	240	480	720	960	1200	1440	1920	2400	2880	3360	3840	4320	4800

(i) Figures above - For single household

(ii) Figures above but below - For 2 to 5 households depending upon water scarcity - (to be stored in one or two tanks)

(iii) Figures above but below - (a) For village community to be stored in two or more tanks - (b) Recharge of wells and tubewells

(iv) Figures below - (a) Village community tank suitable for recharge of wells and tubewells
(b) Large surface storages in the absence of natural catchment i.e. hill tops ridges

Chapter - V

Design Aspects of Basic Components of Roof Top Rain Water Harvesting System

5.1 Catchment Surface or Roof Top

Availability of the suitable roof catchment is the first step towards sound system design. Water quality from different roof catchment is a function of the type of roof material climatic condition and the surrounding environment. The following needs to be considered for roof top selection;

- The material for roof construction should be non-toxic in nature
- Roof surface should be smooth, hard and dense. Such roofs are easier to clean and are less likely to be damaged and release impurities in the rainwater harvested.
- Painting on the roof should be avoided as the paints contain toxic substance and may peel and mix with water. Use of damaged steel sheet should be avoided.
- No overhanging trees should be left near the roof
- The nesting of birds on the roof should be prevented

The catchment roof may consist the following material. Some of these are shown in Fig. 5 & 6.

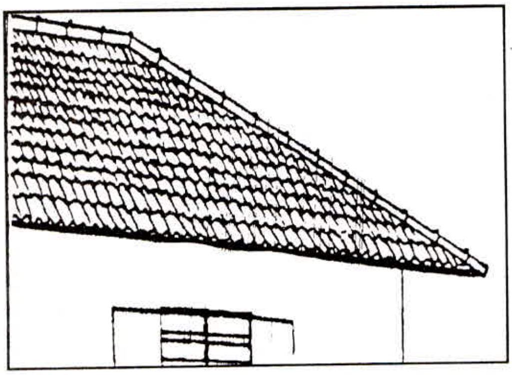


Figure 5: Tiled roof

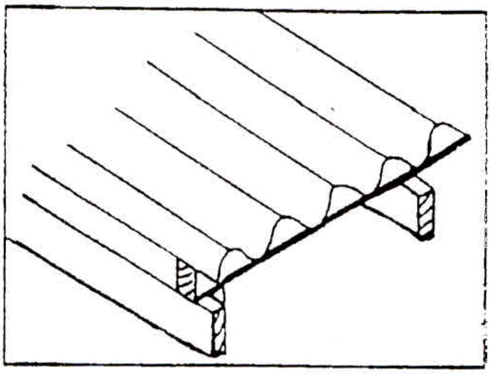


Figure 6: Corrugated GI sheet roof

- Corrugated galvanized iron sheet or aluminium sheet
- Ferro Cement roof
- Thatched roof after covering it fully with PVC sheet
- Flat roof with cement mortar or cement concrete surface at top.

- Wooden roofs with PVC sheet covering
- Stone slab/ slate roof

In case small individual house is to be constructed, the roof should be constructed in a single slope for obtaining considerable saving in the cost of gutter. The slope should be directed towards the entrance of the house so that the storage tank can be constructed in front of house. In this case the entire roof is exposed to rain.

In case new roofs are constructed it should be done using GI/ Aluminium sheets, ferro cement clay tiles concrete or material with no potential for polluting water being harnessed. Tiles of metal roofs are easiest to use and may give cleanest water. The roof, which is unsuitable for collecting water for drinking is the roof with lead flashing or painted with lead based paints. The roofs made of asbestos sheeting should not be used if fibers are being detached from damaged areas, though these can be used after proper repair. Precaution is needed to ensure that debris from roof does not enter the storage tank.

In case of thatched roofs, these need be covered with waterproof plastic LDPE sheet with a thin bamboo strip frame being fixed to keep the sheet in position. Nylone wire/cord may be used for tying the bamboo frame as use of tying wire of iron can damage the sheet.

5.2 Gutters and Downspouts

Gutters are installed to capture rainwater running off the eaves (part of roof jutting over wall of a house). The common materials for gutters and downspouts are half round PVC, Vinyl pipe, seamless aluminium, galvanized steel wooden board, etc. and can be rectangular or semi-circular. (Fig. 7 & 8) For potable water systems, lead, cannot be used as gutter solder. The slightly acidic quality of rain could dissolve lead and contaminate water. Other necessary component in addition to gutter are the drop outlets which route the water from the gutter downwards and at least two 45 degree elbows which allow the downspout pipe to snug to the side of the house. Other components are brackets and straps to fasten the gutters and downspouts to the wall.

Gutters should be installed with slope towards the downspout. The outside face of the gutter should be lower than the inside face to encourage drainage away from the house wall. Gutter should have a uniform slope of 0.5 percent large enough to collect the heavy runoff from high intensity rainfall.

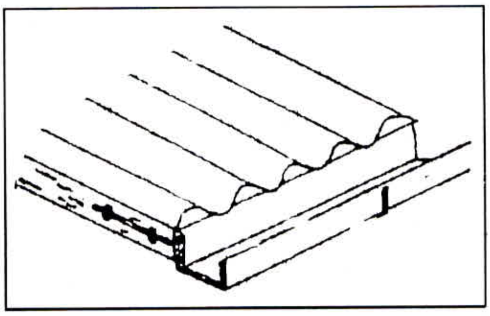


Figure 7: Rectangular gutter

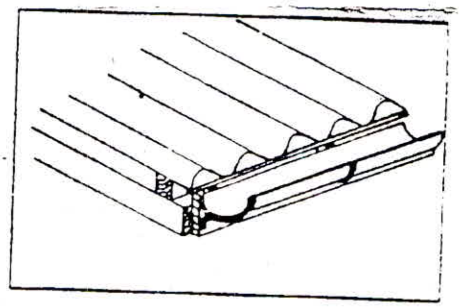


Figure 8: Semi-circular gutter

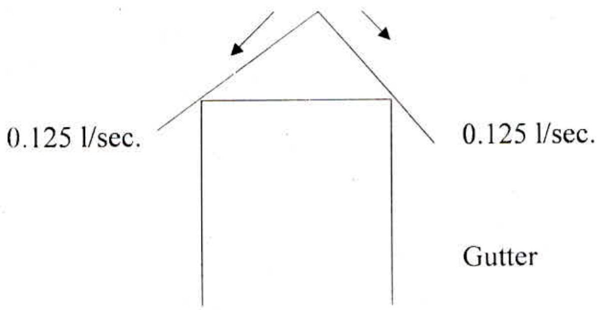
5.2.1 Size of gutters

For deciding the size of gutter the maximum rainfall intensity should be known. This can be illustrated as follows;

