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THE RURAL WATER SUPPLY AND ENVIRONMENTAL PROGRAMME, AMHARA REGION

DESIGN and CONSTRUCTION MANUAL on RAIN WATER ROOF CATCHMENT SYSTEM For HUMAN USE

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1. INTRODUCTION

1.1 General

It is well known that the most common sources of water for human use are ground water, surface water and rain water.

Rain water harvesting means the direct collection of rainwater from roofs and other purpose built catchments (ground or rock catchments) for either human or agricultural use (livestock consumption, nurseries and irrigation).

The contribution of rainwater can make to a water supply will depend on the reliability, regularity and quantity of the rainfall in an area. In wet seasons, directly collected rainwater can provide an important source of drinking water. Rainwater can be collected by:

- The family – roof collection.
- Institution – roof and surface collection at clinics, hospitals, feeding centers, schools, churches.
- The community – ponds, small storage reservoirs.

Based on the type of catchments from where rainwater is collected, rainwater harvesting is divided in to two, namely ground catchments and roof catchment.

1. **Ground catchment** – it is a general term describing all systems, which uses the ground surface as a catchemnt area. These includes natural, treated and covered surfaces, cement or tarmac covered surfaces such as roads, pavements, and suitable rock outcrops (rock catchment). Ground catchments are used where suitable roof surface is not available. The main advantage of using the ground as catchment surface is that water can be collected from a large area. This is particularly advantageous in areas of low rainfall.

The main disadvantage in using the ground as a collection surface is that the water supply can easily become contaminated, and since it can only be stored below the surface it is generally less convenient to withdraw water for use. Although ground catchment systems are sometimes used to collect rainwater for drinking purposes, it is strongly recommended, where possible that this water should be boiled, chlorinated, or at least passed through a slow sand filter before being consumed. For non domestic purposes, however, the water is generally suitable.

2. **Roof catchment-** it is the most common type of catchment used for harvesting rainfall. Corrugated iron sheet, concrete, plastic and tiles roof all make good roof catchemnt surface. Roof catchemnt systems offer a simple and fairly inexpensive method of providing water to individual homes and institutions. Roofs can be adapted with pipes and gutters to trap water and transport it in to a water roof reservoir.

Roof runoff from buildings is usually of a higher quality than surface (ground) runoff and can often be used without treatment as the elevation of roofs protects them from contamination and damage which is common to ground catchments. It requires minimum maintenance, gutters and downpipes must be cleaned often to prevent clogging and contamination. Hence our focus in this design manual will be on the design of rainwater roof catchment system for human use.

The rainfall pattern in Ethiopia comprises a 3-4 month long rains varying between May and October and 8-9 months of relatively little rain a part from 1-2 months of small rains at different periods and intensity dependent on the area of the country. Since it would require 5 mcu of storage to provide for an average family (5 family members) for a period of 50 days without replenishment, it is unlikely that rainwater harvesting will be a viable sole supply alternative on an individual family basis in many, if any, circumstances.

Rainwater harvesting can however provide a careful supplemental supply of high quality in many circumstances and may be particularly useful in mixing with alternative supplies in those areas where poor quality of other supply exist.

1. 2 Advantages and disadvantages of rainwater roof catchment system.

The advantage of rainwater collection system over other water supply schemes are:-

- The quality of rainwater is high
- The system is independent, therefore, suitable for scattered settlements
- Local materials and craftsmanship can be used in rainwater system construction
- No energy costs are needed to run the system
- Ease of maintenance by the owner
- Can be constructed in the yard of the user if the house has a suitable roof.

Some disadvantages or limitations are:-

- The high initial capital cost may prevent a family from buying a system. Arrangements for grant and low interest loans may have to be made.
- The water available is limited by rainfall and roof area. Supplementary water sources may be needed. For long dry seasons, the required storage volume may be too high.
- Mineral - free water has a flat taste while people may prefer the taste of mineral - rich water.
- Mineral-free water may cause nutrition deficiencies in people who are already on mineral - deficit diets.

1.3 The feasibility of rainwater roof catchment system

The initial step in planning and developing a rainwater roof catchment system involves an appraisal of the feasibility of the system. The feasibility can be determined in light of technical, economic, social, environmental and gender issues.

Technical Issues

The initial consideration of the feasibility of the rainwater roof catchment system concerns water availability as compared to its use or demand. The yield or supply of the system depends on how many rainfalls during the years and the availability of the rainfalls. The demand imposed on the community depends on water use. In household water is used for drinking, cleaning, cooking and washing. In rural developing areas each person may use between 15 - 30 liters/person/day.

Reliable rainfall data are required when determining the supply from the system. Rainfall data for a minimum of 10 years period is preferable. The information can be obtained from the government meteorological office, from an agricultural ministry, from university or from an air port and similar other organization that might have the data. If rainfall data for a particular region is not available, data can be obtained from the closest station related to the particular region in question.

The next steep involves estimating the total demand and comparing it with the supply possible from the rainwater catchment area. If the supply exceeds the demand, the rainwater roof catchment system is feasible from technical point of view, based on total maximum supply over a period of the year.

If the supply is less than the demand, then possible solutions include increasing the catchment area or reducing the demand for rainwater. For example, use the rain water for drinking and cooking only, and obtain water required for cleaning and washing from another source (well, river, etc,)

Economic Issues

The rainwater roof catchment system must be economically feasible to the households. Costs of the proposed rainwater roof catchment system must be evaluated and compared with the costs of alternative water supply improvement. Costs of catchment and storage depend on what existing structures can be used and the local prices of additional building materials. Though the system is economically feasible it must also be affordable to the household. If the use of rainwater roof catchment system is to be widespread in a region/an area, financing the tanks should be available from the donors to the community.

The value of rainwater rises with increased distance to or in accessibility of other water sources. This means that if rainwater becomes the only source, its value is extremely high. This high investment in a large reservoir becomes cheaper in relation to the value of water.

Social Issues

Once it has been tentatively established that it is technically and economically feasible to construct the rainwater roof catchment system, the next step involves the social and community assessment. This step is critical to the success of the catchment scheme.

Social issues relate to the needs, perceptions, desires, beliefs, experience and existing practices of the community. For any rainwater catchment system project to succeed, whether at household or across a whole region, it must address the real felt need within a community and be socially acceptable. Further more, not only should be affordable, but people must accept and willing to pay for it.

The project developer must determine the extent of community needs. This must be done in light of traditional practices within the community. The role of women and children in carrying water and the amount of time spent in this activity should be examined. The engineer should collect information on existing catchment technologies and discuss with the community the usefulness of water supplied by a roof system. Users should be informed of the palatability (having good taste and acceptability for drinking) of the rainwater. The community's need for communal versus individual catchemnt system should be evaluated.

The project engineer must also compile a resource inventory of local skills, materials and experience that can be used in rainwater roof catchment system. Materials, which are easy to obtain by local people who know how to work with the materials, will result in a roof system that is cheap and simple to build and repair. An appropriate resource inventory checklist includes availability and cost of materials and constriction skills.

Eventually the community members will decide if they are willing to participate in the project and the amount of time and money households are willing to commit to the project.

Environmental and Gender Issues

In addition to technical, economic and social issues environmental and gender issues need to be considered in designing a sustainable rainwater roof catchment system.

In general, before designing a rainwater system the following questions should be given attention.

1. For which purpose is the rainwater harvesting to be used?
2. What is the likely consumption of water by the users?
3. What amount of water can be harvested?
4. What is the rainfall pattern, and how is rainfall distributed during the year?
5. Which construction materials are available?
6. What is the cost of the system construction?
7. By how much can costs of construction be reduced by community contribution?

Answers to the above questions will lead to a decision on the size and type of the reservoir to be constructed. Compromises must be made on the basis of the answers.

2. CALCULATION OF DOMESTIC WATER DEMAND AND QUANTITY OF RAINWATER FROM ROOF CATCHMENT SYSTEM

2.1 Estimating domestic water demand

Worldwide, levels of domestic water consumption may vary widely from less than 5 liters/person/day in many of the poorest communities in developing countries to 1000 liters/person /day or more for the very richest communities in developed countries.

Domestic water demand include all water used in and around the home for the following essential purposes:

- Drinking
- Food preparation and cooking
- Personal hygiene (washing hands and body)
- Toilet flushing (where flush toilets are used)
- Washing cloths and cleaning
- Washing pots, pans and other utensils.

Additional domestic water used may include:

- Watering gardens
- Watering animals
- Washing vehicles
- Water for construction
- Recreational uses (swimming pool).

In most case, properly designed household roof catchemnt systems can normally meet domestic demand for essential purposes. In cases where rainfall is low or roof and tank size is small, systems needs to meet at least the first three or two essential purposes of domestic water demand.

Based on the above explanation, in determining the household consumptive use, standards have been developed by WHO and adapted to local conditions. In Table 2.1 below suggested figures have been presented for use in rural areas where minimal water is currently available at household level.

Table 2.1 Water demand for different beneficiary categories (liters/person/day)

It No.	Category	Minimum amount of water demand in liters per day	
		For survival	For healthy production
1	People	10 liters/person/day	20 liters/person/day
2	Health institutions	5 liters/outpatient/day	10 liters/outpatient/day
3	Schools	2 liters/student/day	5 liters/student/day

The following formula is used in estimating the total daily water demand.

Total daily water demand (liters) = Daily water demand (liters/person/day) x Number of people to be served by the system (Formula 2.1)

If we want to calculate the water required for certain number of days, use the following formula.

Total Demand water demand (liters) = Daily water demand (liters/person/day) x Number of people to be served by the system x Number of days for which the water is required (Formula 2.2)

2.2 Calculating potential rainwater supply from roof by estimating runoff

The size of supply of rainwater roof catchment system depends on the amount of rainfall in the area, the area of the roof catchemnt from which the water is to be collected and its runoff coefficient (a function of the type roof finish). For a roof or sloping catchment it is the horizontal plan area which should be measured and used in the calculation of rainwater supply.

An estimate of the approximate, mean annual runoff from a given roof catchment can be obtained using the following formula:

Supply (S) = Rainfall (R) x Roof area (A) x Runnoff coefficient (C) (Formula 2.3)

Where: S = Mean annual rainwater supply in liters (l)
R = Mean annual rainfall of the area in millimeters (mm)
A = Catchment (roof) area in square meters from which rainwater is to be collected (m^2)
C = Runoff coefficient

2.2.1 Different types of roof shapes and their suitability for rainwater roof catchment system.

The shape of any given catchment area has a considerable influence on the catchemnt possibilities, therefore, different types of roofs provide different catchment possibilities. Out of the most common roof types shown in Figure 2.1, the single pitch roof is the most appropriate for roof water harvesting, since the entire roof area can be drained in to a single gutter on the lower side and one or two downpipes can be provided depending on the area.

A more difficult roof for roof water catchment is tent roof. It requires a gutter on each side and at least two dawn pipes on opposite corners. If a tent roof is large enough, it could be drained in to four tanks located at each corner of the house. The hip roof is not very efficient either, since it also needs gutter as all round the building.

Flat roofs can be used for catchments if they are furnished with an edge, keeping the water on the slab until it has drained through the gutter or down pipe. However, using flat roof for rainwater harvesting is not very efficient because of the extended runoff time and the evaporation loses. One way to improve the catchment is to provide the slab with a slopping cement screed.

The most useful roofs are the single and double pitch roofs. The double pitch roof offers many advantages.

2.2.2 Effect of roof finish on rainwater roof catchment system

Not all materials used in roofing finishes are equally good, but the most commonly used materials, corrugated/ galvanized iron sheets, concrete, plastic sheets are very suitable for rainwater catchment. Likewise thatch roofs can be used, but can discolor water and give it unpleasant taste hence it is less efficient. To see the effect on the amount and quality of water from different types of roof finishes see Table 2.2 below.

2.2.3 Runoff coefficient (C)

Runoff coefficient is the ratio of the volume of water which runs off a surface to the volume of rainwater which falls on the surface.

The runoff coefficient is not a constant factor instead its value is highly variable and depends on catchment specific factors (type of roof finish) and the construction quality of the roof catchment system.

Based on some studies conducted on different roof finishes the following values of runoff coefficients shown in Table 2.2 below are proposed to be used in estimating of runoff from different roof finish surfaces. The runoff coefficients takes in to account any loses due to leakage, evaporation, overflow and wind effects.

Table 2.2 Runoff coefficient for different roof catchment finishes

It No.	Roof finish type	Runoff coefficient	Notes
1	Galvanized iron sheet	0.8 - 0.90	Good water quality, surface is smooth, high temperature helps to sterilize.
2	Concrete roof	0.75 – 0.9	Good water quality.
3	Plastic roof	0.85 – 0.92	Good water quality, surface is smooth.
4	Thatch roof (roof of traditional hut)	0.2 – 0.25	Poor quality of water, little first flush effect, high turbidity due to dissolved organic materials that does not settle, sometimes used for primary water use after treatment, can be used for secondary uses (uses other than drinking)

Source : DTU, Warwick University, UK 2002

From the above table, we can see that thatched roofs (roofs cover in traditional hut) are not preferable for rainwater harvesting from points of views of quantity and the quality of water to be collected from the roofs.

The runoff values in the above table are suggested assuming the system (roof, gutter and downpipe system) is well constructed. If the roof catchment system is not well constructed the coefficients can be even lower than the above values and much water may be wasted without usage.

2.2.4 Average (mean) annual rainfall (R)

The amount of rainwater collected by a given rain gauge in 24 hours is called daily rainfall, and the amount collected in one year is known as annual rainfall. This annual rainfall at a given station should be recorded over a number of years, minimum of 10 years. For example, in India, this rainfall cycle period is taken to be about 35 years. The mean of the annual rainfalls over a period of say minimum 10 years or so is, therefore, known as average (mean) annual rainfall at a given station.

To calculate the volume of rain water, which can be harvested, the mean annual rainfall figures is commonly used. Mean annual rainfall is the statistical average calculated on the basis of measured rainfall over many years, minimum of 10 years. It has to be understood that there is no guarantee that the calculated amount will be achieved, but there is 95% likelihood that this amount can be expected (that is, with the average rainfall value is to be maintained for 95 percent of the time, but with failures during drought periods for 5 percent of the time). It can happen that the mean annual can not be expected. It can certainly happen the other way round that considerably more rainfalls than the mean annual. This makes the calculation of the storage capacity rather difficult. However, the mean annual is generally accepted as the basis for calculating the volume of rainwater to be collected.

The information on mean annual rainfall can be obtained from the government meteorological office, from an agricultural ministry, from university or from an air port and similar other organization that might have the data. If rainfall data for a particular region is not available, data can be obtained from the closest station, and related to the particular region in question.

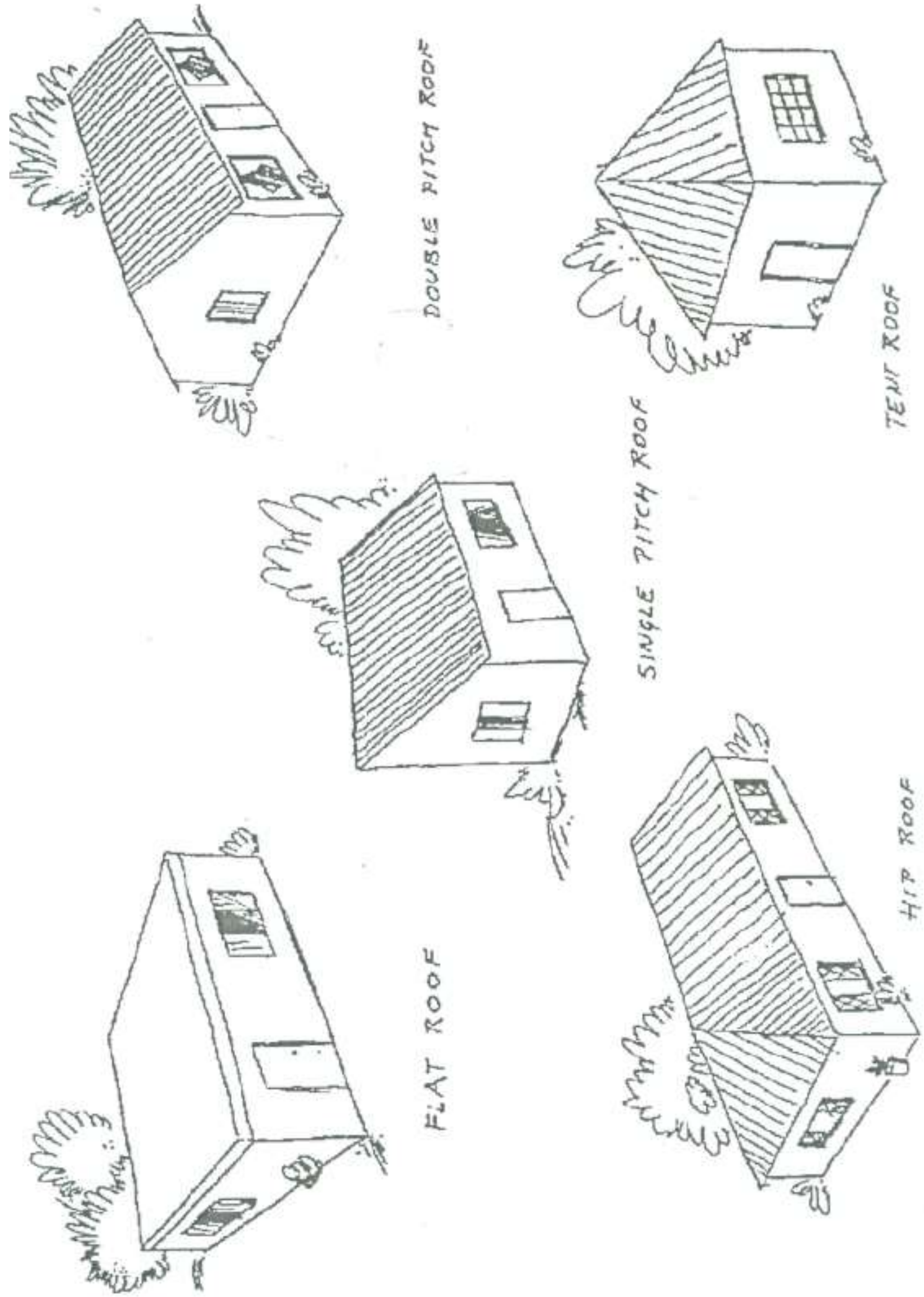


Figure 2.1 Different types of roof shapes for rainwater roof catchment system

3. RAINWATER ROOF CATCHMENT SYSTEM COMPONENTS AND DESIGN PROCEDURE OF THE CATCHMENT SYSTEM

3.1 Components of rainwater roof catchment system

In general every rainwater catchment system consists of a number of components mainly:

- A catchment surface where the rainwater runoff is collected (either ground or roof).
- Storage reservoirs large enough to store and supply water throughout any gap between sufficient rainfall events. If that gap is a few days, the storage volume can be quite small. If the gap between rain events is a 'dry season' of several months, the storage volume has to be several thousands liters depending upon the productive use of which the water is put.
- A delivery system for transporting the water from the catchemnt to the storage reservoir (channel, pipes, downpipes, gutters etc.)
- In addition systems always need some form of extraction device to take the water from the roof storage reservoir (a tap, rope and bucket, or pump).