Consider Maximum rainfall intensity as 10 mm/hr. During heavy rains with maximum intensity of 10 mm/hr and taking 90% as runoff coefficient (assuming net loss of 10% rainfall). The maximum rate of runoff from roof on either side is as follows:-

$$= \frac{10}{1000} \times \frac{50 \times 0.9}{2 \times 3600}$$

$$= 0.000125 \text{ cum/sec.} = 0.125 \text{ litres/sec.}$$



The minimum slope of gutter is provided as 5 cm in a length of 10 m i.e. with the discharge calculated as above the diameter of gutter can be found. It is advisable to provide gutter of 15 to 20% over capacity. This has been done for different rainy intensity and roof top area and the diameter of gutter and width of G.I. sheet is given in following Table 2 for use.

Table 2 : Diameter of Gutter and Width of G. I. Sheet

Rainfall Intensity(I) (in mm/hr)		10	15	20	25	30	35	40	45	50	60	70	80	90	100	
Roof Top Area (A) (sq.m)		Diameter (D) of Channel and Width (W) of G.I. Sheet (in mm)														
10	D	20	23	26	28	30	32	33	35	36	39	41	43	45	47	
	W	51	56	60	64	67	70	72	74	77	81	84	88	91	93	
20	D	26	30	33	36	39	41	43	45	47	50	53	56	58	61	
	W	60	67	72	77	81	84	88	91	93	99	103	108	112	115	
30	D	30	35	39	42	45	48	50	52	54	58	62	65	68	71	
	W	67	74	81	86	91	95	99	102	106	112	117	122	127	131	Provide minimum Diameter of channel - 100 mm and Width of sheet - 176 mm
40	D	33	39	43	47	50	53	56	58	61	65	69	72	76	79	
	W	72	81	88	93	99	103	108	112	115	122	128	134	139	144	
50	D	36	42	47	51	54	58	61	63	66	71	75	79	82	86	
	W	77	86	93	100	106	111	115	120	124	131	138	144	149	154	
60	D	39	45	50	54	58	62	65	68	71	76	80	84	88	92	
	W	81	91	99	106	112	117	122	127	131	139	146	152	158	164	
70	D	41	48	53	58	62	65	69	72	75	80	85	89	93	97	
	W	84	95	103	111	117	123	128	133	138	146	153	160	167	172	
80	D	43	50	56	61	65	69	72	76	79	84	89	94	98	102	
	W	88	99	108	115	122	128	134	139	144	152	160	167	174	180	
90	D	45	52	58	63	68	72	76	79	82	88	93	98	102	107	
	W	91	102	112	120	127	133	139	144	149	158	167	174	181	188	
100	D	47	54	61	66	71	75	79	82	86	92	97	102	107	111	
	W	93	106	115	124	131	138	144	149	154	164	172	180	188	194	
150	D	54	63	71	77	82	87	92	96	100	107	113	119	124	129	
	W	106	120	131	141	149	157	164	170	176	188	197	207	215	223	
200	D	61	71	79	86	92	97	102	107	111	119	126	132	138	144	
	W	115	131	144	154	164	172	180	188	194	207	218	228	237	246	
250	D	66	77	86	93	100	105	111	116	121	129	137	144	150	156	
	W	124	141	154	166	176	186	194	202	209	223	235	246	256	266	
300	D	71	82	92	100	107	113	119	124	129	138	146	154	161	167	
	W	131	149	164	176	188	197	207	215	223	237	250	262	273	283	
400	D	79	92	102	111	119	126	132	138	144	154	163	172	179	186	
	W	144	164	180	194	207	218	228	237	246	262	276	290	302	313	
500	D	86	100	111	121	129	137	144	150	156	167	177	186	195	203	
	W	154	176	194	209	223	235	246	256	266	283	299	313	326	339	
1000	D	111	129	144	156	167	177	186	195	203	217	230	242	253	263	
	W	194	223	246	266	283	299	313	326	339	361	381	400	417	433	
2000	D	144	167	186	203	217	230	242	253	263	282	298	314	328	341	Diameter to be limited to - 300 mm and Width of sheet - 510 mm
	W	246	283	313	339	361	381	400	417	433	462	489	513	535	556	
3000	D	167	195	217	236	253	268	282	294	306	328	347	365	382	397	
	W	283	326	361	391	417	441	462	482	501	535	566	594	620	644	

5.2.2 Number and type of gutters

The type of roof decides the number of gutters to be installed. Single roof system needs one gutter only. For a multiple roof house, the roof valley where two-roof plane meet, serves the passage for the rainfall runoff from two roof planes before the collected rain reaches the gutter. In such case the size/ diameter of gutter should be determined for flow from both the roof for maximum intensity rainfall. The material used to fabricate gutter are;

- Galvanized iron sheet 18 to 20 gauge. The edges of gutters should be reinforced by bending the edge and fixing G.I. wire in it.
- PVC rigid pipe and be half cut for using of gutters
- Large diameter bamboo can be half cut to gutters.

5.3 Downspout or Inflow Pipes

The pipe, which connects the gutter to the tank/ cistern, is known as Downspout or Inflow pipe (Fig. 9). The pipes normally consist of G.I. sheet bent in pipe shape, rigid PVC pipe or galvanized iron pipe of A Class. The size of pipe should be able to carry the rainwater being harvested. Normally, the minimum diameter of pipe is kept 10 mm. The downspout should be provided with a 20-mesh wire screen at inlet to prevent dry leaves or debris from entering it. This is known a leaf screen.

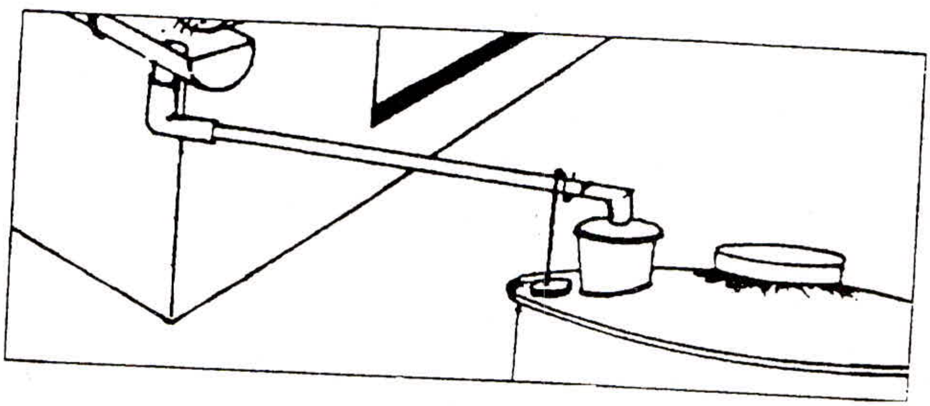


Figure 9: Down pipe

5.4 First Flush Diverter

The first flush diverter is incorporated in the rooftop rainwater harvesting system to dispose off the first flush water so that it does not enter the tank (Fig. 10). A procedure for eliminating the foul flush after a long dry spell deserves particular attention. The first part of each rainfall should be diverted from the storage tank since it is most likely to contain undesirable materials like dust, leaves, twigs, insect bodies, animal faces and other air-borne residues accumulated on the roof between rainfalls. Generally water captured during the first 10 minutes of rainfall during a event of average intensity is unfit for drinking purposes. The quantity of water lost by diverting this runoff is usually about 14 litres/m2 of catchment area.

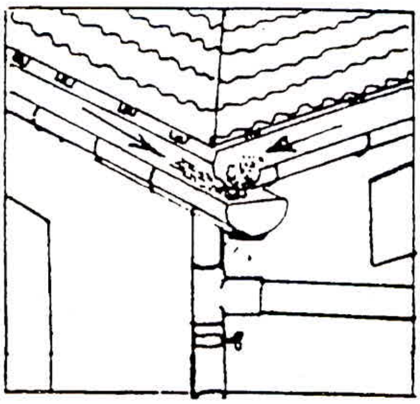


Figure 10: First flush pipe

The first flush diverter routes the first flow of water from the roof surface away from storage tank. The first flush diverter is a bye-pass arrangement made at the point where in the downspout is connected to filter. The leave screen removes the large debris like leaves, twigs, etc. that fall on roof, the first flush diverter removes the smaller contaminants such a dust, pollen, bird dropping, etc. This can be done in two ways;

a) Simple diversion of first rains: In this the downspouts/ down pipe is moved away from the inlet of storage tank during initial rains until clean water flows.

b) Installation of foul flush system: By making an inbuilt stopper for stopping entry of initial rainwater in the filter and conveying the water into a bye pass pipe-carrying water outside the system. After few minutes of rain the bye-pass stopper is closed and stopper at filter is opened.

5.5 Filter

This is an important component for purification of roof water which is mixed with impurities like dust, bird dropping etc. This cannot only affect the water quality but can decrease the storage capacity of storage tank due to siltation. The filter is placed on or between inflow and storage tank. The filters can be made in several ways utilizing locally available sand, gravel, etc. Sand filters are commonly use filter media. Sand filters are easy and cheap to construct.

5.5.1 Aluminium bucket filter

The aluminum bucket filter is used for ferro - cement storage tank.. In an aluminium bucket having top diameter of 0.45 m and bottom diameter as 0.30 m and height of 0.45 m., 20 holes of 5 mm diameter uniformly distributed are provided at the bottom. The bucket is filled with the following filtering media; (Fig. 11).

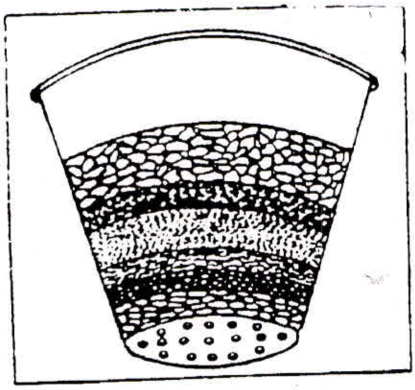


Figure 11: Filter unit

Layer	Material	Thickness In mm	Position
I	Gravel of 20 mm size	50	At the top
II	Charcoal	50	
III	Coarse sand	50	
IV	Coconut fiber	50	
V	Pebbles of 10 mm size	10	
VI	Gravel of 20 mm size	50	At the bottom.

5.5.2 GI Sheet / ferro cement filter

Filters can be made using thick G. I. sheet (thicker than 18 gauge) or with ferro-cement. The container normally circular in shape is kept over top of reservoir. The container is filled with stone boulders, coarse sand, coconut fibre, gravel of different size. Perforated ferro-cement plate with PVC pipe pieces of 10 mm diameter is casted for making 180 holes in the plate and is kept at the bottom. The filter is made using following material:

I	Layer -	40 mm thick layer of natural gravel of 12 mm size
II	Layer -	30 mm thick coconut fibre
III	Layer -	80 mm thick sand of over 1 mm size
IV	Layer -	30 mm thick coconut layer
V	Layer -	80 mm round gravel

5.5.3 Dewas filter

On line filters have been designed to clean the roof water in Dewas district, by the local administration and technical experts. This was mainly used for directly recharging the ground water. Such filters can also be used on line between inflow pipe and storage tank. This filter can be easily made using PVC pipe (4 Kg/m2 pressure) of size 1.2 to 2 meter in length. The diameter of pipe is normally 6" to 8" depending on the roof area and rainfall. Readymade filters are also available.

The filter is horizontally divided into three equal compartments separated by two PVC meshes to prevent the movement of pebbles of filter media from one compartment to other. The filter pipe is fitted with the reducers of 140 mm x 63 mm. at both the end to ensure the connectivity with the inflow and outflow pipe. The three compartments are filled with filter media consisting of pebbles of size of 6 mm to 40 mm from water entry point the pebble size varies from 6 to 12 mm in first compartment, 12 to 20 mm in middle and 20 to 40 mm in third compartment towards outlet side.

The filters are shown in Fig. 12, 13, & 14.

Readymade filter from the manufacturers mainly those associated with manufacturing irrigation implements are readily available. These are available from different flow rates varying from 3 m3/hr to 25 m3/hr with diameter varying from 180 mm to 490 mm.