In particular the most important components of rainwater roof harvesting system are:
- A collection surface (roof)
- Gutters to receive water from the roof area.
- Downpipes to transport water from the gutter to the reservoir.
- Reservoirs with all the necessary fittings for storage of rainwater.
- Pipe connecting reservoirs with water taps.
- Water taps.

3.2 Design procedures of rainwater roof catchment system

In order to select the storage available to households or small group of houses or institutions (to design a suitable rainwater roof catchment system), the following steps are recommended to be followed:

Step 1. Obtain average annual rainfall data for the area for 10 years (minimum).
Step 2. Select the type and size of roof catchment that is available to the users.
Step 3. Decide on the type and number of the beneficiaries of the rainwater system (community members, students, patients etc.).
Step 4. Decide for what purpose the rain water system is to be used (for drinking, cooking, cloth washing etc.) and also determine the required per capita demand
Step 5. Calculate the total water demand required by the beneficiaries yearly or monthly (Formula 2.2)
Step 6. Calculate the amount of rainwater per months or per year that can be collected from the available catchment area/roof area (Use formula 2.3).
Step 7. Compare water available from the roof catchment and the water requirement of the beneficiaries.

When comparing, if there is more water supply from the roof catchement at the end of the year than the beneficiaries demand, the design is considered suitable. If the amount of rainwater stored (supply) is less than the total water requirement of the beneficiaries, then take possible solutions include increasing the catchment area or reducing the demand for rainwater. For example use the rainwater for drinking and cooking only, and obtain water required for cleaning and washing from another source (well, river, etc,)

Step 8. Determine the required capacity of the reservoir.
Step 9 Select the type of reservoir to be constructed and the dimensions of the reservoir (height, internal and external diameter etc.).
Step 10 Select on the type and dimensions of the gutters and downpipes required.
Step 11 Show construction drawings with details.

3.3 Determining the size of storage tank and types of rainwater storage tanks

For most rainwater catchemnt systems, the storage tank represents the single greatest cost. This is especially true for roof catchemnt systems where an existing roof structure provides a free catchemnt system. The choice of a suitable tank design to match an existing catchemnt and local conditions is very important, and careful consideration should be given to selecting the right one. As well as having the appropriate volume with respect to the catchment area, rainfall conditions and demand, it should have a functional, durable and cost-effective design. There are a number of key requirements for effective tank design listed below.

- A functional and water tight design
- A solid, secure cover to keep out insects, dirt and sunshine
- A screened inlet pipe
- A screened overflow pipe
- A drainage (washout) pipe which will aid cleaning the tank
- A manhole (and ideally a ladder) to allow access for cleaning
- An extraction system that does not contaminate the water, E.g. tap/pump
- A soak away pit to prevent spilt water-forming puddles near the tank
- A maximum water height of 2 meters to prevent high water pressure (unless additional reinforcement is used in the walls and foundation).

Other features might include:

- A device to indicate the amount of water in the tank
- A sediment trap, tipping bucket or other foul-flush mechanism (for removing the first rain a dry period)
- A lock on the tap.

3. 3.1 Determining capacity of reservoir (storage tank)

Water storage capacity is required to balance out the differences between rainwater supply and household demand. If the rainwater supply exceeds demand in any given months, storage is needed to allow this water to be carried over and used in a future months when demand exceeds supply. For rainwater system to provide a total year round water supply, two conditions must be met. First, the total rainwater supply must exceed the total demand. Secondly, there must be sufficient storage capacity to allow enough surplus water collected in wetter periods to be carried over to meet the demand in drier periods. The storage capacity required in any situation, therefore, can be determined by balancing the inflow to the tank (rainwater collected) against the outflows (rainwater used).

Therefore if rainwater is found to be the only source of water, rainfall patterns must be studied carefully and the capacity of the reservoir is to be calculated on the following methods.

A) Dry season demand versus supply method

This is the simplest approach to system design but is relevant only in areas where distinct dry seasons exist. In this approach, the tank is designed to accommodate the necessary water demand throughout the dry season. The dry season is taken as the period during which there is no significant rainfall and hence no inflow to the tank is expected. If the daily household water demand is 100 liters and the dry season lasts for 120 days, the tank with a capacity of at least 12000 liters would be required. While this method is easy to calculate and provides a rough estimate of storage volume requirements, it does not take into account variations between different years, such as the occurrence of drought years. This method also centrally ignores rainfall input and the capacity of the catchemnt to deliver the runoff necessary to fill the storage tank. If the method it to be used it is important that some crude estimate of the available roof runoff is made to ensure that the sufficient rainwater to fill the tank. This technique does, however, have some advantages. It can be used in the absence of any rainfall, data and is easily understandable by laypersons. These points are especially relevant where designing systems in the remote areas of developing countries where obtaining reliable rainfall data can be difficult.

B) Graphical method

Another simple method which can be used to estimate the most appropriate storage tank capacity for maximizing supply is to represent monthly/weekly or daily roof runoff and water consumption graphically. The method will give a reasonable estimation of the storage requirements, but daily or weekly data should be used for a more accurate assessment, especially for climates with year round rainfall.

The basic steps that have to be followed are:

1. Obtain average rainfall for the area for minimum of 10 years (preferably on daily weekly or monthly basis).
2. Select the type of catchment and the area of catchment that is available to the users.
3. Calculate the amount of runoff for each month. It is to be determined by multiplying the average monthly rainfall by the horizontal area covered by the roof, and then multiply by the runoff coefficient.
4. Determine the water demand required by the beneficiaries for each month. (For the sake of simplicity uniform consumption of water per month may be used).

5. Plot a bar graph of mean, monthly runoff calculated in step 3 with runoff as vertical axis and months as horizontal axis. Note when plotting the graphs of such kind, it is important to start at the left hand side with the beginning of the rainy season, when the tank is assumed to be empty, so that the way in which the water level rises during the rains is clearly illustrated.
6. Plot a cumulative roof runoff graph, by summing the monthly runoff totals.
7. Add a dotted line on the cumulative roof runoff graph showing cumulative water use (water withdrawn or water demand). The greatest difference between the cumulative roof runoff curve and the cumulative water use line is equal to the storage capacity of the tank.

This approach is illustrated in Figure 3.3 below. For the illustration, the monthly roof runoff totals one might expect from a 100 msq catchments in a semi arid region with mean annual rainfall of 550 mm and a five month dry season are used.

When expected monthly volume of water have been estimated in this way, the figures are plotted on a diagram such as Figure 3.3. In this diagram, each calculated monthly total is added to the total for previous months so as to represent, by an approximate, stepped form a graph, the way in which water levels in a cistern would rise through the year if none were drawn off and used. In Figure 3.3, the dry season is from May to September. In these months very little water enters the tank then, so the line on the diagram remains almost horizontal.

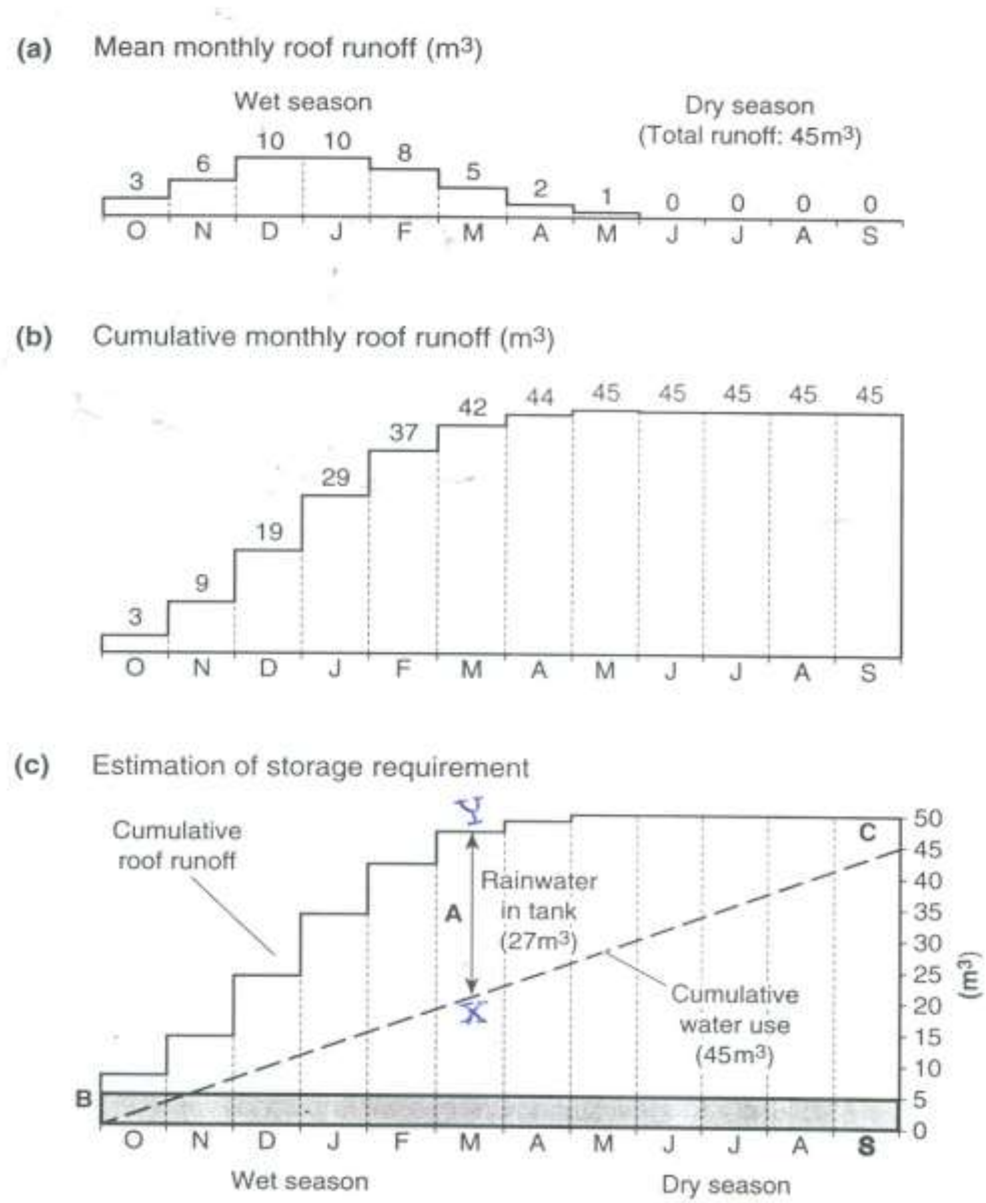
When plotting the graphs of such kind, it is important to start at the left hand side with the beginning of the rainy season, when the tanks is assumed to be empty, so that the way in which the water level rises during the rains is clearly illustrated. In Figure 3.3, the graph begins in October, which is the first month of really heavy rainfall.

Usually it is assumed that people, will take the same amount of water from the tank each day throughout the year. This is unrealistic because consumption varies greatly with the seasons, and according to whether water from other sources is being used. However, for the sake of simplicity by assuming a constant rate of consumption, we get a rough indication of the system's capabilities.

Again referring to Figure 3.3, the total amount of water running off the roof in a year of average rainfall is recorded as about 45 mcu, so theoretically, if their tank is of adequate size, the owner of the roof could ration themselves so as to use all this water in 365 days at withdrawals of 123 liters each day. This steady rate of use is represented by the straight line A-B. At point B, where this line meets the stepped line representing rainwater entering the system, the tank has been emptied, though it should be filled again almost immediately with the onset of the new rainy season.

However at point X, where the two lines are farthest apart, the tank is fuller than at any time. A distance separating the two lines, X-Y, then represents a volume of 27 mcu, which is thus an estimate of the capacity of the tank if it is to provide 123 liters daily ration. Note, however, that the commulative water use of 45 mcu for the year (equivalent to 123 liters per day) is significantly more than the volume of the tank, since a significant amount of water is removed from storage throughout the wet season while the tank is filling.

Figure 3.1 Step-by step graphical method to determine approximate storage requirement for maximizing rainwater supply.



A Storage requirement (25m^3) – the minimum tank volume needed to satisfy water demand throughout the dry season, allowing for small amount in reserve **(B)** in the case rains start late.

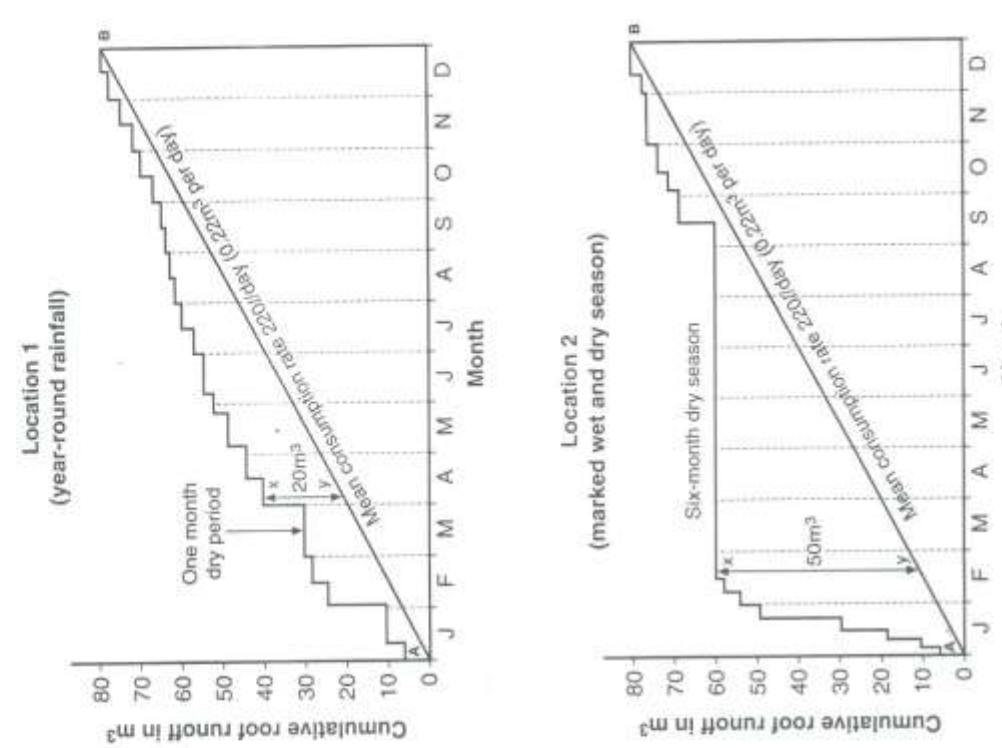
B Residual storage (5m^3) – rainwater remaining in the tank at the start of wet season.

C Residual storage (5m^3) – rainwater remaining in the tank at the end of dry season.

NB. If we are not proposing to have a residual storage of 5m^3 at the end of the dry season or at the start of wet season ten the capacity of the tank will be only 25m^3

For two locations having equal mean annual rainfall but with different rainfall pattern for different months, the capacities of the storage tank vary and are illustrated as follows. Although mean monthly data are easy to use, a more accurate graphical data involves the analysis of cumulative daily rainfall data. Figure 3.4 shows two graphs indicating cumulative roof runoff from a 100msq roof in two hypothetical locations with very different rainfall patterns. In both cases, the mean annual rainfall is 1000 mm and a runoff coefficient of 0.8 is assumed. The roof runoff is shown as a cumulative total for each month (stepped line) while the water consumption is shown as a continuous line A-B assuming a regular consumption rate of 220 liters/day (80 mcu/365 days). In this case, the line X-Y represents the storage capacity required in order to guarantee the maximum level of supply of 220 liters per day in a normal year. For location 1, the longest dry period is only one month, but for location 2 a six-month dry season is experienced. It is clear by comparing the two that for a greater storage volume is required to provide a constant year round supply when there is a prolonged dry season, 50mcu for location 2, compared to 20mcu for location 1. Of course, since no year is normal, the supply will vary and may have to be rationed slightly in drier years, or severely during drought periods if a continuous supply is to be maintained. If rationing is introduced during the dry season, or if alternative water sources can be used during this period, the storage requirement can be greatly reduced. In practice in areas with low or seasonal precipitation, rainwater is often used for drinking and cooking purposes only, and this greatly reduces both the storage requirements and the cost of the system.

.2 A graphical method to determine rainwater tank storage requirements for a constant water demand in two markedly different rainfall regimes



C) Where the rainfall is extremely unevenly distributed with frequent drought periods

Where the rainfall is extremely unevenly distributed with frequent drought periods, a reservoir should be as large as possible, based on the maximum rainfall (to collect all the yearly demand of the beneficiaries or all the water falling in the roof area whichever is critical). In this case the size of the tank will be larger and expensive but still economical after taking all other factors in to account (if rainwater is the only source to the community).