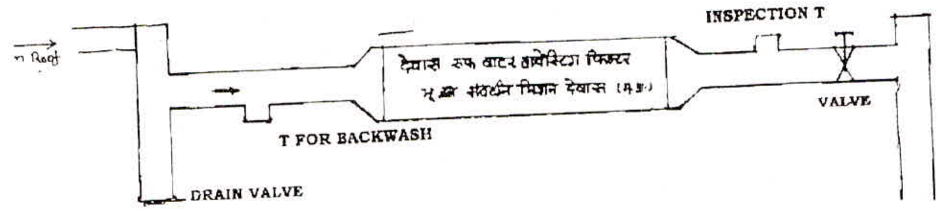


Figure 12 : Dewas roof top rain water harvesting filter

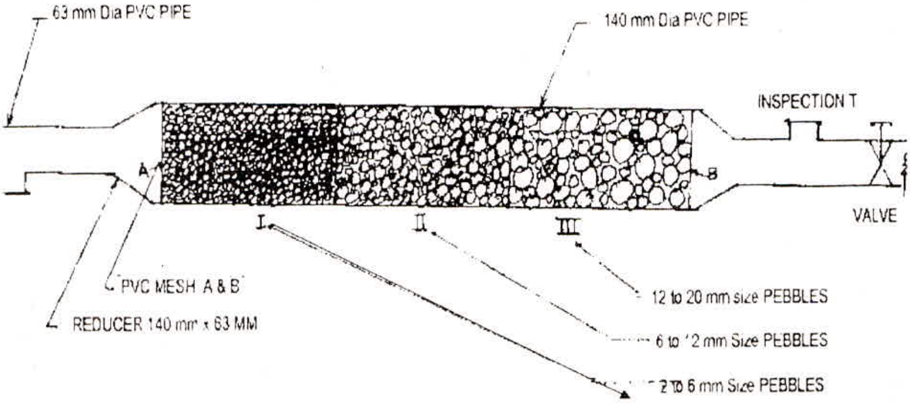


Figure 13 : Dewas filter details

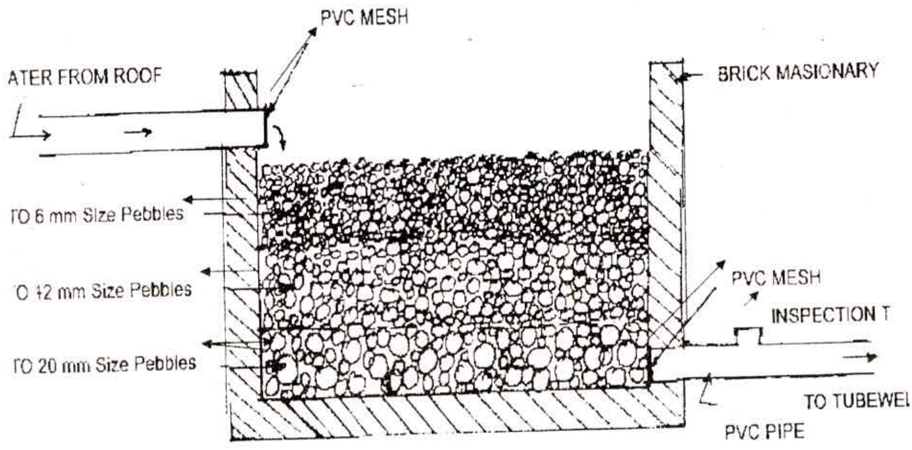


Figure 14 : Filter pit for roof top area

5.6 Storage Tank or Cistern

The storage tank is the most expensive component of the roof top rainwater harvesting system. The capacity of the storage tank is controlled by several variables like water demand, rainfall availability, length of dry period, the roof top area etc. Basic requirement of the Storage Tank are as follows:

- Tank should be opaque to inhibit algae growth
- Storage tank should be covered and vents screened to discourage mosquito breeding
- Tank should be durable and watertight
- A smooth clean interior surface of tank is necessary.

The storage tank should be located as close to the house and demand points as possible to reduce the distance of water to be transmitted. The tank inlet should be lower than the lowest downspout from the rooftop. Any tank overflow and drainage should be routed away so that it does not effect the foundation of tank.

A myriad of variations of storage tanks have been used over the centuries in different parts of India and world. The tanks in vogue are described below.

5.6.1 Reinforced concrete tanks

Concrete tanks are either poured in place or prefabricated. These can be constructed above or below the ground surface. Concrete tanks are constructed of stacked rings with sealant around the joints. Concrete tanks are susceptible to cracking and leaking, "Leaks though" can be easily repaired but the tanks need to be drained for repair. Concrete tanks are expensive to construct. These require expertise of skilled technicians and costly material like reinforced steel. These are difficult to construct and maintain in rural areas. One possible advantage of concrete tank is, however, a desirable taste imparted to the water by calcium in concrete being dissolved by the slightly acidic rainwater.

5.6.2 Galvanized sheet metal tanks

These tanks are attractive option for urban areas but transporting fabrication facility like welding machine, etc. or transporting readymade metal tanks to rural areas is very difficult. These tanks are required to be replaced after 5 to 7 years due to corrosion and as such may prove a costly proposition for rural areas.

5.6.3 Polypropylene or plastic tanks

These tanks are readily available as factory finished products in different capacities. These are to be transported from manufacturing site/ wholesale dealer to site and are likely to be damaged. The cost is also comparatively high. These are suited to urban areas.

Fiberglass tanks are also used for storing water. Though these are durable but are very costly.

5.6.4 Ferro-cement tanks

Ferro-cement is a low cost steel and mortar composite 'material'. Ferro-cement a flexible material is being successfully used for moulding into the shape. (Fig. 15). Circular/ Cylindrical tanks are most commonly used due to low cost and saving in 'space'. Circular shapes are structurally durable. The Ferro-cement tanks of capacities 5000 to 15000 litres are usually constructed above ground level. The tanks constructed above ground level have advantages such as (a) ease in finding structural problems/ leaks, (b) easy to maintain and clean and (c) easy to draw water. Water from these tanks can be drawn by gravity. For higher capacity tanks underground tanks or partially underground tanks are constructed. Some kind of manual or power lifting devices need to be used for drawing the water. The storage tank is provided with cover on the top to avoid contamination of water from external sources. The cover is in dome shape having a raise of about 20-30 cm in the middle. The dome is provided with two circular openings one for manhole and another for accommodating the filter. A lid covers the manhole avoiding exposure to outside environment. The storage tanks is provided with pipe fixtures at appropriate places to draw the water to clean the tank and dispose of excess water. These are tap or outlet drainpipe and overflow pipe respectively. In underground tank small hand pump is provided to draw water.

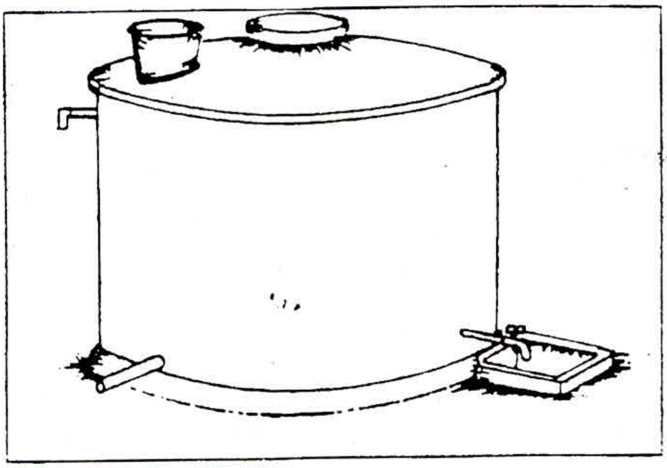


Figure 15: Storage tank

Water storage tank using Ferro-cement technology can be constructed either using a pre-fabricated mould or using a skeletal cage. Both these methods have their own advantages and cost of construction is comparative.

5.6.5 Pre-fabricated mould technique

It makes the construction of storage tank easy. Because of use of mould a perfect cylindral shape of tank is achieved. Once a mould is assembled at site, wire mesh can be tightly wrapped around it with little expertise. (Fig. 16). A single prefabricated mould could be used repeatedly for constructing number of water storage tanks. The economics of construction depends on cost of fabrication of mould, cost of transportation for one site to another and number of structures to be constructed.

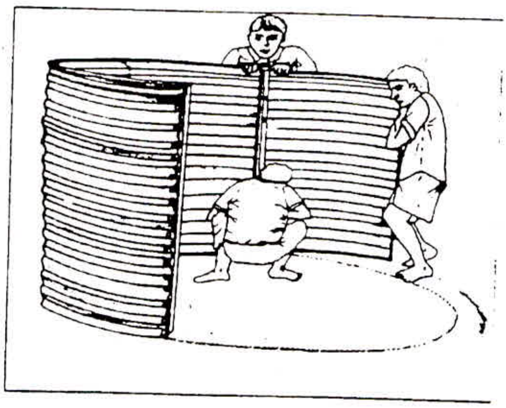


Figure 16: Erection of mould

5.6.6 Skeletal cage technique

A cylindrical skeletal case is prepared at the site using mid steel rods which are cut and bent to different shapes and sizes based on dimension of storage tank. Preparation of skeletal cage requires some degree of skill and consumes time. As the skeletal cage is wrapped with two layers of wire mesh, one inside and other outside plastering need to be done carefully filling all the gap in between. By using skeletal cage technique tanks of any dimension can be readily prepared at the site of construction. Cost of fabrication and transportation of mould is avoided. This method is widely used for construction of domestic roof water harvesting storage tanks. The following steps are involved in construction for storage tank:

1. Selection of site :
   - Site should be close to house to reduce cost of down pipe
   - Site should have good drainage and away from cattleshed
   - Site should be away from trees to avoid littering from leaves and roof project
2. Marking the circular foundation for the diameter of tank of required storage capacity on the ground.
3. Excavation of Foundation in the marked area to a depth of 0.3 m for clayey soil and 0.15 m for other soil.
4. Compacting the excavated pit by using temping rod.
5. Placing cement concrete in foundation of 1:4:8 mix
6. Preparation of Elements of Skeletal Cage.
7. Marking of Foundation
8. Assembling the elements
9. Tying of Mesh over Skeletal Cage
10. Plastering Tank's outside wall
11. Plastering Tank's inside wall
12. Casting of Tank Floor
13. Curving the Tank

These operations from Step 2 to Step 13 are further explained with illustrative note and are given in Fig. 16 to 29.

5.6.7 Collection pit

A collection pit is a rectangular pit dug below ground level beneath the tap of storage tank. The storage tank is elevated above ground by 45 to 50 cm for keeping vessels for water collection.

5.7 Ground Water Recharge Facility

The outflow from the storage tank can be utilized for recharging ground water. For this the existing open wells, borewell or tubewell can be utilized to divert the overflow from the tank to the well through flexible pipes. This would involve nominal expenditure. Since the roof top rain water has already been filtered before entering storage tank, the overflow from the tank would be clean for directly recharging ground water through well.

Step 2: Marking for Circular Foundation

* Clear the vegetation and top loose soil at the construction site
* Level the cleaned site
* Mark a cricle of diameter'Df' on the ground using a rope and peg as shown in Fig. 17

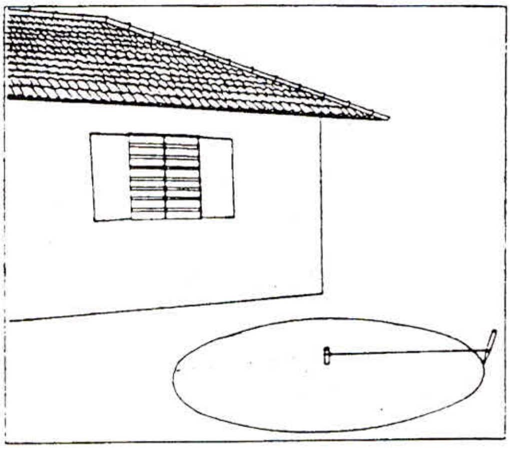


Figure 17 : Marking of circular area

Step 3: Excavation for Foundation

* Excavate the soil on the marked area to a depth of 0.3m for clayey soils and 0.15m for other type of soils as shown in Fig. 18

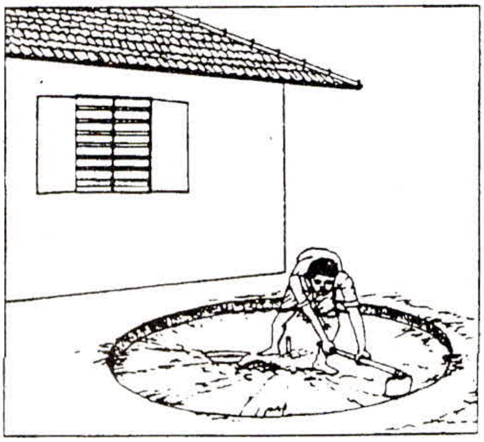


Figure 18 : Excavation of foundation

Step 4: Compacting the Excavated Pit

* Sprinkle water on the excavated pit and compact the ground by using tamping rod as shown in Fig. 19