3.3.2 Types of rainwater storage tanks

Storage of rainwater can be provided by:

- Locally produced clay pots (locally known as Insera)
- Concrete well rings, set on a concrete base and with cement mortars sealing the joints (like the concrete cylinders used for well lining)
- Ferro - cement water tanks
- Steel water tanks
- Masonry made tanks
- PVC (plastic) made tanks
- Reinforced concert tanks
- Reinforced brickwork tanks.

The selection of the different types of tanks mainly depends on the availability of construction materials in the area to construct the type of reservoir, availability of skilled labor, the required capacity of the tank and the amount of budget allocated for the rainwater roof catchemnt system.

3.4 Gutters and dawnpipes

Gutters and downpipes are the most commonly used systems for transporting rainwater from roof catchment to the storage tank.

A carefully designed and constructed gutter and downpipe system is essential for any roof catchment system to function effectively.

The gutter and downpipe systems are critical to any rainwater roof catchment systems, yet they are frequently the weak link, which results in poor system efficiency. Broken gutters often lead to little or no water reaching the tank. Regular gutter maintenance is therefore, essential, gutters and downpipes need to be thoroughly inspected, and minor repairs and cleaning conducted at least once in a year.

A common method for excluding leaves and othre debris entering the tank is to place a coarse, 5 mm or smaller wire mesh over the top of the slightly raised downpipe inlet at the end of the gutter. If used this material must be checked regularly to ensure it is not blocked.

Guttering will be made from:

- Purpose made pre-formed plastic
- Half section of pipe
- Galvanized steel roofing sheet, cut in to strips and formed in to a U-over a pipe or bent in to a V- shape
- Wooden planks, sealed at the joints
- Split bamboo.

Guttering is usually fixed to building just below the roof and catches the water as it falls from the roof. Gutters must be placed 3 cm inwards from the edge of the roof to catch the back-drop of water from light intensity rainfall.

The efficiency of any rainwater catchemnt depends on a greater extent on the gutter and down pipes. Qualified plumbers work is demanded to fix gutters for roof catchment. Large roofs especially need precise workmanship. Often workers are seen using ladders, rather than scaffolding, but precise gutter fixing cannot be achieved without a scaffold on the overall length of the eave.

A common mistake observed in the under dimensioning of the gutter bracket or not strongly fixing the gutter with strong bracket. It has to be kept in mind that during heavy downpours gutters can suddenly be filled with water and their weight might increase up to 40 kg/m. To avoid deformation or even collapse of gutters, gutter fixing brackets must be strong enough and spaced at distances not exceeding 1 meters.

In rainwater catchment system down pipes often channel the water over long distances (from one globe side to the other) with a slope of sometimes only 1%. In all these cases they are not working as down pipes but rather as covered channels. As a result the down pipes sometimes develop a weight similar to the gutters and must therefore be securely fixed to the wall.

Reservoirs at public buildings are often large and, so as not to block the passage, sometimes constructed at more than 2 meters away from the building. In such cases the down pipe must be supported at least at an interval of 1 meters length of the down pipe.

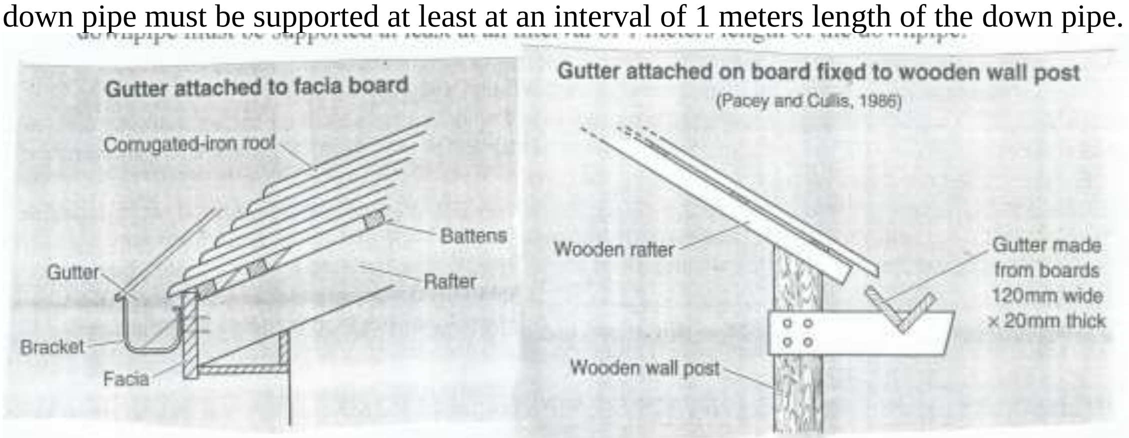


Figure 3.3 Examples of different gutter systems

3.4.1 Calculation of gutter and downpipe dimension (sizing)

Gutter and downpipe sizing is the critical element of the design of any roof catchemnt system. Large quantities of runoff may be lost during heavy storms if gutters are too small and, therefore, overflow. The capacity of gutters will depend upon the cross sectional area of the gutter and the amount of rainfalls in the roof.

As a general rule the gutter dimensions for catchment areas of different sizes, a useful rule of thumb is to make sure that there is at least 1 cm^2 of gutter cross - section for every 1 m^2 of roof area. To avoid overflow during heavy downpours, it makes sense to provide a greater gutter capacity. The gutter must be of a sufficient size to discharge water to the tank without any overflow in the gutter. The figures shown in Table 3.1 and Table 3.2 can be used as a guide for sizing gutters and downpipes.

One thing, which should be given emphasis in the design of gutters, is the slope of gutter to be fixed. Preferably, gutters should slope towards the tank and downpipe entrance with a slope of not less than 1% (a fall of 10 mm for 1000 mm length of gutter) to eliminate the chance of gutter blockage from leaves or other debris as these are more easily flushed out and to avoid standing water.

In normal house construction, downpipes cross section are sometimes smaller than those of gutters as it is assumed that since they are normally vertical, water will pass through them faster than through gutters. In roof catchement systems, however, downpipes should have similar dimensions to gutters. This is because the downpipes are often not vertical and usually acts as channels to convey water from the end of the gutter into the tank.
In order to avoid standing water and prevent blockage by leaves, downpipes should have a minimum slope of 1% (a fall of about 10 mm for 1000mm length of downpipe) towards the inlet of storage tank.

Table 3.1 Dimension of different gutters having half round shape

It. No.	Catchment area/roof area in msq	Gutter diameter in mm	Cross sectional area of gutter in sq.cm	Thickness of sheet in mm if the gutter to be made of galvanized iron sheet
1	Up to 25	80	25	0.65
2	25 – 40	105	43	0.65
3	40 – 60	127	63	0.7
4	60 – 100	153	92	0.7
5	100 – 150	192	145	0.7
6	150 – 250	250	245	0.8

Table 3.2 Dimension of different gutters having rectangular shape

It. No.	Catchment area/roof area in msq	Gutter size in mm		Cross sectional area of gutter in sq.cm	Thickness of sheet in mm if the gutter to be made of galvanized iron sheet
		Height in mm	Width in mm		
1	Up to 30	41	65	27	0.65
2	30 – 40	51	85	43	0.65
3	40 – 100	75	112	84	0.7
4	100 – 150	90	140	126	0.7
5	150 – 250	115	190	219	0.8
6	250 – 450	180	225	405	0.8

Example 3.1. Determine the cross sectional area of gutters for a catchment area of 8 m x 30 m = 240 msq.

Solution 1.
Using the general rule, for every 1 msq of roof area the minimum cross-section of gutter and downpipe is 240 sq.cm.

Solution 2
According to Table 3.1, for a roof area of 240 msq, you can choose a gutter of half-round shape, inner diameter 250 mm or

Following Table 3.2, you can choose rectangular gutter, height 115 mm, width 190 mm.

3.5 Water point (tap point) for collecting stored rainwater for use

Water taps for collecting water from the rainwater roof catchemnt system must be provided at convenient location for use by the beneficiaries. Very often water tap on the rainwater roof catchment system is built in to the tank wall.

When installing water taps on tanks, the following two conditions should be satisfied.

- Wastage of storage capacity called ‘ dead storage’ should be avoided.
- The height of the tap point should have sufficient height for a bucket /pot to be placed under the tap

In order to satisfy the above two conditions, the following alternative methods are recommended to be used.

1. The outlet pipe (tap point) to be placed at a level not more than 5 cm from the floor slab of the tank and the point for placing the bucket/pot be situated at 60 cm below the tank floor slab level (below ground level). See Figure 5.21.
2. The foundation (floor slab) of the tank can be located at about 60 cm above ground level and the outlet pipe or tap position is installed at a maximum height of 5 cm above the tank floor. See Figure 5.22.

The number of taps to be used depends on the number of beneficiaries of the system and is decided based on this.

The other possibility of drawing water from the tank for use is that outlet pipe can be installed in the tank wall and can be connected to different public (water points) constructed at different locations.

3.6 Possible arrangements of storage tank for rainwater roof catchment system.

The arrangements of the tanks and the size of one tank is very important in determining the location, number of tanks, and the size of one tank required for a rainwater roof harvesting system. Out of the different possibilities of arranging tanks, the following are the most commonly used ones.

1. Storage tank for each block. See Figure 3.4.a
2. Two tanks placed next to each other and connected by an over flow pipe for draining the overflow from the first tank to the second. See Figure 3.4.b
3. Two tanks located at each of the gable side, collecting water from each gutter. See Figure 3.4.c
4. One tank for more than one block of a building. See Figure 3.4.d

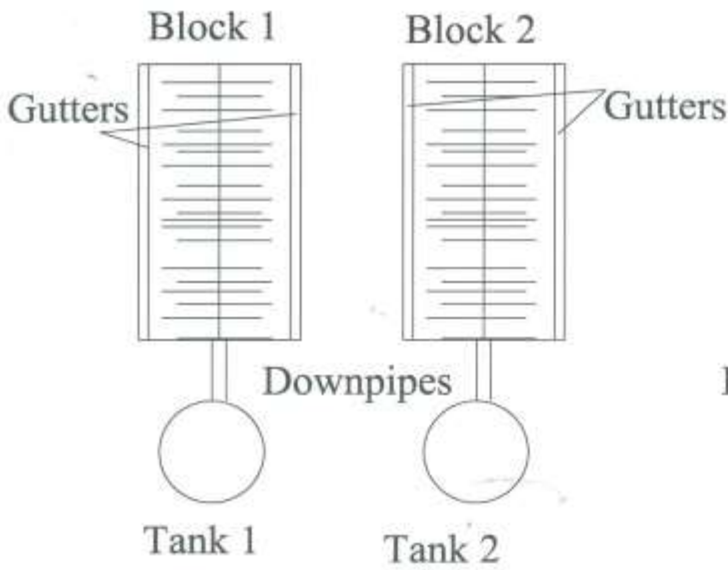


Fig. 3.4.a

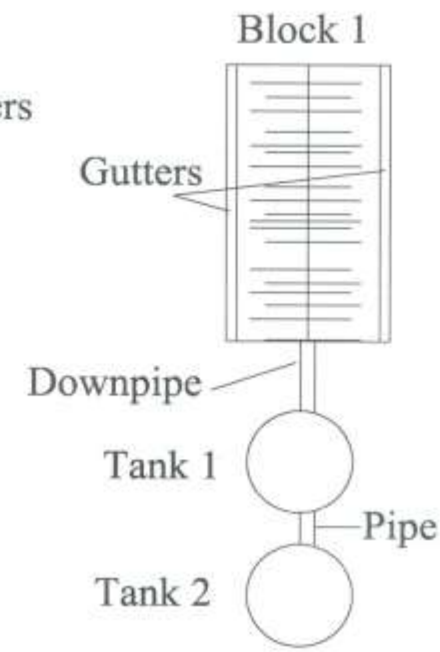


Fig. 3.4.b

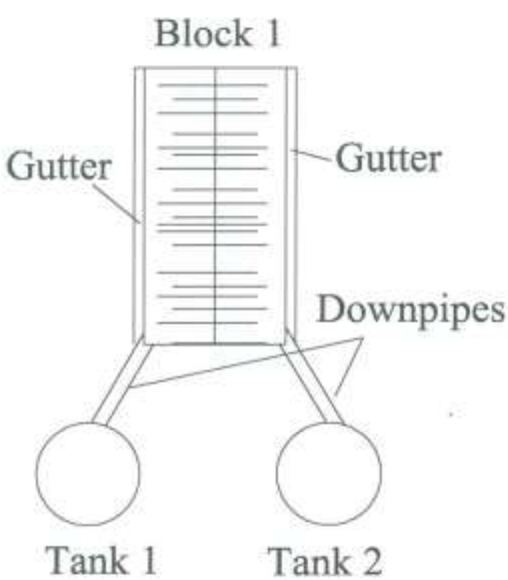


Fig.3.4.c

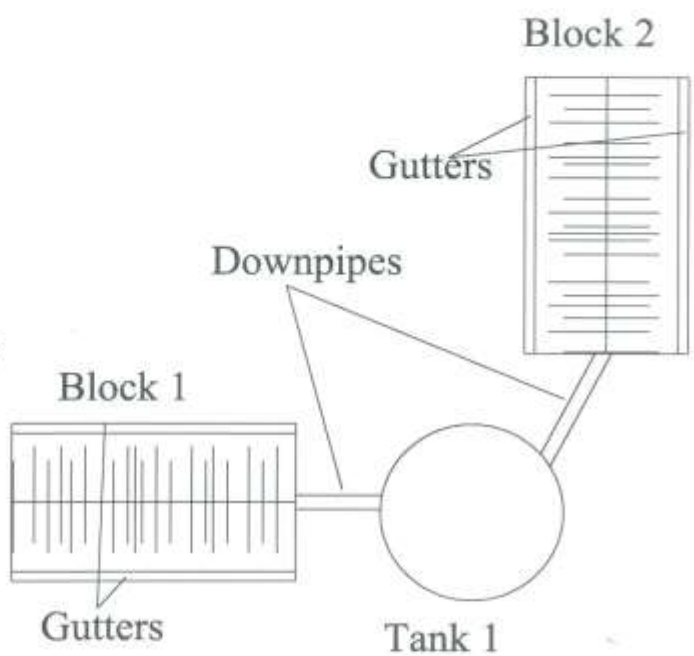


Fig. 3.4.d

Fig 3.4 Possible arrangements of storage tank for rainwater roof catchment system

3.7 Common problems with roof catchment system design

Many roof catchment systems are poorly designed. Common mistakes include:

- Gutters that are horizontal or sloping away from the tanks
- Overflow pipes placed well below the top of the tank
- Outlet taps high above the base of the tank
- Downpipes leading to wastage
- Only part of the roof area being used.

The following diagram in Figure 3.5 compares a good and bad roof catchment system. The poorly designed system is much less efficient than the good one. Less than a quarter of the roof area is being effectively utilized, and only half of the storage capacity. This is based on the real example observed in some countries.

Therefore, when constructing a roof water catchment system, the above mentioned common mistakes should be avoided.

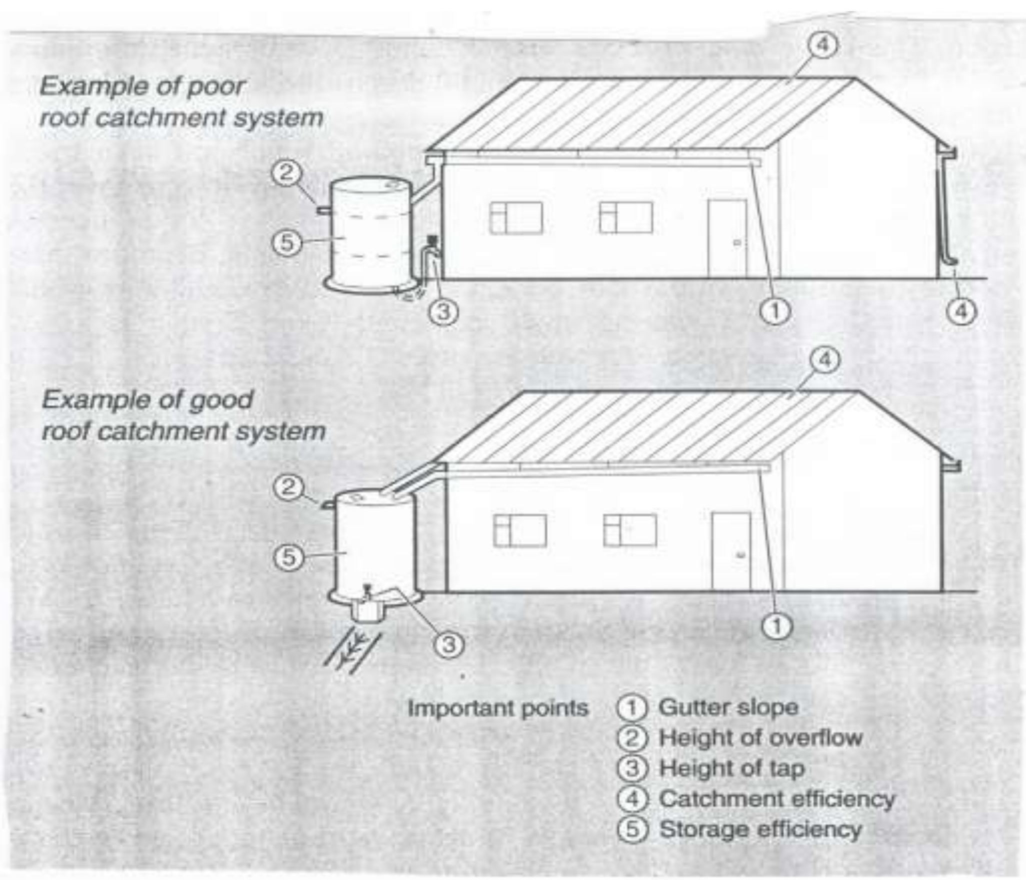


Figure 3.5 Examples of poor and good roof catchment systems

4. QUALITY OF RAINWATER FROM ROOF CATCHMENT SYSTEM

4.1 Rainwater quality

The quality of rainwater used for domestic supply is of vital importance because, in most cases, it is used untreated for drinking. The issue of water quality is a complex and sometimes controversial one, mainly because rainwater does not always meet WHO drinking water standard especially with respect to bacteriological water quality. The same however is true for many improved rural water sources in much of the developing world. Only where water is being provided for larger settlements in systematic treatment and water quality monitoring common and even here water quality standards may vary considerably. For more smaller and remote settlements, especially in developing countries, treatment is both impractical and often unrealistically expensive. For such settlements across the world, the emphasis remains on providing and maintaining any sort of improved water source as hundreds of million people still remain unserved.

Generally while rainwater quality will not always match WHO water quality standard, when compared with most unprotected traditional water sources, rainwater from well maintained roof catchment usually represents a considerable improvement and is generally safe to drink without treatment.

4.2 Protecting rainwater quality

4.2.1 Good design, operation and maintenance

The best initial step to protect water quality is to ensure good system design and proper operation and maintenance. A part from tank cleaning and keeping the gutter and downpipes clear.

It has been carefully demonstrated that, if careful measures are taken, roof catchment can provide rainwater clean enough to drink. To achieve this, a certain design features must be incorporated and other criteria met.

A study was carried out recently at the Indian Institute of Technology in Delhi, India, to determine the quality of rainwater from domestic rainwater harvesting systems. The major conclusions reached are as follows:

a) Generally, the physico-chamical quality of water in terms of color, odor, taste, pH, total dissolved solids (TDS) and total hardness (TH), meet the prescribed standards. Occasionally pH has been reported to be low (acidic) or high (alkaline).
b) Toxic metals and toxic chemicals are reported only in rare cases and may arise from material used for the roof or atmospheric pollutants adsorbed on dust.
c) Most of materials used for storage tanks e.g. cement, iron, wood and plastics do not generally affect the physico-chemical quality, with a few exceptions.
d) The physico-chemical parameters can be tested easily by using available field kits.

e) The main problem with the quality of stored water in design of roof water harvesting system lies with its bacteriological quality. The following are the main issues.
    - Dust from the soil, and droppings of birds and animals can also be the source of contamination by the above bacteria.
    - In any case where first flush eliminating devices are absent, all the indicator bacteria are generally present in water samples in numbers beyond what is acceptable by any standards. Higher temperature reached by a metallic roof due to solar heating may lead to reduction in bacteria.
    - From the health point of view, it is important to clean the gutter from time to time and ensure that water does not stagnate. This leads mosquitoes breeding.
    - Tree hanging in the vicinity, definitely enhances that possibility of contamination due to increased access of the roof to birds and animals.
    - On storage, generally due to limitation of nutrients, bacterial count falls. Different indicator bacteria under study decay over 7 – 20 days depending on the initial amount of bacteria, nutrient availability and other storage conditions.
    - Mosquito breeding generally occurs if mosquitoes are already available in the vicinity of storage. Water quality deteriorates with the bearding of mosquito. The only way to prevent mosquito in the tank is by covering the openings by appropriate screens. Thus the basic conclusion from the study, substantiated by actual experimentation under the project are that design of rainwater harvesting must be designed, taking the following in to consideration:

a) Convenient first flush device must be integrated. Roughly, the first flush to be taken may be 2 mm rainfall and the volume is obtained by multiplying this by the area of the roof.
b) Wire mesh should cover all inlets to prevent any insects, toads, snakes, mosquitoes, small animals or birds entering the tank.
c) It is preferable to allow water to stand for some time before drawing. The bacterial count is more at the bottom. Hence the water may be drawn from a higher level, e.g. withdrawing water from an overflow system may be useful. Thus, instead of one tank of large capacity, more tanks in a series may be used, but increase in total cost has to be considered.
d) Some rapid testing methods are useful in the field for indicating presence of bacteriological contamination. The safest method of treatment for domestic use is boiling.
e) The roof surface should be smooth and any moss, lichens or other vegetation removed, including branches from over-hanging trees, since these provide sanctuary for birds and access for rats and other animals to the catchemnt surface, where defection could contaminate the rainwater runoff.
f) Taps or draw off pipes in roof tanks should be at least 5 cm above the tank floor, this allows any debris entering the tank to settle on the bottom where, provided it remains undistributed, it should not adversely affect water quality.
g) Roof guttering should slope evenly towards the downpipe to avoid stagnation of water.
h) The tank must be covered and all light must be excluded to prevent the growth of algae and micro-organisms.

i) Tanks, gutters, downpipes, screens and all system components should be inspected and cleaned annually if possible. A tank floor slopping towards a sump and washout pipe can greatly aid tank cleaning. A well fitting manhole to allow access is essential.
j) Water should not, if possible, be consumed directly from the tank without treatment for the first few days following major rainfall.
k) Water from other sources should not be mixed with that in the tank.

Immediately following heavy rainfall, the quality of water in the tank may be lowered due to any debris washed into the tank or stirred up from the bottom which may take some time to settle out. It is appropriate, therefore, to avoid drinking water directly from the tank for few days. Contrary to popular myth, however, rather than becoming stale (smelling and testing bad) with extended storage, rainwater quality usually improves. This is because bacteria and pathogens gradually die off during the first several days of storage. For this process to occur, however, it is essential that both light and organic matter be excluded from the tank. Any light getting into the tank will allow algal growth, and organic matter will provide nutrients enabling bacteria and other micro-organisms to survive. In such situation, the stored water may become stale and unpalatable.

4.2.2 First/foul flush system

The simple operation and maintenance of rainwater catchment systems is one of the most attractive aspects of the technology. The amount of maintenance required for roof catchemnt system is limited to the annual cleaning of the tank, regular inspection of the gutters and downpipes, and the removal of any leaves, dirt or any other matter from the roof.

These debris, dirt, dust and bird droppings will collect on the roof of a building or other collection area and when the first rains arrive after a dry period, this unwanted matter would be washed into the tank. This will cause contamination of the water and the quality will be reduced. Many roof water harvesting systems therefore incorporate a system for diverting this ‘first flush’ water so that it does not enter the tank.

There are a number of simple systems that are commonly used for diverting the first flush and also a number of other, slightly more complex, arrangements. Based on experience, it is recommended that if any kind of first/foul flush design is to be used, it should be very simple, and easily maintained systems be used, as these are more likely to be repaired if failure occurs. Examples of simpler systems include:

a) **Movable downpipe for diverting the runoff from the season's first down-pour** (see Figure 4.1.a)

The simpler and more convenient method of cleaning the roof is to detach the downpipe (inlet to tank) from the tank before the start of the first major downpour, to allow the initial rainfall to wash the roof and allow the first flush to run to waste for several minutes until the roof is clean and then replaced again once the initial first flush has been diverted. The method is more appropriate in regions with distinct wet and dry seasons.

This method has obvious drawbacks in that there has to be a person present who will remember to move the pipe.

b) Using a branched pipe with removable end (See Figure 4.1.b)

This system is well practiced in Thailand. It consists of a length of large diameter pipe suspended alongside the rain water tank. This is sealed at the bottom with plug. When rain begins to fall, this length of pipe must fill before any water can enter the tank. It will thus retain any sediment carried by the first flush water. After each storm, the plug is removed and the pipe is drained. The water containing capacity of the pipe can be calculated based on the amount of water needed to be flushed at the end of a dry period.

c) Self-cleaning inlet mesh (See Figure 4.1.c)

This system consists of placing the end of the downpipe or down gutter about 3 cm from the mesh screen in front of the inlet hole. The galvanized 5 mm mesh screen should slope at not less than 60 degree from the horizontal above the tank inlet. Objects larger than 5 mm, such as stones, small branches and leaves, are pushed down the gutter and downpipe by flowing water until they strike the mesh. Here the debris will be caught and roll downward off the screen while the water shoots through the mesh into the tank. Any dust from a roof, which is finer than the mesh, will enter the tank along with the water, and settle at the bottom of the tank. Since dust lying on roofs is sterilized by prolonged exposure to sunshine and it will settle on the tank floor below the draw off pipe intake, it should not affect water quality adversely once it has settled. Nevertheless, dirt and dust from the initial roof wash at the beginning of a storm can be diverted from the inflow of the tank by lifting the end of the down-gutter out of the tank inlet and placing it on the roof for a few minutes, then the down gutter can be placed. Alternatively the mesh inlet can be covered with a removable metal sheet to prevent the initial dirt runoff from entering the tank.

d) Sedimentation chamber requiring only occasional cleaning (See Figure 4.1.d).

In this case the capacity of the sedimentation tank can be calculated to have the amount of the first rain required to be flushed/removed.

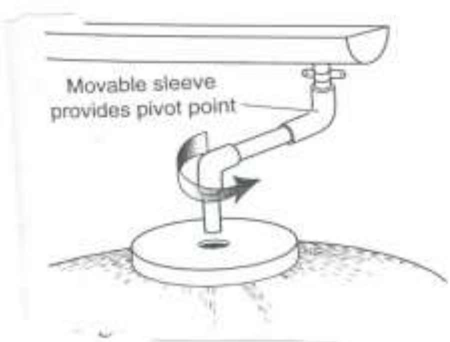


Figure 4.1.a

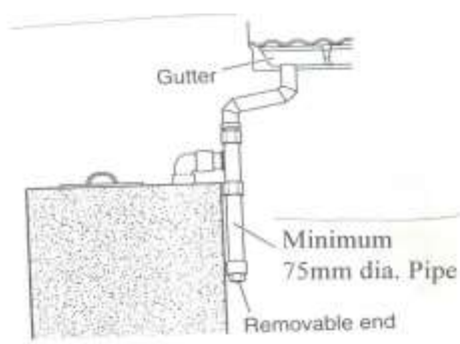


Figure 4.1.b

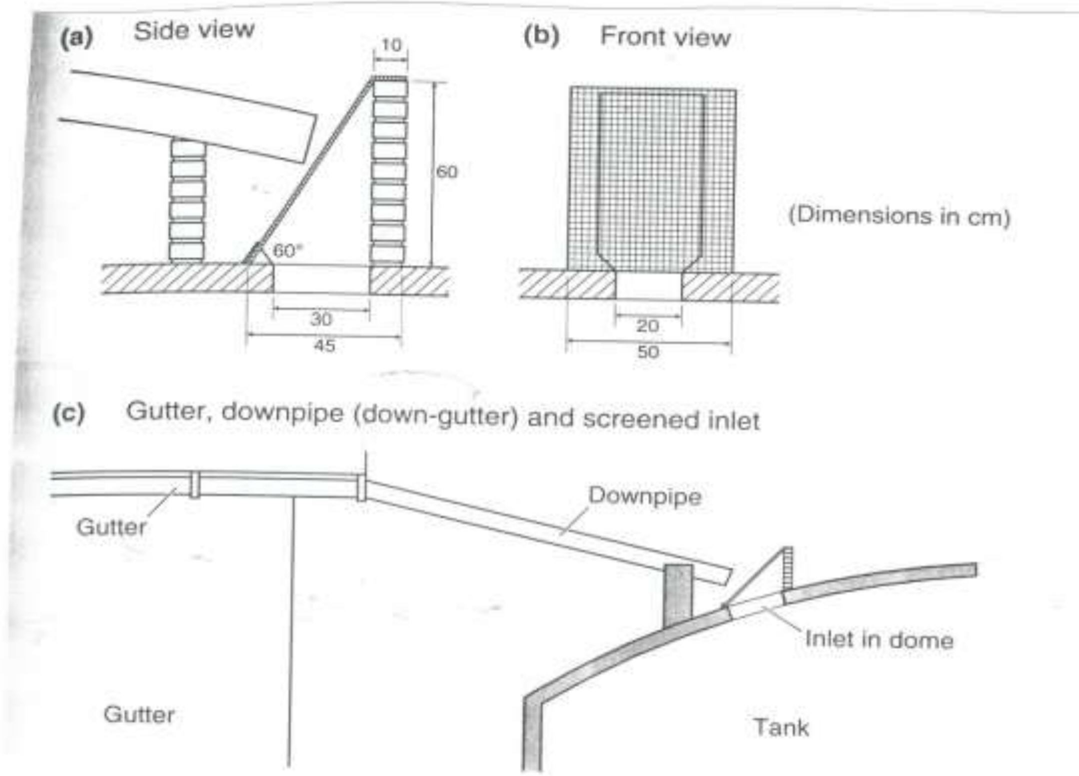
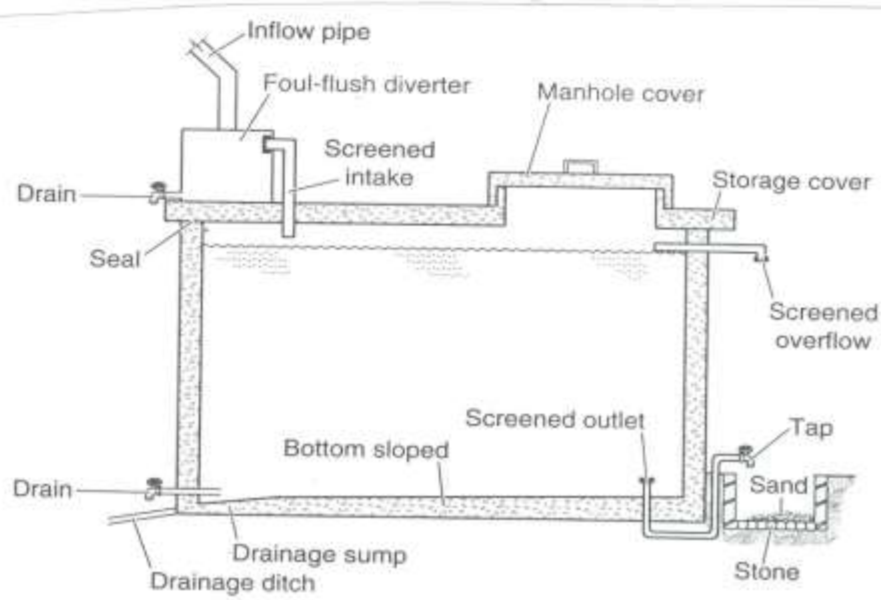

(a) Side view
10
60
60°
30
45
(b) Front view
20
50
(Dimensions in cm)
(c) Gutter, downpipe (down-gutter) and screened inlet
Gutter
Downpipe
Inlet in dome
Gutter
Tank

Figure 4.1.c


Inflow pipe
Foul-flush diverter
Manhole cover
Screened
intake
Drain
Storage cover
Seal
Screened
overflow
Screened outlet
Bottom sloped
Tap
Sand
Drain
Drainage sump
Drainage ditch
Stone

Hygiene education and monitoring

Since the problem of secondary contamination of rainwater supplies has been highlighted in several studies, hygiene education and monitoring of the condition and maintenance of systems along with sanitary practices are essential if rainwater supplies are to fulfill their potential and provide clean water. In the absence of hygienic water practices, attempts to ensure high water quality will be impractical hence education on proper use of the water should be given to the users.

4.4 Treatment of stored rainwater

Treatment of stored rainwater makes sense only if it is done properly, and if hygienic collection and use of the water will ensure it does not suffer from re-contamination. There are several types of treatment possible, the more common being chlorination, sand filters, boiling, and exposure to sunlight.

Chlorination

Chlorination of the water, either in the tank or after extraction, can be an effective way to purify the water, but must be conducted with care. The chlorine can affect the taste of the water and over-application could cause problems. These factors can sometimes make chlorination somewhat impractical in remote rural locations. Since chlorine is available in different forms and local brand names can confuse this farther, if uncertain, it may be best to seek advice from the near by woreda health or water office.

Chlorination procedure to be applied for the treatment is outlined as follows:

- If you suspect water in your tank is contaminated, it should be treated by adding swimming pool calcium hypochlorite (60-70%) or sodium hypochlorite (12.5%). The initial dose to treat the contamination should be 7 gram of calcium hypochlorite or 40 ml of sodium hypochlorite per 1000 liters of water in the tank at the time of treatment. The water should be stirred and left to stand at least for 24 hours to allow the chlorine tastes and smell to dissipate. To maintain a safe water supply after the initial dosage, 1 gram of calcium hypochlorite or 4 ml of sodium hypochlorite per 1000 liters should be added to the rainwater tank weekly and allowed to stand for a minimum of two hours. The water will be safe to drink provided the chlorine smell is not too strong.
- It is important to mix the chlorine in plastic bucket in the open air before adding it to the tank. Mix it thoroughly with the tank water. Do not pour water in to chlorine. Always add chlorine to water. Avoid skin contact and store in a cool, dark place out of reach of children. To ensure sufficient chlorine has been added, the water is normally tested for a chlorine residual using simple color-coded testing kit – normally a chlorine residual in the range of 0.2 – 0.5 mg/liters should be maintained.

Boiling

Although boiling water thoroughly for two or three minutes normally ensures it is free from any harmful bacteria or pathogens, it is not always a practical option. Boiling requires a lot of energy which, in areas where fuel is scarce or expensive, may be a problem, and waiting for the water to cool is also tiresome.

Exposure to sunlight

Another way to kill many of the harmful bacteria in water is to put it in clear glass or plastic bottles and place it in direct sunlight for several hours. This technique has undergone extensive subsequent field tests. The process works in two ways: bacteria and micro-organisms are killed both by exposure to direct radiation and, if heated sufficiently, by water temperature exceeding 70^{o}C. This latter effect can be increased by painting half of the bottle black to increase solar radiation absorption. To be effective in using this method, the water should not be too turbulent or excessively contaminated.

5. CONSTRUCTION OF FERRO-CEMENT TANK (RESERVOIR)

5.1 History of ferro-cement

Ferro-cement is a construction method provided by applying cement mortar composed of a fine aggregate (sand) and cement onto wire reinforcement and/or wire mesh using plaster techniques.

Ferro-cement was first developed by a Frenchman, Joseph Monier as early as 1887. The technology has been used in a variety of constructions including boat building. Its use in water tank construction is a relatively recent phenomenon and really took off only in the 1950s and 1960s.