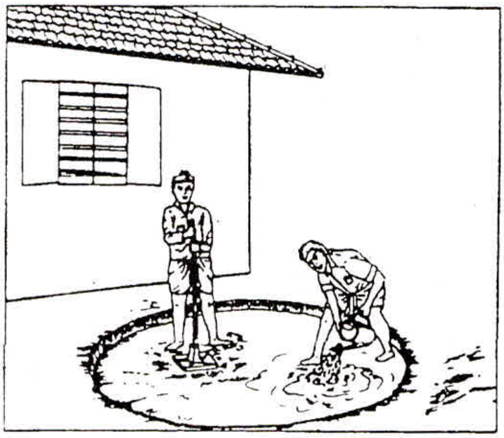


Figure 19 : Compaction of pit

Step 5: Placing Cement Concrete in Foundation

* Provide stone packing to a depth of 0.15m in case of black cotton soils. Other types of soils do not require stone packing
* Pour water and compact the stone packing by using rammer.
* Prepare Plain Cement Concrete of 1:4:8 mix (1 cement : 4 sand : 8 stone aggregate of 40mm size)
* Pour the concrete into the excavated pit and compact (Fig. 20)
* Keep the foundation height one inch above the ground level.
* Allow the base concrete to set for 12 hours.

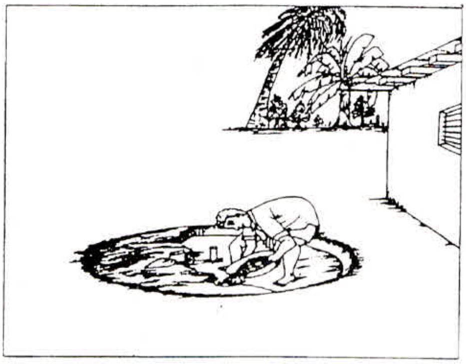


Figure 20 : Placement of foundation

Step 6: Preparation of Elements of Skeletal Cage

Skeletal cage is an assembly of 4 types of elements (of different shapes) made from mild steel rods. They are

1. 'U' shaped elements
2. 'L' shaped elements
3. 'I' shaped elements
4. 'O' shaped elements

These shapes are prepared to the required dimensions (height, lenght and diameter) and assembled together using binding wire for making the cage. Fig. 21 shows the position of these elements in the cage .

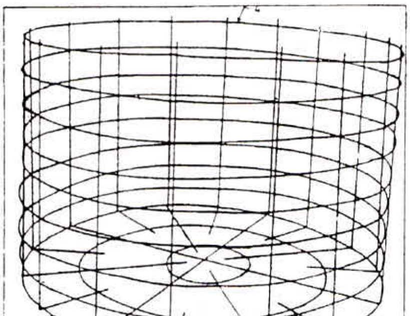


Figure 21 : Elememts of skeletal cage

Step 7: Marking on the Foundation

* Mark the centre of the foundation
* Draw three circles of diameteres D_1, D_2 and D_3 on the foundation, in such a way that, the center of these circles coincide with the center of foundation
* Divide these circles into 16 equal parts.

Step 8: Assembling the Elements

* Place the two 'U' shaped rods vertically over the foundation, perpendicular to each other.
* Place the outer, middle and inner rings over the two 'U' shaped rods, coinciding with the circular marking and tie the intersections with binding wires (Fig. 22)
* Place and tie 4 'L' shaped elements on the centre marking of each quarter, each rod extending upto the inner-most ring (Fig. 23)
* Place and tie 8 'I' shaped elements on the remaining markings, each element extending to the middle ring (Fig. 23)
* Place and tie all the rings of diameter 'D1' over the vertical reinforcement at a uniform spacing of 20 cm.(Fig. 24)
* For providing cylindrical shape to the skeletal cage, fix cross bars at the top of skelatal cage and tie with ropes, 3-4 vertical rods to wooden pegs pegged to the ground.

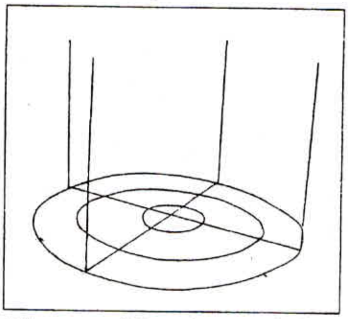


Figure 22: Assembling 'U'shaped - elements

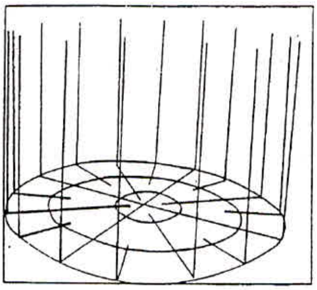


Figure 23: Assembling 'L'shaped - and 'L' elements

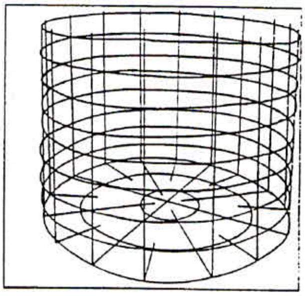


Figure 24: Assembling and tying rings

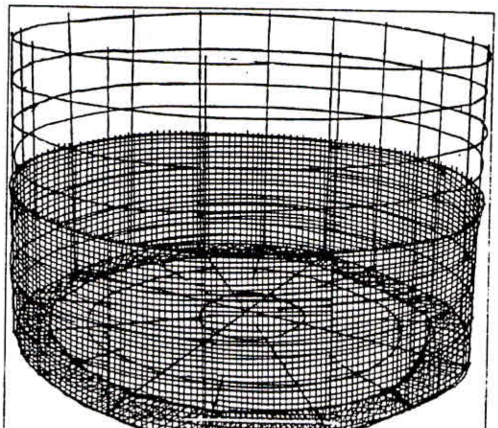
Step 9: Tying of Mesh over Skeletal Cage

Select the reinforcement mesh that suits the capacity of the tank from the table below :