Its high labor input requirement really makes ferro-cement most appropriate in countries with cheap skilled labor. Cracks in ferro-cement tanks can be repaired fairly easily and leaks can be sealed by using different techniques.

5.2 Commonly used sizes of ferro-cement tanks

Although the technology is possible to build surface tanks with volumes of over 100 m^3 or more, most of the tanks built in some countries have been less than 20 mcu in volume. The success of the technology on larger capacities of tanks varies from country to country or region to region (more success was reported in Asian countries) which stems form a variety of reasons, in particular, problems with the level of skills and workmanship.

The technology also has been used in our country for some semi urban water supply schemes and the capacity of the tanks constructed in most cases is in the range of 20 to 50 muc, therefore till the construction of tanks using this technology is widely spread and proven that the necessary skill is well developed, it is proposed to use this technology for tanks having capacities less than 50 mcu. For capacities more than 50 mcu, reinforced concrete or masonry made tanks are recommended to be used.

Table 5.1 Dimensions of ferro-cement tanks

It. No.	Dimension	Capacity of the ferro-cement tank			
		10 mcu	20 mcu	30 mcu	40 mcu
1	Internal diameter in meters	2.66	3.76	4.68	5.34
2	Foundation slab diameter in meters	3.02	4.1	5.04	5.7
3	Diameter of the mesh circle for the tank wall in meters	2.72	3.82	4.74	5.4
4	External diameter of the tank wall in	2.76	3.86	4.78	5.44

	meters				
5	Height of the structure excluding the dome in meters	1.8	1.8	1.9	1.9
6	Height of the dome in meters	0.25	0.45	0.5	0.6
7	Height of the structure including the dome in meters	2.05	2.25	2.4	2.5
8	Level of overflow pipe in meters	1.7	1.7	1.8	1.8
9	Mesh circumference including 200 mm overlap in meters	9	12.4	15.3	17.4

5.3 Construction procedure of ferro-cement tank

The construction procedure of different capacities of ferro-cement tanks to be constructed above the ground level is discussed below.

Day 1

- Excavate a shallow circular level foundation, 100 mm deep having a diameter equal to the diameter of the tank floor (see Fig. 5.1).
  - Within the diameter of the tank floor remove all topsoil. If the depth of the topsoil is more than 100 mm, you have to refill with hardcore and the refill must be well compacted.
  - Note that no foundation should be made on top soil which is loose/unstable because the tank can crack
- Prepare a mesh of 6 mm diameter steel reinforcement bars spaced 15 cm center to center in both directions for the floor slab reinforcement. Tie each mesh with binding wire so as to keep the 15 cm spacing between bars constant (see Fig. 5.2).
- Prepare the wall reinforcement from 6 mm diameter bars spaced 15 cm center to center and forming a mesh. The bars are prepared to make a cylinder with good circular shape. Tie the meshed bars together with binding wire as you did for the floor slab reinforcement. Bend the vertical bars of the meshed wall reinforcement at the bottom alternatively inwards and outwards, forming right angles (90 degree). Bend the top of these vertical bars inwards at an angle of 45 degree.
- Prepare the roof reinforcement from of 6 mm diameter bars spaced 15 cm center to center to form a mesh. The mesh is to have a dome shape and the height of the dome for different capacities of reservoirs is shown in Table 5.1. For example for reservoir capacity of 20 mcu, the roof slab is to be made as follows.
  - The reinforcement is made by marking the circle of the roof slab dimension in your preparation area. Put an upright hollow concrete block of about 450 mm high for support at the center of the circle. The roof has to be a dome shape, so the cement block marks the highest point of the dome. Cut the reinforcement bars as required and tie the bars together with binding wire to form the mesh.

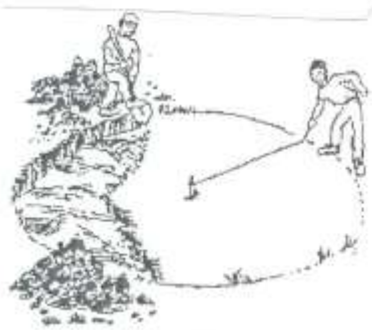


Figure 5.1

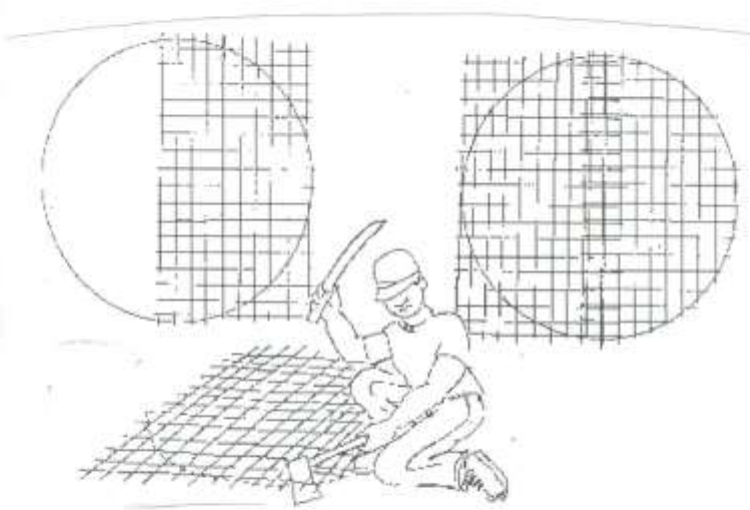


Figure 5.2

Day 2

- Prepare one part cement with two parts sand and three parts aggregate (1:2:3 mix) concrete. The maximum size of aggregate is 20 mm diameter. Mix the required amounts dry, that means without water, until the color is uniform. Now add water carefully to make the mixture workable.
- Fill the prepared concrete on a layer of 5 cm thick of the 10 cm thick floor slab and compact it and level it. Place the prepared floor reinforcement on the concrete (see Fig. 5.3).
- Mix the same amount of concrete as for the first layer, pour the concrete on the second layer 5 cm thick without delay on the top of the reinforcement keeping a 400 mm ring from the edge of the circle, open, without concrete. Compact the concrete as you did for the first layer (see Fig. 5.4).
- Position any outlet or drainage pipe stuffed with paper on the open end of the pipes to keep cement out. Tie strongly the pipes with the floor reinforcement to make sure it is fixed in position.
- Position the prepared wall reinforcement, pull into circular shape and tie them at the bottom with the reinforcement bars laid for the floor slab (see Fig. 5.5).
- Using the remaining concrete from the second layer, pour it in the space inside and outside the wall reinforcement erected. Tamp the concrete down carefully and firmly. After this work is finished, cover the floor with plastic sheeting, cement bag etc. and keep it covered overnight (see Fig. 5.6).
- Continue the preparation of roof reinforcement by cutting and placing chicken wire on the prepared roof weld mesh. This is made as follows (see Fig. 5.7).
    - Cover the dome of the roof reinforcement mesh with chicken wire and tie it well to the mesh. Overlapping of the chicken wire is important, 200 mm overlap is required.

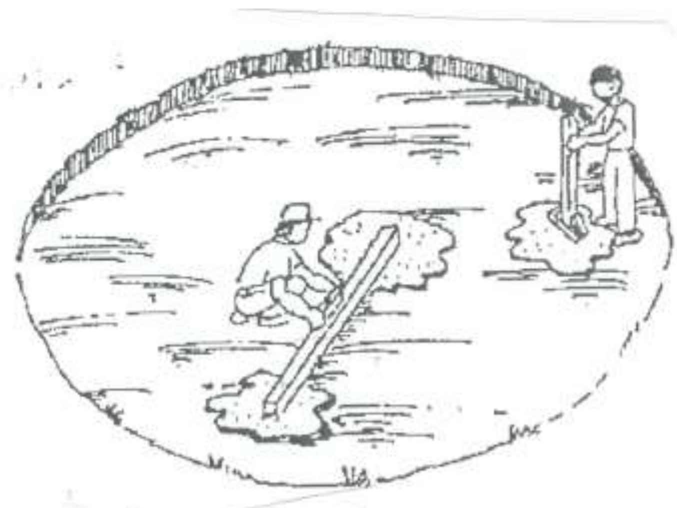


Figure 5.3

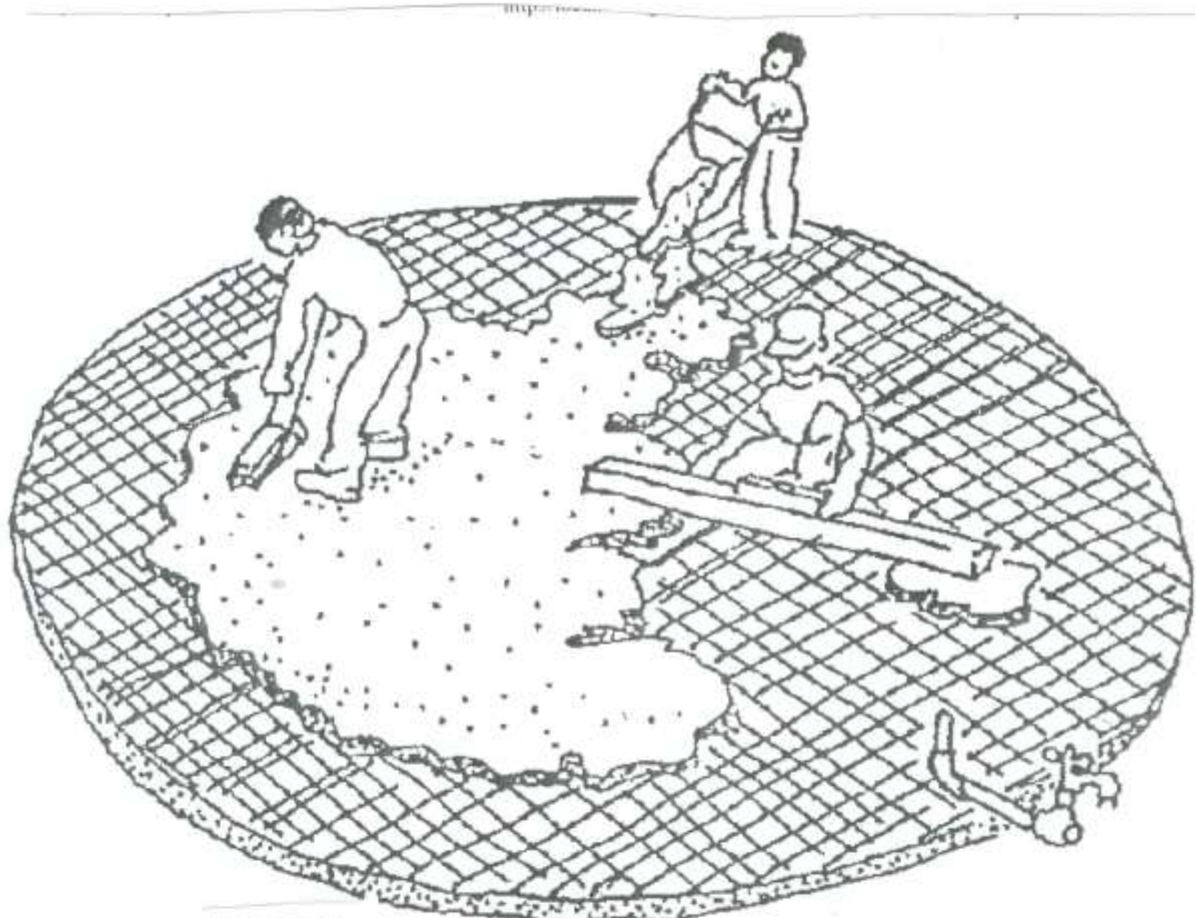


Figure 5.4

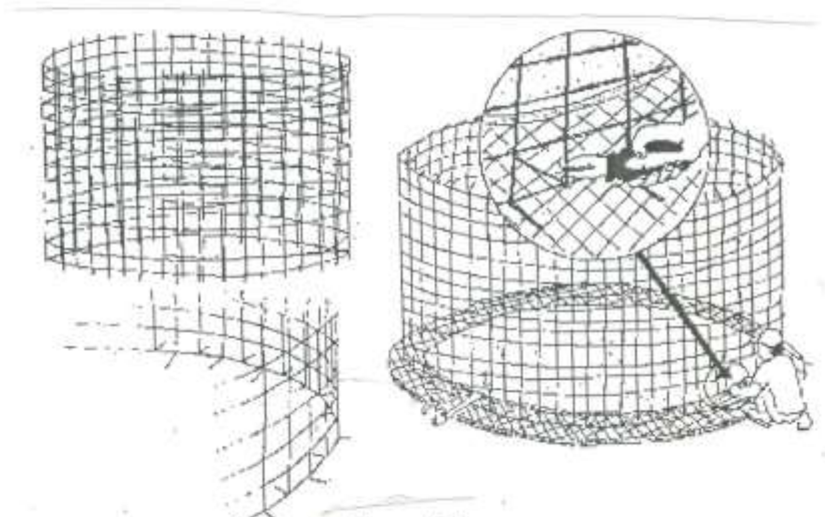


Figure 5.5

Figure 5.7

Figure 5.6

Day 3

- Keep the concrete wet throughout the day by splashing water on it every three hours.
- Prepare the wall for plastering.
  - Before you start plastering, remember that the entire first coat of the tank must be plastered in one day. It is not possible to keep the unfinished plaster overnight. Where one - day - old plaster is joined with the fresh plaster, leaking will occur. Make sure you have enough labor for mixing the plaster and carrying it to plasterers. If necessary have two plasterers and start on two opposite sides of the tank wall.
  - Warp the outside of the wall reinforcement mesh with one layer of chicken wire, from the top to the concrete floor. Take the roll of the chicken wire and push the top long edge over the free vertical mesh. While continuing to encircle the cylinder, keep pulling the chicken wire tight in both vertical and horizontal direction (see Fig. 5.8). Try to do this job with three people, one carrying the roll and pulling the wire, one fixing it with prepared short pieces of binding wire on

  the mesh, and the third assisting him in pulling the chicken wire tightly in position. Overlap the two ends of the chicken wire by 200 mm and fasten it. The chicken wire has to cover the entire wall reinforcement and tied to the weld mesh in several places.
  - The reinforcement must be lined with cloth or any cover (to be used as formwork) from the outside to hold the plaster which will be smeared to the reinforcement from the inside. For this purpose sacks made of nylon or sisal material, bamboo carpets or corrugated iron sheet can be used as available. The formwork should be fixed to the reinforcement temporarily. To fix the formworks in position it is proposed to use a sisal string or nylon ropes and warp the formwork from top to bottom at an interval of 50 mm (see Fig. 5.9). After the tank is entirely warped, make sure there is no gap where the reinforcement is feasible.
  - Prepare scaffolding to bridge the wall without touching it. Remember all the plaster has to be transported via this scaffold and during all this procedure the wall will be protected from vibrations. Inside there should be enough space between the scaffold and the wall to allow one man to plaster it. In case material for stable scaffolding is not available, fix two ladders together at the top as shown (see Fig. 5.10).
  - Now it is necessary to adjust the wall to make it stand straight and in good circle. The foreman climbs the ladder or scaffold and inspect the shape. Where it is not in good cylindrical form, fastening lengths of binding wire to the reinforcement mesh makes adjustments. Pull the wire with just the right strength to remove any sags or bulges (see Fig. 5.10).
  - If it is windy, postpone further work until the wind calms.
- Plaster the inside wall as follows:
  - Add water to a cement sand mortar (1:3 mix) until it is just workable. The consistency of the mortar is critical. Start plastering at the bottom and push the plaster into the wire walls from the inside of the tank until you reach the top horizontal reinforcement wire. However, leave a space in the top of the weld mesh for an overflow and any inlet pipe installation. No plaster should leak through the outside cover used as formwork (see Fig. 5.11).
- After the plastering is finished, cover the inside plastered wall with plastic sheeting. The plastic sheet should be protected against blowing by the wind.
- Splash the floor with water.

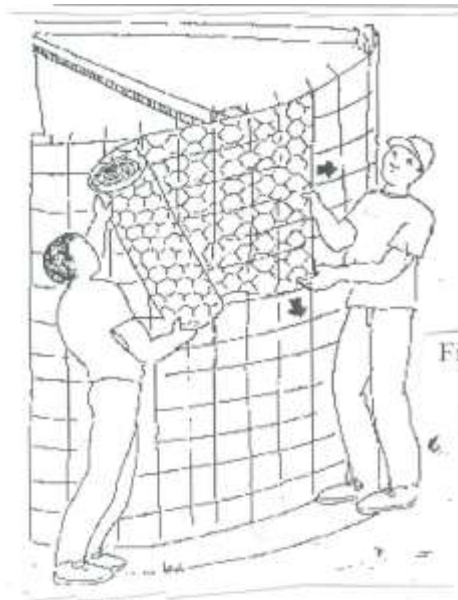


Figure 5.8

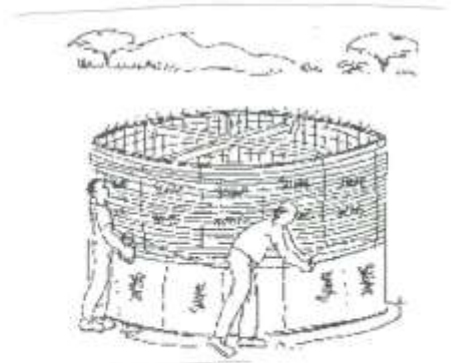


Figure 5.9

Figure 5.10

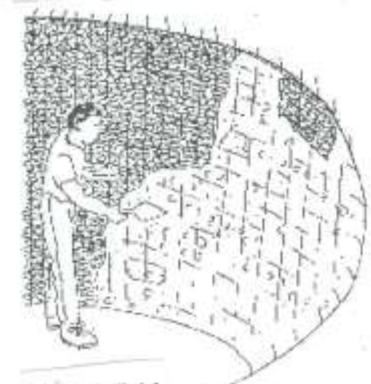


Figure 5.11

Day 4

- Remove the plastic sheeting and wet the floor and walls. Keep the concrete wet throughout the day.
- Start the second coat of the inside wall by throwing plaster evenly. The plaster can be a slightly wetter mixture than you used the day before, but it should not be shiny. Remember that the wall thickness when finished is only 50 mm, 30 mm of which are on the inside. Fill up the sags and level them. Finish with a wooden float. Work with two plasterers and finish the job in one operation (see Fig. 5.12). After you have finished, cover the inside again with plastic sheeting like you did the day before.
- Remove the sacking (formwork) from the outside wall and plaster it as for the inside, but not more than 10 mm thick. Fill sage and level them (see Fig. 5.13). Do not float.
- Cover both the inside and outside walls with plastic sheeting and keep covered for at least one night. Make sure that the plastics can not be blown away by wind.
- Wet the floor by splashing with water.