Capacity of Tank (Lt)	**5000 & 6000**	**7000 & 8000**	**9000 & 10000**
Specification of wire mesh	Chicken wire mesh of 22 gauge and 12 mm (½") opening	Chicken wire mesh of 20 gauge and 25 mm (1") opening	Chicken wire mesh of 20 gauge and 25mm (1") opening

Note: *Woven wire mesh of rectangular opening, of same specifications mentioned above on be used if chicken wire mesh is not available.*

Figure 25: Mesh over skeletal cage



Step 10: Plastering Tank's Outside Wall

* Prepare cement slurry (cement mixed with water) and add anti-rust agent (chrometrioxide tablets).
* Apply one coat of cement slurry (mix of cement and water) over the mesh using a painting brush.
* Prepare cement mortar of 1:3 mix (1 cement : 3 sand)
* Apply the first coat of cement mortar on the outer surface to a thickness of 1 cm. Care has to be taken to fill the space between the two mesh layers completely. This could be done by using a GI sheet; slightly curved in shape to be held close to the skeletal cage from inside by a person, while cement mortar is applied by another from outside (Fig. 26)
* Leave 10 cm of mesh projected above the cage unplastered in order to join the dome skeletal to the tank.
* After 2 hours, apply second coat of mortar to a thickness of 1 cm.

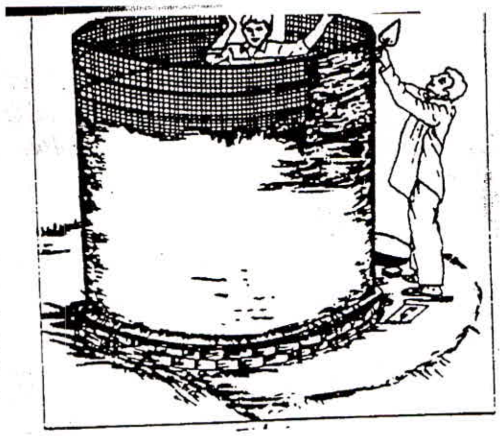


Figure 26: Plastering outside tank wall

Step 11: Plastering the Tank's Inside Wall

* After two hours of outside plastering, apply cement slurry to the inner surface of the tank wall.
* Prepare cement mortar of 1:3 mix and add water proof compound in liquid form.
* Apply first coat of cement mortar of 1 cm thickness on the inner surface, starting from bottom of the tank moving laterally and progressing towards the top (Fig. 27)
* After 2 hours, apply second coat of mortar to attain a total wall thickness of 2 cm.
* Apply cement slurry as final coat on outer and inner surfaces of tank and smoothen using coir brush.

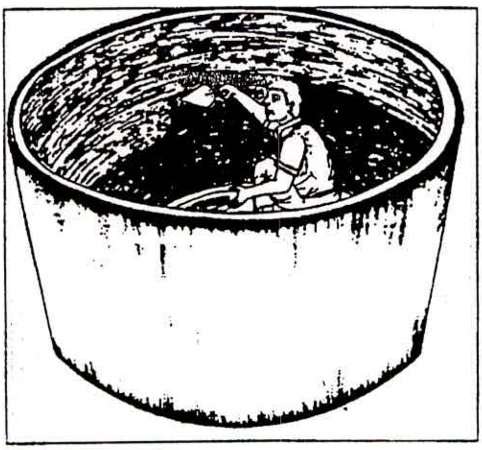


Figure 27 : Plastering inside tank wall

Step 12: Casting of Tank Floor

* Sprinkle cement slurry over the foundation concrete.
* Prepare Plain Cement Concrete 1:2:4 mix (1 cement : 2 sand : 4 stone aggregate of 12 mm size), pour it over the base and compact to a thickness of 50 mm (2 inch)
* Finish the floor base using cement mortar keeping the slope towards the drain pipe (Fig. 28)
* Finish the wall and base joints (inner and outer) with cement mortar
* Afte 12 hours of setting of tank floor, add waterproof compound (liquid form) with cement slurry and apply it over inside surface of tank and smoothen by coir brush.

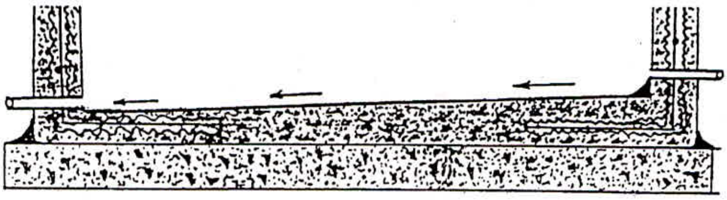


Figure 28 : Tank floor

Step 13: Curing the Tank

* Cure the tank for 14 days by pouring water thrice a day or covering the tank with wet gunny bags (Fig. 29)
* In coastal areas, after curing for 14 days, apply rust proof paint over the outer surface of tank wall.

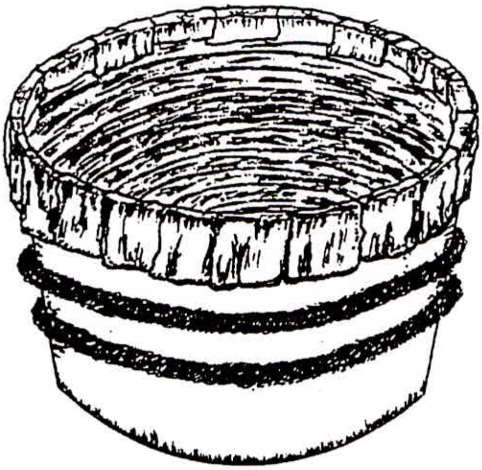


Figure 29 : Curing the tank

Chapter - VI

Purification of Water For Drinking

Water stored from rooftop is presumed to be pure and potable. Rainwater while passing through gutter etc. comes into contact with dust debris, leaf, litter, etc. The water collected in tank is stored for about 100 to 150 days before using as drinking water. During this time the water is in contact with tank wall and pipefittings. If the stored water is accidentally exposed to outer environment, growth of algae and breeding of mosquitoes can take place. The chemical and bacteriological contamination of roof water can be prevented by proper and regular maintenance of the system.

To detect bacteriological contamination the samples of stored water should be collected and analyzed. Water from the tap of the tank is taken in clean and dry sterilized glass or plastic bottles of 100 ml for getting the sample tested for presence of E-coli bacteria.

The presence of E-coli indicates contamination. The water can be disinfected by using bleaching powder. The dosage recommended is 10 milligram bleaching powder containing 25% of free chlorine per litre of water. After adding bleaching power, the water should be stirred and kept without use for about 30 minutes.

Chlorine tables are also available and can be used. One tablet of 0.5 g is enough for 20 litres of water.

Chapter - VII

Management and Maintenance of Roof Top Rain Water Harvesting

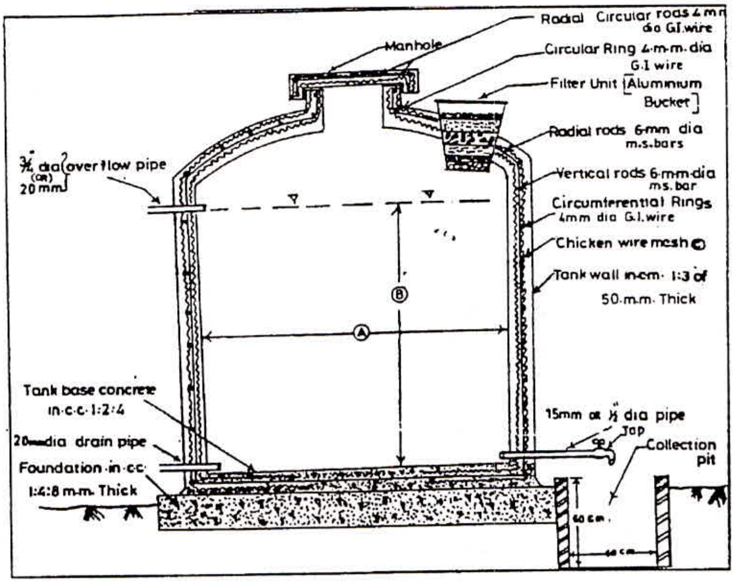
Maintenance of the system which is mostly household based is simple and is best maintained by users themselves. Cleanliness of surrounding as well as system including its various components like roof gutters, filtration unit and storage tank can ensure supply of potable water. Following are some of the points for maintenance of the system :-

- The surrounding of the storage tank should be kept hygienic and clean.
- The algae from roof tiles should be removed before the monsoon.
- The gutters and downspout should be cleaned before first monsoon and also during rainy season.
- The storage tank should be completely drained and cleaned before monsoon.
- The first 15 to 20 minutes of rainfall based on its intensity should be avoided using first flush diverter.
- The filter material should be replaced every rainy season.
- The inlet and outlet pipes should be covered with closely knit nylon nets or cap during non-monsoon period to avoid entry of insects, mosquitoes, etc.
- The leakage and cracks in the ferro-cement storage tank should be repaired by cement plastering.
- The lid of storage tank should not be burdened with heavy lad and persons.
- Training should be provided to roof top rainwater harvester in maintenance of the system.

Chapter - VIII
Storage Tanks

Keeping in view the details and designs of different components of the rain harvesting system, any particular scheme of desired capacity would be based on roof top size, rainfall amount and intensity. The computation of roof area and quantity of rainwater to be harvested based on rainfall has already been discussed in detail. The gutters, downspouts and storage tanks can accordingly be designed. The gutters and downspouts are having simple designs, the details for which have already been given. The most important component is that of storage tank. The dimension and design details are therefore discussed and elaborated in this section. Design details of storage tank construction using skeletal cage are given in the Fig. 30.

Design Details of Storage Tank
(Construction using Skeletal Cage)



A - Internal diameter, B - Net height, C - Chickenwire mesh
Figure 30 : Design details of storage tank

Dimensions of Storage Tank

The ferro-cement storage tank of 5000 and 10000 litres capacity would be constructed on the ground and water can be drawn from these by simple taps and collection tank. The design of this tank on the ground to serve as implementation model is given in Fig. 30.

The ferro-cement tank of 25000 and 100000 litres capacity would be underground. The withdrawal of water from these tanks would be through hand pumps.

For small capacity tanks there can be variation based of roof top area and family size and hence in the following Table - 3 gives dimension of storage tanks of 5000, 6000, 7000, 8000, 9000, 10000, 25000 and 100000 litres.

Table - 3: Dimensions of Storage Tank

Tank Size (in litres)	Dimensions (in meters)		Wire / Chicken mesh specifications
	Internal Diameter	Net Height	
5000	2 . 00	1 . 65	22 aguge 12 mm (1/2") opening
6000	2 . 00	1 . 90	- do -
7000	2 . 30	1 . 70	- do -
8000	2 . 30	1 . 90	- do -
9000	2 . 60	1 . 70	20 gauge 12 mm (1/2") opening
10000	3 . 00	1 .70	- do -
25000	3 . 00	2 . 00	- do -
100000	6 . 00	3 .50	- do -

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INDIAN NATIONAL COMMITTEE ON HYDROLOGY (INCOH)
(IHP National Committee of India for UNESCO)

Constituted by the Ministry of Water Resources in 1982

INCOH Activities Related to UNESCO's IHP-VI Program

India is actively participating in IHP-VI activities and a detailed program has been chalked out in accordance with IHP-VI themes towards preparation of reports, taking up research studies, organisation of seminars/symposia at national and regional level, and promotion of hydrological education in the country. It is envisaged to participate in all the relevant and feasible programs identified under the various focal areas of IHP-VI themes as given below.

India's participation in IHP-VI program

Theme	Selected Focal Area
1. Global Changes and Water Resources	Integrated assessment of water resources in the context of global land based activities and climate change.
2. Integrated Watershed and Aquifer Dynamics	Extreme events in land and water resources
3. Land Habitat Hydrology	Dry lands
4. Water and Society	Raising public awareness on water interactions
5. Water Education and Training	Continuing education and training for selected target groups

INCOH Publications

Publication of Jalvigyan Sameeksha Journal

To disseminate information and promote hydrological research in the country, INCOH brings out the Journal *'Jalvigyan Sameeksha'* (Hydrology Review Journal). The papers published in the Journal are by invitation only. The Journal is widely circulated amongst major organisations and agencies dealing with water resources.

Publication of State of Art Reports

In pursuance of its objectives to periodically update the research trends in different branches of hydrology, state of art reports authored by experts identified by INCOH from various institutes and organisations in India, are published regularly. These reports are circulated free of cost to central and state government agencies including academic and research organisations.