Figure 5.12

Figure 5.13

Day 5

- Remove the plastic sheeting and wet the floor and walls. Keep the concrete wet throughout the day by splashing with water.
- Prepare the overflow pipe. Choose the place to install the overflow pipe carefully. It is proposed not to place the overflow pipe at the same side as the outlet pipe. With a hacksaw cut at the top section of the wall mesh and install the overflow pipe, bend outwards 90 degree and wrap in chicken wire mesh. Place a flat board under the overflow pipe and use one or two posts to support it. Plaster the top of the overflow pipe and smooth it (see Fig. 5.14).
- If the inlet of the water from the roof to the tank is to be through the wall, leave an opening slightly larger than the downpipe having the same shape as the downpipe. Do not cut through the top wires.
- Plaster the outside wall with about 10 mm thick plaster. Then smooth it with a wooden float until the entire outside is smooth plumb wall and cover it with plastic sheeting (see Fig. 5.14).
- Prepare the roof for plastering by sewing sacking to be used as formwork to the underside of the roof mesh. This is one of the methods to be used for formworking in the roof slab construction of the ferro-cement tank. If other methods of formworking are to be used, this activity will not be performed at this stage but be done after plastering the floor slab as listed in day 7.

Figure 5.14

Day 6

- Wet the floor and walls by splashing water.
- Complete the inside wall:
    - Remove the plastic sheeting from the inside wall and prepare a nil. If possible the nil coat should be applied on the wooden-float-finished plaster from inside on the same day you plaster. If this is not possible the wall must be splashed with water before applying the nil. Mix pure cement with water until you have a thick soupy consistency. This is achieved by nearly equal parts of cement and water. Stir until smooth and free of lumps. This is done most easily by adding cement to the water, in small portions, while stirring constantly, not the other way round. The mixture is called nil. Use a steel trowel and smooth it very evenly onto a new plaster. If the nil is still too thin add more cement. Leave a 100 mm strip around the bottom of the wall free of nil. These 100 mm should be marked first to make sure you always meet the right height (see Fig. 5.15). After, the nil is finalized, cover the wall again with plastic sheet, clean the concrete floor of all leftover material, and splash with water to keep it wet.
- If you have enough time in this day, complete the floor as follows:
    - Prepare a cement mortar (1:3 mixture) for plastering the floor. The plaster to the floor is to slope towards the outlet from the tank. You should start on the opposite side with a thickness of about 40 mm and slope down towards the outlet, reducing the thickness to not less than 15 mm (see Fig. 5.16). Finish the plaster with a wooden float.
    - Give the plaster a few hours before you start the next job. For this job you need a clean, round bottle glass of about 100 mm in diameter. Cut a few straight timber boards for use as walkways on the still fresh floor plaster. Start at the part of the floor, which you plastered first. Prepare a very well mixed cement sand mortar (1:3) with a minimum of water. This plaster is to be thrown in to the corner

between the wall and the floor up to the mark of the nil coat at the wall. Do this a few meters at a time. Then use the glass bottle to smooth it and at the same time shape a round concave arch (see Fig. 5.17). Working in steps of about 2 meters, move round the tank until you reach the starting point.

- From here you start the operation again, but this time using a nil coat. If the plaster is still too wet, wait for a while. This is an important operation and has to be done very carefully, since this part of the tank sometimes leaks. After the corner all around that tank is neatly shaped and covered with nil coat, pour water onto the floor slab. The nil coat for the floor is not to be done before the roof is finished.

N.B. In this day, if you do not have enough time to complete the floor, the completion of the floor slab can be done in the next day.

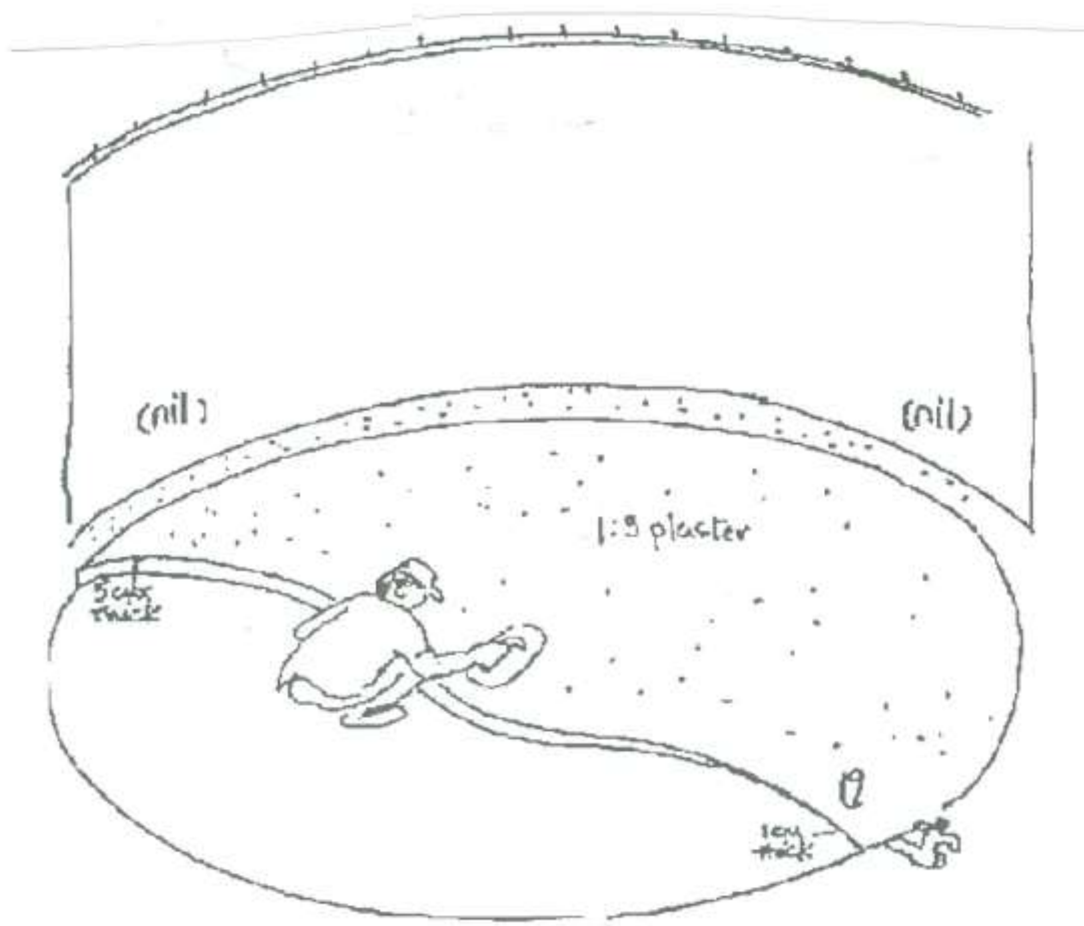


Figure 5.16

Figure 5.15

Figure 5.17

Day 7

- If plastering of floor slab is not done in the previous day, plaster the floor of the tank this day using the procedure outlined in day 6.
- Position and plaster the roof:
    - Construct the supporting structure of poles and rafters inside the tank like that of a traditional hut for the formwork (see Fig. 5.18). Construct a formwork for the roof slab reinforcement using one of the following methods.
        - Cut in shape, lay the ply wood and nail them to the rafter or
        - Cut in shape, lay the corrugated iron sheet and nail them to the rafter or
        - Cut in shape, lay bamboo carpets and nail to the rafters or
        - Sew sack made of sisal materials or nylon (as indicated in day 5).
    - Place the roof reinforcement on the tank wall and put it in position, then tie it in this position using the former 45-degree bended ends of the wall reinforcement mesh, with binding wires. After the roof reinforcement is secured, cut out of a minimum dimension of 500 mm x 500 mm manhole using a hacksaw.
    - Mark the place (or places) where the downpipe from the roof will be fitted into the tank if the inlet to the tank is decided to be through the roof slab. The shape and dimension of the opening will depend on the shape and dimension of the downpipe to be fitted. This remains an opening.
    - Plaster the roof with cement mortar (1:3 mix) as you used for the wall. After the roof is plastered with the first coat, cover it with plastic sheeting (see Fig. 5.19).
    - Prepare a manhole cover using the same size and shape as the opening. The cover is to be made of meshed reinforcing bars and chicken wire. Make sure that the manhole cover does not exceed 3 cm thickness. Cure the cover for a week.

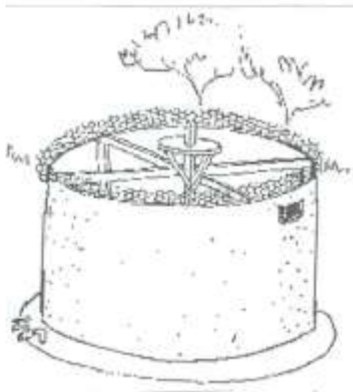


Figure 5.18

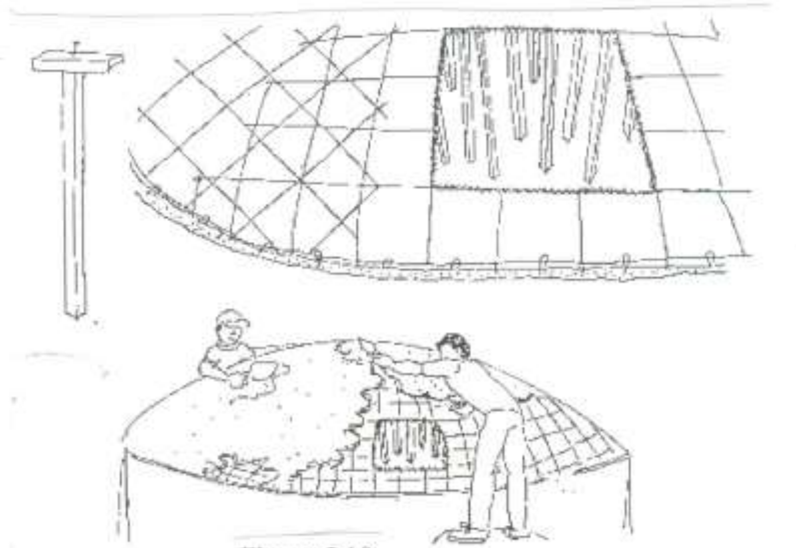


Figure 5.19

Up to the seventh day of roof slab first coat plastering

- Wet the roof, floor and walls of the tank by splashing water daily.
- After two days of roof slab first coat plastering, you can plaster the roof from outside (10 mm thick) for the second time, smooth it with a wooden float and cover with plastic sheeting.

After seven days of roof slab first coat plastering

- Remove the roof sheeting and wet the roof, floor and walls by splashing with water.
- Remove the support poles and formworks from inside the tank very carefully so that the formwork can be saved for reuse.
- Start plastering of the dome from the inside. This plaster is mainly to cover sags and the reinforcement bar and is not supposed to be entirely smooth. But is important that the reinforcement still visible is covered by at least 10 mm thick plaster (see Fig. 5.20). If you need a scaffold inside the tank to reach the dome for plastering, make sure it does not damage the floor plaster. Always use straight timber boarding underneath the scaffold. After the roof plaster is finished, remove everything from inside the tank and clean the floor, using a wire broom if available. If there are marks or holes in the floor plastered, patch them with 1:3 mixture cement sand mortar.
- Prepare a mixture like nil, but add one part fine sand (two parts cement, one part fine sand) and water. The consistency should be slightly stiffer than the nil coat you used for the wall. Plaster this mixture on the floor inside the tank using a trowel.
- Install/connect the inlet to tank (downpipe), overflow and outlet pipes (taps).
- After the manhole cover has been inserted, the reservoir is ready. Before the crew leaves the site, water be filled in to the reservoir if possible up to the full height of the tank if not, must be filled up to the level of at least 100 mm. Keep the water in the tank for at least two weeks to cure the tank strongly.

- In filling the tank with water use the water carefully. Do not pour a bucket of water on the floor from the manhole. The water will spoil the smooth surface. If you have a hose, put the end on the bottom of the floor and open the tap. If a hose is not available, take a timber board covered at one end with some cloth, and place this end carefully on the floor through the manhole. The upper end must lean on the edge of the manhole. Then take a bucket of water and pour it along the board slowly, so that it turns down to the bottom. Repeat this until the floor is covered with water.
- The tank should now be strong enough to hold water.

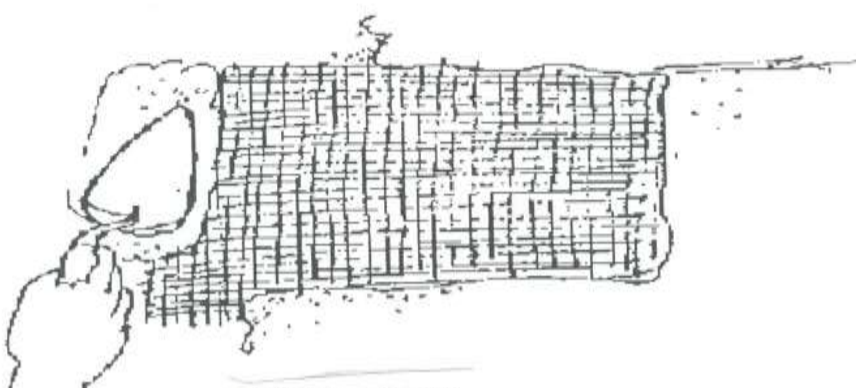


Figure 5.20

In Figure 5.21 and 5.22 See designs of 20 mcu capacity ferro - cement reservoir

By studying the design drawings shown in Figures 5.21 and 5.22 and using table 5.1(dimensions of different storage capacities of ferro-cement tanks), the design drawings for other capacities of ferro-cement tanks can be prepared.

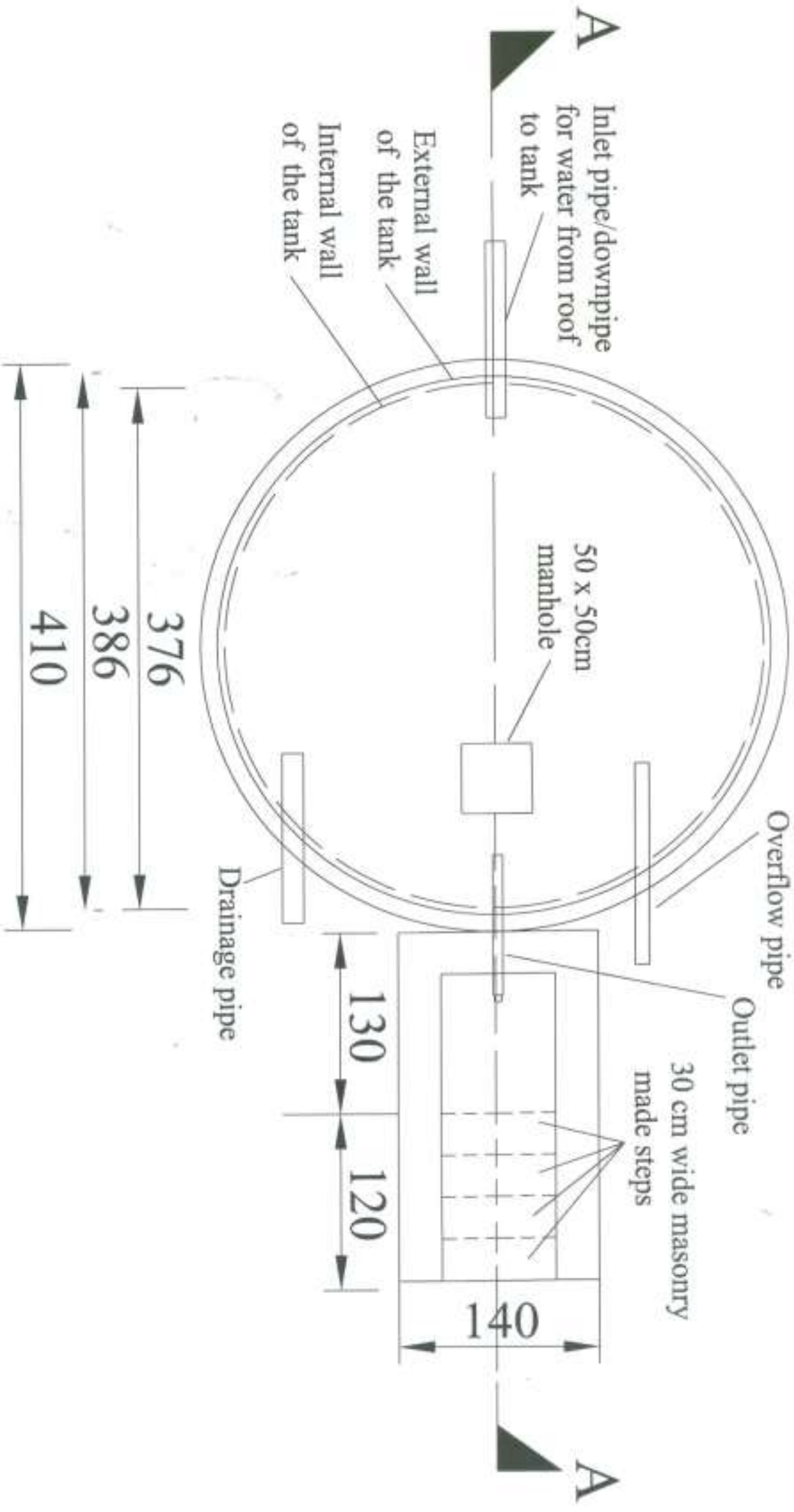
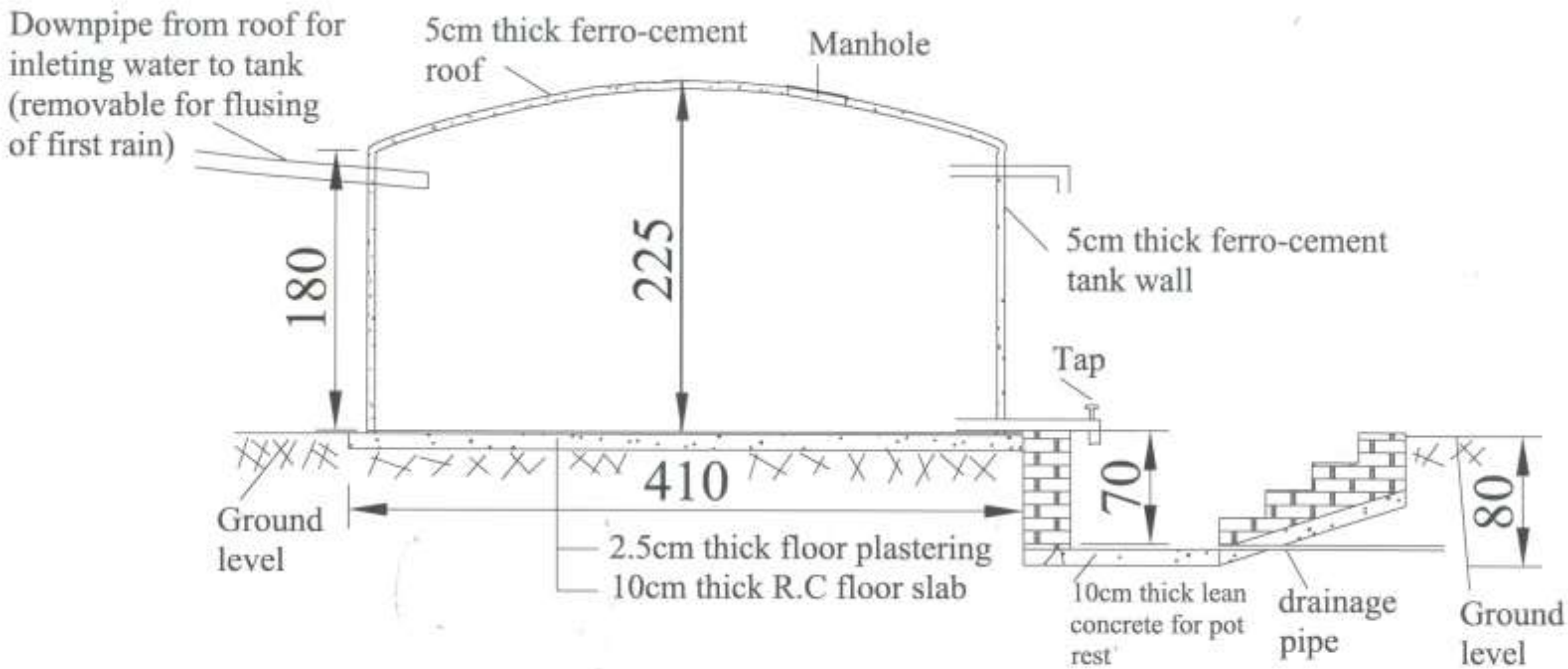


Fig 5.21 Plan of 20 mcu capacity ferro-cement reservoir where the pot rest is below the ground level

N.B. Unless stated otherwise all dimensions are in centimeters



SECTION A - A for Figure 5.21

N.B 1. Unless stated otherwise all dimensions are in centimeters.

2. The inlet pipe/downpipe and the over flow pipes can be installed into the roof slab.

3. If the length of the downpipe is more than 1 meters, it must be supported at every 1 meter length.

4. The floor slab is reinforced with 6 mm bars spaced 15 cm center to center bothways and filled with 1:2:3 concrete mix.

5. The tank wall is reinforced with 6 mm bars spaced 15 cm center to center in both ways and covered with chicken wire mesh and then plasted with 1:3 mix cement sand mortar.

6. The roof slab is reinforced with 6 mm bars spaced 15 cm center to center in both ways and covered with chicken wire mesh and then plasted with 1:3 mix cement sand mortar.

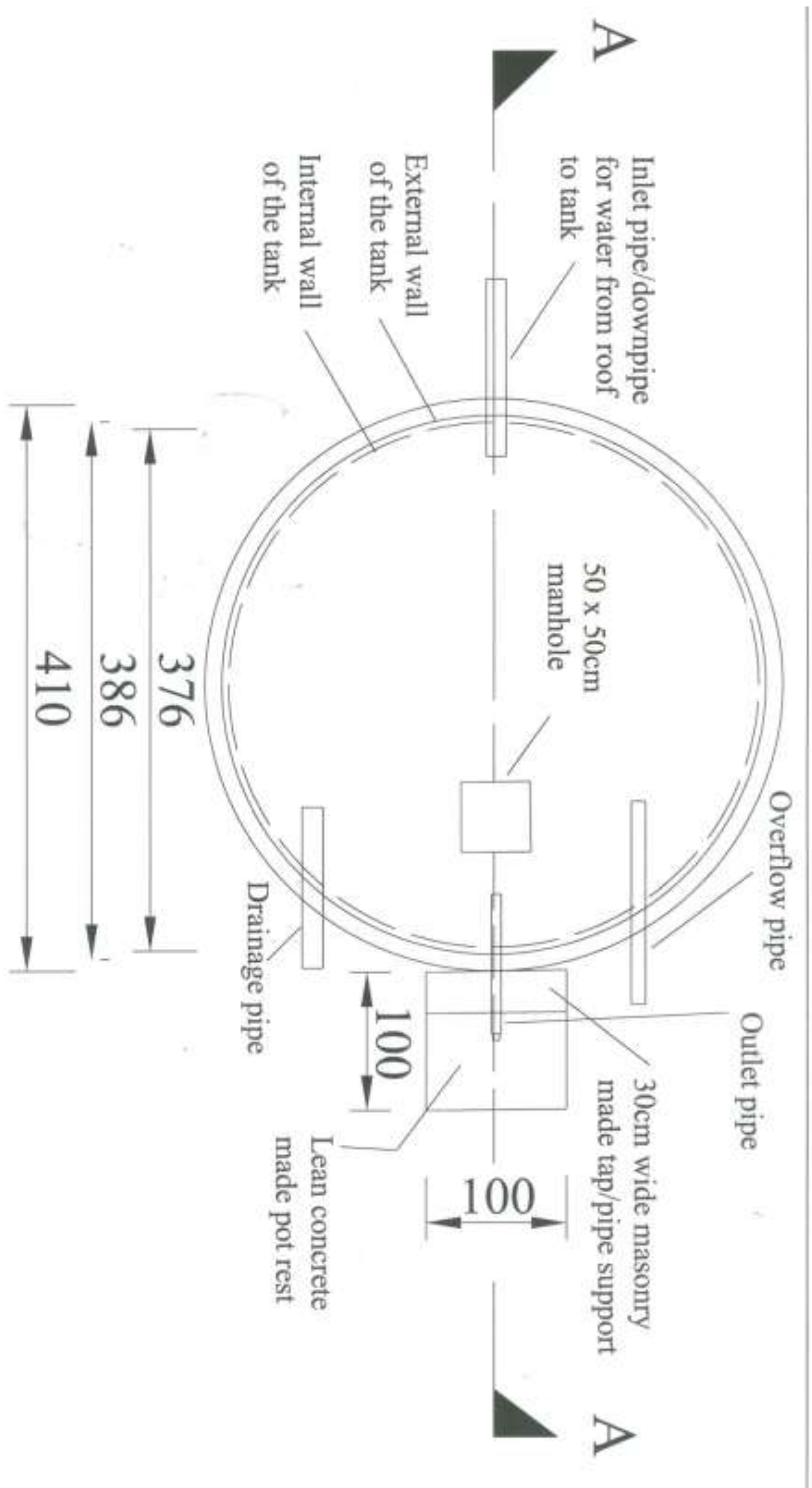
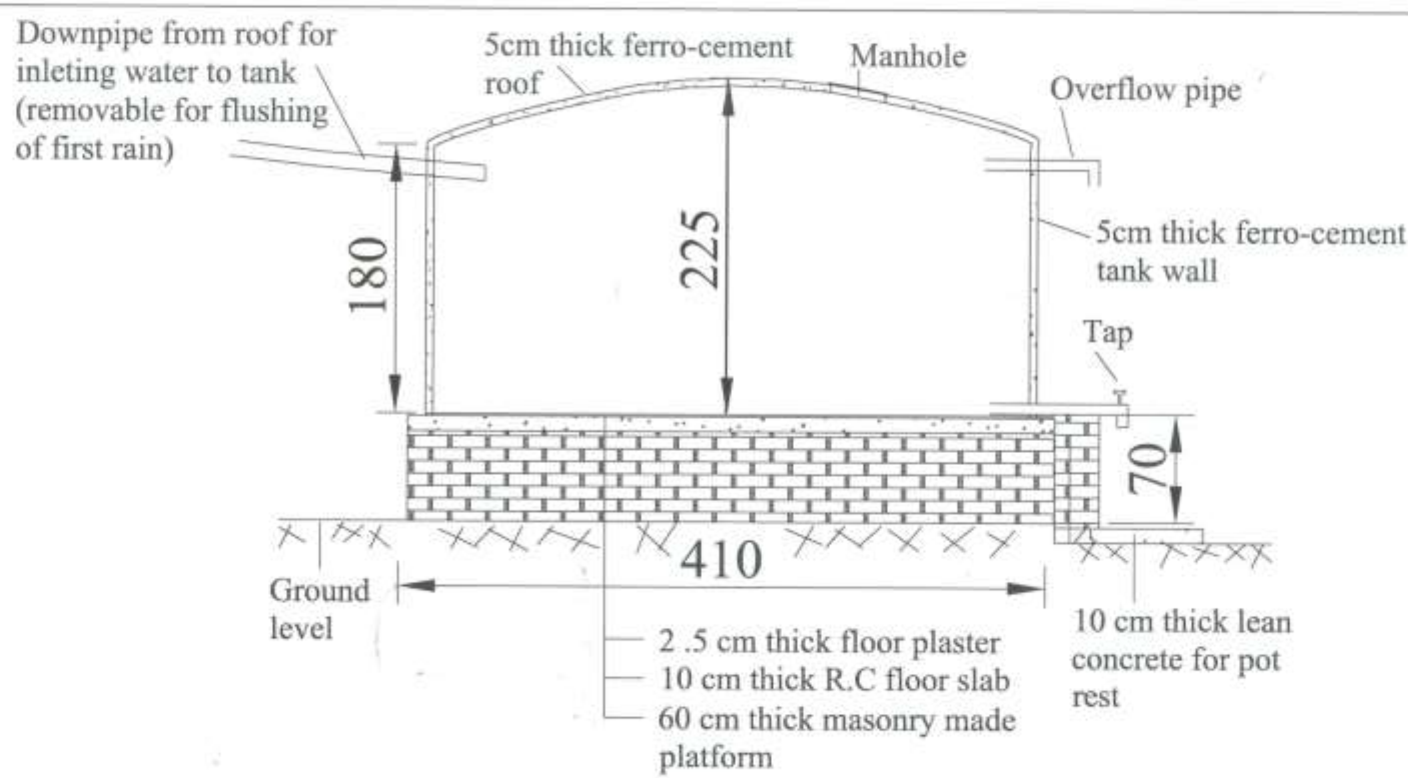


Fig 5.22 Plan of 20 mcu capacity ferro-cement reservoir where the pot rest is above the ground level

NB. Unless stated otherwise all dimesnsions are in centimeters



SECTION A - A for Figure 5.22

N.B 1. Unless stated otherwise all dimensions are in centimeters.
2. The inlet pipe/downpipe and the over flow pipes can be installed into the roof slab.
3. If the length of the downpipe is more than 1 meters, it must be supported at every 1 meter length.
4. The floor slab is reinforced with 6 mm bars spaced 15 cm center to center bothways and filled with 1:2:3 concrete mix.
5. The tank wall is reinforced with 6 mm bars spaced 15 cm center to center in both ways and covered with chicken wire mesh and then plasted with 1:3 mix cement sand mortar.
6. The roof slab is reinforced with 6 mm bars spaced 15 cm center to center in both ways and covered with chicken wire mesh and then plasted with 1:3 mix cement sand mortar.

5.4 Repair of ferro -cement tanks (reservoirs)

Repairing ferro-cement tank is easy but should not encourage poor quality of work. If the structure is constructed using good quality of materials, good workmanship and cured as described in the construction procedure, then leaks are likely to occur. Small leaks which create only a wet stain need not be attended to, since they will close after some time. Only leaks where water flows out to be repaired.

The possibility of repairing leaking tanks depend on several factors, including:

- Being able to locate the point of leakage
- The size of the leak
- Whether the leak is above or below the level of water in the tank.

Usually, locating leaks in the walls of surface (above the ground constructed) tanks is straightforward – unless these are in the tank floor. The repair system to be used for leaking tanks will depend on whether the tank is in use, meaning leak occurs on the part of the tank filled with water or in the upper part of the wall where the ferro-cment is rather dry.

a) Tank repair method on dry surfaces

If the area of the tank-requiring repair is dry the repair method to be used is as follows:

- Chisel out the damaged area around the leak, wet the whole area thoroughly by splashing with several times from inside and outside until an area of at least half a square meter is moist, and apply new mortar (with the same cement: sand ratio as the original) with a trowel and the surface smoothened (trowel finish). A coat of nil can be applied the next day and the patch covered with plastic sheeting and cured for at least three weeks. For this method of repair see Figure 5.23 in the next page.

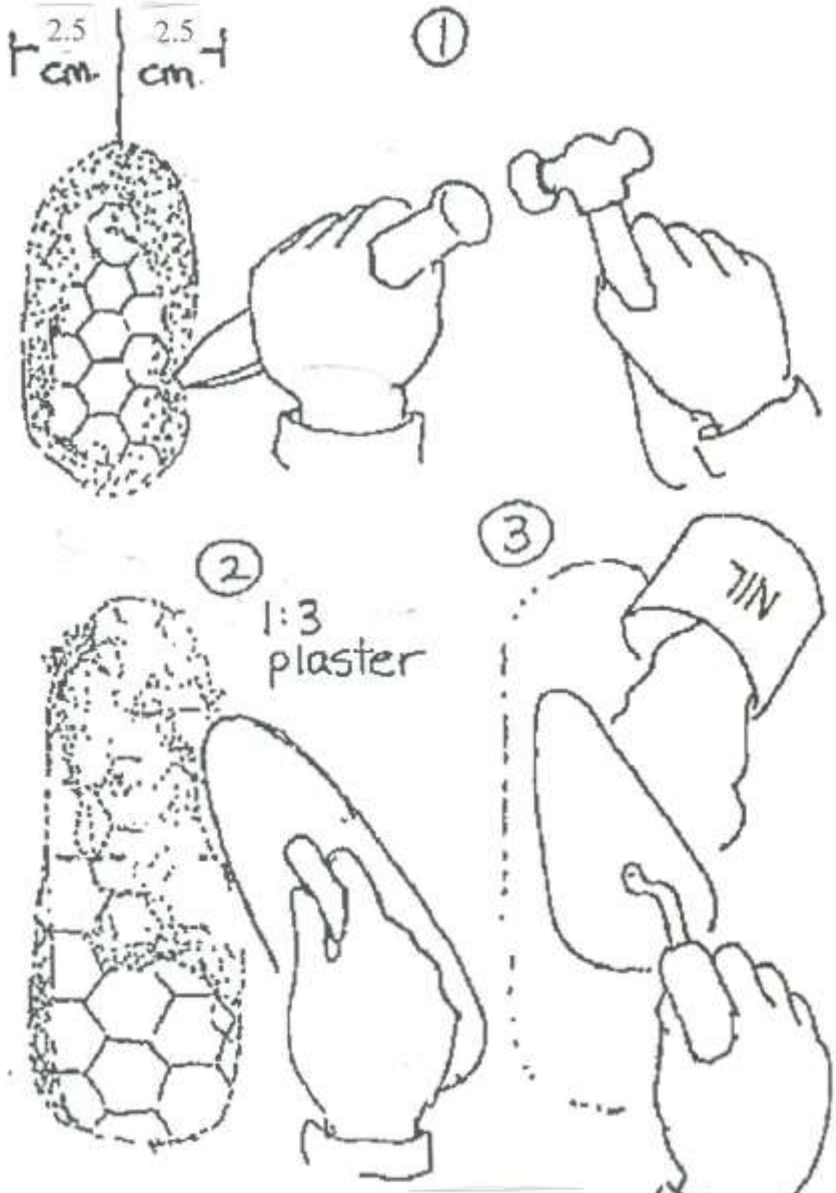


Figure 5.23

b) Tank repair methods on wet surfaces

In most tanks, small leaks are generally much easier to rapier than large ones. If a leak appears if tank is eventually filled with rainwater, it is more appropriate to consume the water than drain it to repair the leak. Two different methods of sealing an already filled reservoir from the outside can be tried, provided the material needed is available. However, there is no guarantee that these methods, will seal the tank, but since they do not affect professional repair, they might be tried if large amounts of water are at risk.

b.1) Rapid setting cement

The first method involves the use of rapid setting cement. If it is possible to obtain a few bags of this cement, make a simple test before you buy it. Take a clean tin, pour in some clean water, and add some cement slowly, stirring it with a stick. When the water/cement mixture becomes plastic, take some of it in your hand and mould it. This cement must become very warm in your hand and by the time the heat disappears it must harden instantly. If this test fails to produce the required result, you have either got the wrong cement or the materials is over dated, or has become moist, losing its property, and can not be used. If the test is successful, buy the amount you estimate you will need.

In using the above method, at the tank leak start to enlarge the hole where the water is running out. The hole should at least be 10 mm large and the wire reinforcement should be visible. While you enlarge the hole more water will flow out. Therefore you should make all preparations in advance, having all tools and material at hand. The best way to do the job is with two people. One prepares the hole for sealing, the other prepare the material. Experience has shown that the best tools for this job are a screwdriver used as a chisel, a light hammer, and a piece of timber a little bit smaller than the hole. As you have experienced during the test, there is a very short time span during which the cement is still plastic. The rapid setting cement should be added to water in a tin, stirred with a stick and then moulded in the hand until it has a plastic consistency. Then a piece of appropriate size cement (mould) should be forced (pressed) in to the hole using your thumb. Take the timber piece and the hammer at the last moment before the cement sets and press the plug in by hammering the timber. This method is likely to work if the leak is not big and some tests are first made to find out the cement's exact setting time. All that is for this repair work is a fast action. For this method see Figure 5.24.

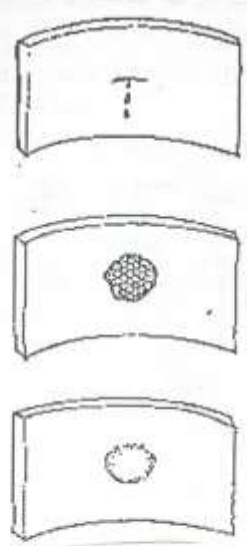


Figure 5.24

b.2) Sodium silicate

The second method requires the application of sodium silicate to the leak. Sodium silicate is a clear viscous liquid, which hardens on contact with air. This can be applied to a leak if the water flows out without pressure. In using this method first sanding down the wall around the leak with sandpaper to achieve a slightly rough surface of the cement wall. Open the bottle or container with sodium silicate only when you have completed preparations, since this chemical hardens on contact with the air. Use a spatula or a thin metal sheet to apply it, using the same technique as described for the nil coat. The sodium silicate should cover an area slightly larger than the leak. This method has often been used with much success.

6. DESIGN EXAMPLE OF RAINWATER ROOF CATCHMENT SYSTEM

6.1 Given the following design data

Design a rainwater roof catchemnt system for a school with the following data.

- Mean annual precipitation of the areas is 750 mm.
- Rainy seasons in the area are March to May and June to September known as Belg and Meher respectively. And according to the agroclimatic data collected by FAO in the area, about 73% of the annual precipitation occur during June to September.
- The roof area of an administration block in the school is 6 meters x 10 meters.
- The roof area of a teaching block in the school is 7 meters x 14 meters.
- The roof of both the administration and teaching blocks are made of corrugated iron sheet.
- The total number of beneficiaries is 225 of which 200 are students and the remaining are inhabitants in the school compound.
- The average daily water consumption per capita is 10 liters and 2 liters for inhabitants and students respectively.
- It is proposed to use one reservoir for each block.

6.2 Runoff calculation

Administration office block

Plan area of the block = 6 m x 12 m = 72 msq
Effective yield of the roof, Q in liters = Runoff coefficient x Mean annual rainfall in mm x Roof area in msq = 0.8 x 750 mm/year x 72 msq = 43200 liters/year

Teaching block

Plan area of the block = 7 m x 14 m = 84 msq
Effective yield of the roof, Q in liters = Runoff coefficient x Mean annual rainfall in mm x Roof area in msq = 0.8 x 750 mm/year x 98 msq = 58800 liters/year

Total effective runoff

The total effective runoff is the sum of the effective runoff from the administration block and teaching block = 43200 + 58800 = 102,000 liters/year = 102 mcu/year

6.3 Calculation of water requirement

School children

Number of students = 200 pupil
Per capita daily water demand for a student = 2 liters
Number of teaching calendar days in a year = 200 days

Water demand for students, Q = 200 students x 2 liters/student/day x 200 days = 80000 liters/year = 180 mcu/year

To calculate the water requirement per month = 80 mcu/6.67 months = 12 mcu/month

NB. 6.67 months are calculated based on that there are 30 days in one month hence 6.67 months are present in 200 days.

Community beneficiaries.

Number of inhabitants = 25 people
Per capita daily water demand for a person = 10 liters

Water demand for inhabitants, Q = 25 inhabitants x 10 liters/person/day x 365 days = 91250 liters/year = 91.25 mcu/year

To calculate the water requirement per month = 91.25 mcu/12 months = 7.6 mcu/month

Total water requirement

The total volume of water required = Water required for students + Water required for inhabitants = 100 mcu/year + 91.25 mcu/year = 171.25 mcu/year

Please note that the total effective runoff from the administration blocks and from the teaching block = 43.2 mcu + 58.8 mcu = 102 mcu/year. Though the design criteria was set deliberately considering only the water usage for drinking and cooking purposes, there is still a deficit of 69.25 mcu of water to satisfy the whole requirements of the beneficiaries. However, it is important to bear in mind that the scheme is not intended to supply the whole population but it is to supplement the usual water shortage occurring during the dry seasons from ponds, and hence, improve the health condition of the beneficiaries to a certain level.

Moreover, it is believed that the scheme will have a great impact and role on community awareness towards the use of other alternative water sources such as rainwater other than the traditional ponds and may encourage the beneficiaries to similar replication of the roof water harvesting individually or on group basis. Therefore, rather than abandoning the construction of the system, it is recommended to implement it hence the design is completed as follows.

6.4 Determination of reservoir capacity (size)

According to the agroclimatological data collected by FAO, of the area, about 73% of the annual precipitation occur during June to September. Therefore, the sizes of reservoirs were considered in order to accumulate about 73% of the annual precipitation. And the remaining 27 % of the precipitation which will fall during March to May will fill the part of the reservoir which is not occupied by water as a result of consumption of months before March.

Thus,

For administration block

Effective runoff, Q = 43.2 mcu/year
Reservoir capacity = 0.73 x 43.2 muc/year = 31.54 mcu
Use a 30 mcu capacity Ferro-cement reservoir.

For teaching block

Effective runoff, Q = 58.8 mcu/year
Reservoir capacity = 0.73 x 58.8 mcu/year = 42.9 mcu
Use a 40 mcu capacity Ferro-cement reservoir.

6.5 Determination of gutters and downpipes size

a) Gutters and downpipes size

The roof in each building is assumed to be constructed as double pitch roof hence each size of the roof requires its own gutter and downpipe.

a.1) Administration block

Total projected horizontal area of the block = 72 msq
Projected horizontal area of the block in each side = 72 msq/2 = 36 msq
If we use a half round gutter made of galvanized iron sheet, from Table 3.1 we choose a gutter having an area of 43cm^2, gutter diameter =105mm and thickness of sheet 0.65mm.

The same size of downpipe with an area of 43 cm^2 is proposed to be used.

For the downpipe, PVC or G.I pipe having the same cross sectional area of the galvanized iron made downpipes can be used.

The length of each gutter to be fixed for the teaching block is 12 m (length of the block) + 12 m x 1/100 (1% slope is used per meter of gutter) = 12.12 m

a.2) Teaching block

Total projected horizontal area of the block = 98 msq
Projected horizontal area of the block in each side = 98 msq/2 = 49 msq
If we use a half round gutter made of galvanized iron sheet, from Table 3.1 we choose a gutter having an area of 63 cm^2, gutter diameter = 127 mm and thickness of sheet 0.7 mm.

The length of each gutter to be fixed for the teaching block is 14 m (length of the block) + 14m x 1/100 (1% slope is sued per meter of gutter) = 14.14 m

The same size of downpipe with an area of 63 cm^2 is proposed to be used.

For the downpipe, PVC or G.I pipe having the same cross sectional area of the galvanized iron made downpipes can be used

b) Fixing of gutters and downpipes

The gutter is required to be fixed/laid at minimal slope of 1% (1 cm per 1 meter length of gutter) towards the entrance of the downpipe to avoid standing water due to debris, bird droppings, dusts etc. Also, the distance from the roof drip to the top of the gutter would be mot more than 40 mm in order to minimize excessive loss of water from wind effect.

The downpipe is also required to be fixed/laid at minimal slope of 1% (1 cm per 1 meter length of downpipe) from the end of the gutter towards the inlet to the tank. The length of the downpipe depends on the location of the tank.

For example, if the location of the reservoir is proposed to be at a distance of 2 meters from the edge of the building, then the minimum length of the downpipe = 2 m + 2m x 1/100 = 2.02 meters.

6.6 Tap points

Tap points need to be located at convenient location for use by the beneficiaries. If it had been only for community use, we would have installed only one tap for each reservoir as one tap can supply 150 to 200 beneficiaries per day as per the design criteria being used in our country.

Here since the beneficiaries are mainly students which have only 15 minutes break in each morning and afternoon session hence not to create a load in faucets, it is recommended to install two taps (¾" faucets) in each reservoir so that 50 students can use per tap.

For sake of convenience by students use, it is recommended to excavate 60 cm below the tank level and construct the tap point/pot rest point. Or if the height of the roof of the building allows, we can construct 60 cm high masonry/concrete made platform and construct the reservoir on the platform so that enough height is provided for students use or pot rest.

6.7 Design Drawings

The layout of the design is shown in Figure 6.1.

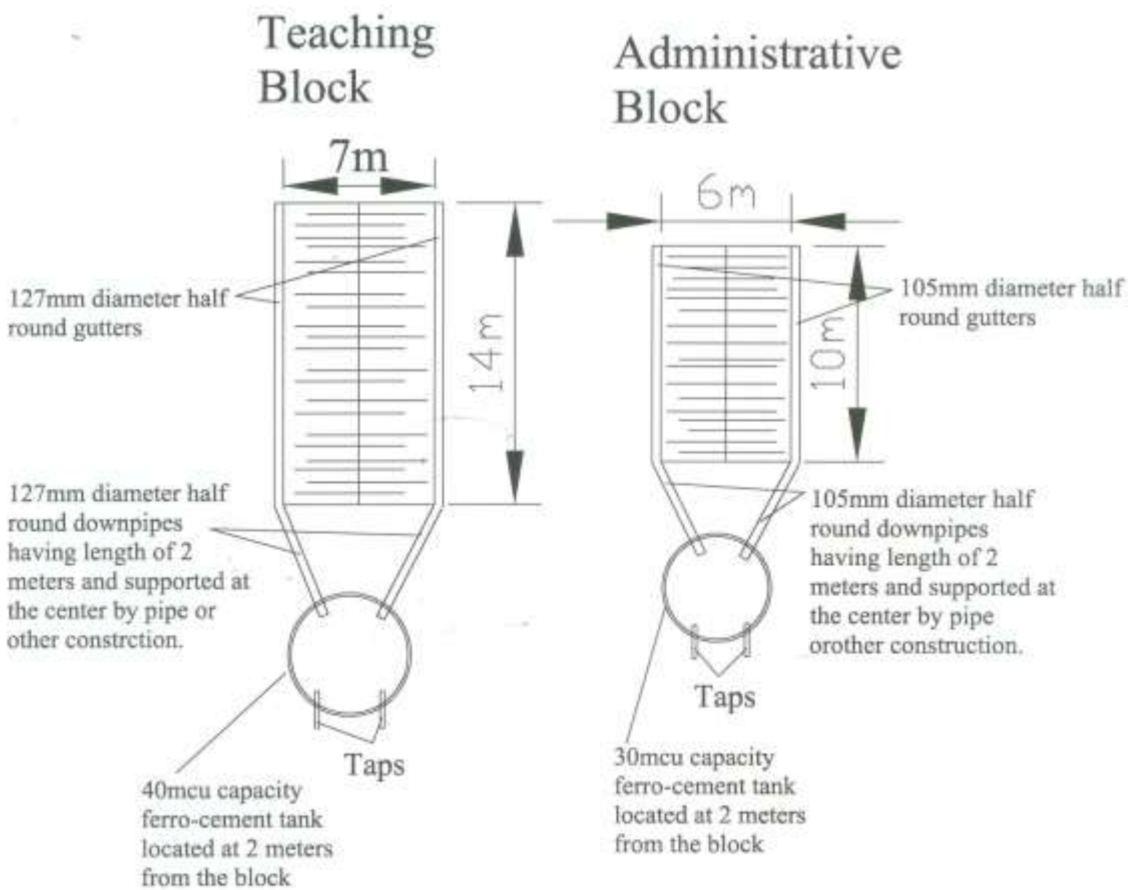
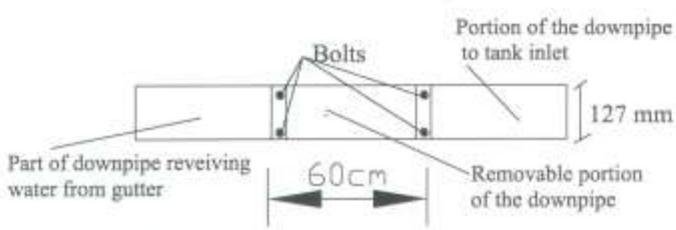


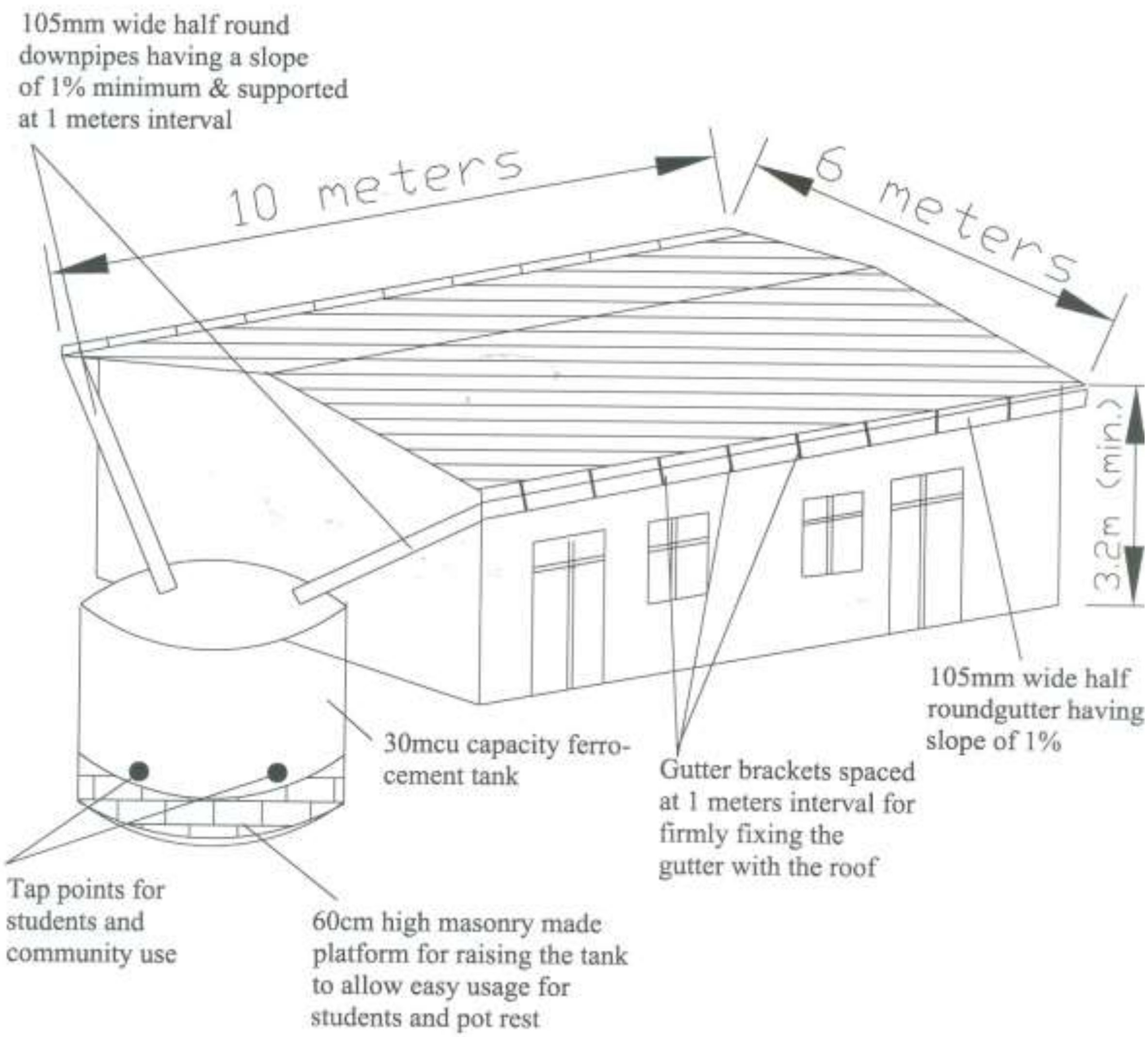
Fig. 6.1 Layout of design example



Detail of downpipe

N.B. 1. All the drawings are not to scale.

2. 60 cm long portion of the downpipe is removable for flushing the first rain afetr a dry season. This removable part of the downpipe is fixed to the downpipe part coming from the roof and the part of the downpipe entring the tank with bolts. So that the middle portion of the downpipe can be removed by untiting the bolt when the rain is to start afetr a dry season and after the fisrt rain is flushed this portion of the down pipe must be fixed again with the two ends with the bolts so that good quality water can enter in to the tank. The system requires a very responsible person which will make this operation.



Elevation plan of administration block for figure 6.1

N.B. 1. All the drawings are not to scale.
2. Althogh not shwn in the drawing, the tank has manhole cover, overfow and drainage pipes.

REFERENCES

Arnold Pacey and Adrain Cullis, 1986. “Rainwater harvesting”. The collection of rainfall and runoff in rural areas.

Jan Davis and Robert Lambert, 1995. “Engineering in Emergencies”. A practical guide for relief workers**.**

John Gould and Erik Nissen-Petersen, 1999. “Rainwater Catchment System for Domestic Supply”. Design, construction and implementation.

“ETHIOPIA: Small - Scale Rainwater Harvesting Technologies “. Report on assessment of experience, June/July 2002.

Erik Nissen – Petersen, Dr. Michael. Nairobi, 1990. “Harvesting Rainwater in Semi - Arid Africa”